THE USE OF MULTIPLE REPRESENTATION APPROACH IN ENHANCING THE LEARNING OF FLUID MECHANICS IN UNDERGRADUATE PHYSICS CLASSES IN ETHIOPIA

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DECLARATION

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I declare that "The use of Multiple Representation Approach in enhancing the learning of fluid mechanics in undergraduate Physics classes in Ethiopia" is my original work and has not been presented by another person at any institution. Besides, all sources used for this study were paraphrased with a few quoted works. Nevertheless, the work of all authors that have been used in this research is properly acknowledged.

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ABSTRACT

The inadequate understanding of fluid mechanics is a phenomenon widely experienced by undergraduate Physics students. The study aimed to establish students' preconceptions on this topic then develop Multiple Representation teaching sequences and establish the effect thereof in two iterations. Multiple intelligence theory, variation theory, and cognitive theory were used to guide the study. This study was conducted at two Ethiopian universities. Students' preconceptions were first categorised and then analysed using categories and frequency counts. This informed the development of a Multiple Representation Approach aimed at enhancing the learning of fluid mechanics. Research methods used to evaluate multiple representations' effectiveness comprised a quasi-experimental design. Open-ended questionnaires, the Fluid Mechanics Concept Inventory and the Test of Multiple Representation Approach Related Attitudes were used to collect data from N = 128 undergraduate students, 64 in Iteration I and 64 in Iteration II. Every iteration consisted of two groups of students selected from two universities. Before any intervention, the students' prior knowledge was established by using the Open Ended Questionnaire and fluid mechanics conceptual inventory. Both groups received instruction based on both the Multiple Representation Approach and the traditional lecture method. The first version of the multiple representations only used four representations, which resulted in no significant difference between the experimental and control groups. Before the second intervention, the new group of students included 64 students, of which 32 were from each group. The second development of the multiple representations followed, using eight representations. This resulted in a significant difference between the intervention and control groups on both Open-Ended Questionnaire and fluid mechanics conceptual inventory. The results showed that using eight multiple representations was significantly effective compared to using two, three, or four in students' understanding of fluid mechanics concepts. In addition, students had positive attitudes towards the use of the Multiple Representation Approach. The study included two phases, perhaps it would have been better to include more than two phases. It is recommended that scholars in the field of study ought to conduct further research on other Physics topics.

Keywords: Alternative conception; conception model; categorising; model analysis; multiple representations; Physics education; variation theory.

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DEDICATION

I dedicate this work to God, who has made this study possible, and to my family members, who endured with me throughout this accomplishment.

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ABBREVIATIONS AND ACRONYMS

ANCOVA	Analysis of covariance
FMCI	Fluid mechanics conceptual inventory
OEQ	Open-ended questionnaire
PER SAMRA	Physics education research Students' attitude towards Multiple Representation
SPSS	Statistical package for social Sciences
TTCI	Thermal transport conceptual inventory
UNISA	University of South Africa
VTL SAMRA	Variation Theory of Learning Students' attitude towards Multiple Representation

PAPER PRESENTATIONS AND PUBLICATIONS

- Ashenafi, L. (2017). The use of Multiple Representation Approach in enhancing the learning of fluid mechanics. 11^{th} Annual Conference of EPS at Dire Dawa University (see the certificate of participation in Appendix Y).
- Ashenafi, L. (2016). Categorisations of alternative conceptions in 10th Annual Conference of EPS at Debre Markos University (see the certificate of participation in Appendix Y).

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Fluid mechanics is a fundamental topic that is usually taught at the undergraduate level in Physics and Engineering classes. It is one of the branches of Physics that is concerned with the interaction of molecules in fluid dynamics and fluids in statics. Fluids are physical states of matter that comprise gases and liquids. The four basic topics that make up fundamental fluid mechanics are Archimedes' principles of buoyant force, Pascal's principle, the continuity equation of fluid dynamics (moving fluids), and Bernoulli's principle (Walker, Walker, Resnick & Halliday, 2014).

The first topic, Archimedes' principle, was developed around 250 B.C. by the Greek mathematician Archimedes. He describes that any object that is partially or completely submerged in fluid experiences a buoyancy force that equals up trust pressure acting in the opposite direction on the submerged object and pushing the submerged object upward. This is the reason that objects appear to weigh less while submerged in a liquid. Furthermore, Archimedes' principle can be expanded as follows: when an object is completely submerged in a fluid, the weight of the displaced fluid is due to the insertion of the object into the fluid and is equal to the weight of the submerged object (Walker, et al., 2014).

A second topic is Pascal's principle, which states that the pressure applied to a container with a limited flow of fluid will be equally distributed between the fluid and all the walls of the container. The hydraulic press that we use indoors and in other openings is one of the main applications of Pascal's principle (Raymond & John, 2014).

The third topic is the continuity equation of fluid dynamics (moving fluids). The above two concepts deal with fluids at rest or static fluids. The third topic is hydrodynamic fluids or fluids in motion. Fluids in motion can be categorised into different sections, like a steady flow of fluid, in which the speed of the fluid remains constant at any time. The fluid in one part is permanently flowing at the same speed. A flow can be classified as compressible or incompressible, depending on whether it is compressed or not. The other classification can be a non-viscous or viscous fluid, depending on its flow nature. A viscous fluid, such as butter, does not flow, and a non-viscous fluid, such as water, can flow easily (Raymond & John, 2014).

The equation of continuity is about the conservation of the mass of an incompressible fluid. This states that the amount of fluid flowing through all cross-sectional areas given the time interval is the same. This can be expressed in mathematical equations: "the product of the area and the fluid speed at all points along a tube is constant for an incompressible fluid." One can observe this by holding a finger over the outlet of a garden hosepipe. According to this principle, when the cross-sectional area decreases, the speed of the water will increase. This shows the condition of the principle, which is AV = constant. If there are no leaks during a given interval, the volume of the fluid leaving the tube at one end is the same as the volume of the fluid entering the tube at the other end. At the undergraduate Physics level, the course deals with a constant flow of incompressible, non-viscous fluids (Walker, et al., 2014).

The fourth topic in this course is Bernoulli's principle. In the 18th century, physicist Daniel Bernoulli discovered this principle. This equation deals with the relationship between the velocity and pressure of a fluid, and it is Bernoulli's principle that swiftly moving fluids exert less pressure than slowly moving fluids. This principle is tremendously important in our daily lives; for example, in the aeronautics industry, it applies to the lifting of an aeroplane wing and helps an aeroplane fly. Engineers, therefore, need to understand the principle in order to design safe and efficient aircraft. The aircraft example illustrates an essential and central principle of Physics that deals with the conservation of energy (Brophy & Alleman, 2003).

Many aspects of fluid mechanics are applicable in many areas of Science and Technology, as well as in our everyday lives. To name a few practical examples in our lives: water supply from reservoirs, turbines, swimming, fans, pumps, ships, planes, pipes, windmills, rivers, sprinklers, engines, and jets (John & Raymond, 2014; Jewett, & Serway, 2008).

Therefore, these principles are included in the curriculum of the undergraduate Physics major and Engineering classes (MOE, 2013). However, studies show that undergraduate university Physics students have misconceptions about the buoyant force and Archimedes' principle even after instruction (Absi et al., 2011; Jesse et al., 2006; Robertson & Shaffer, 2016). They also have difficulty with a conceptual understanding of fluid flow and laboratory activities in learning fluid mechanics (Faour & Ayoubi, 2018); and they do not identify the relationship between Bernoulli's principle and kinetic energy in learning fluid mechanics and thermodynamics (Distrik, Supardi & Jatmiko, 2021; Prahani, et al., 2021; Raissi, Yazdani, & Karniadakis, 2020).

Furthermore, university undergraduate Physics students have difficulties distinguishing between pressure and volume (Ornek, Robinson, & Haugan, 2008), as well as between pressure and temperature (Hartini & Sinensis, 2019; Minichiello et al., 2020). Similarly, students encountered difficulty in understanding displaced fluid volume and buoyant force (Aksit, 2011; Minichiello et al., 2020; Raissi et al., 2020). It appears that the difficulty in understanding fluid mechanics and thermodynamics comes from a lack of understanding of these concepts in high school Physics programmes (Prahani et al., 2021).

Different teaching approaches have been used to enhance students' alternative conceptions of fluid mechanics. Recently, Brenner, Eldredge and Freund (2019) found that machine learning (ML) can accelerate the learning of fluid mechanics when using numerical or experimental methods. In addition, computer simulations have assisted in the learning of fluid mechanics (Frazer et al., 2013; Wang & Zhau, 2009). A group of researchers developed mobile applications for enhanced learning in fluid mechanics (Minichiello et al., 2020). Their focus was to generate interest in and enhance perceptions of fluid flow and to develop an understanding of mathematical notions relating to fluid mechanics. According to recent literature, a Multiple Representation Approach to teaching Physics improves the understanding of students (Munfaridah, Avraamidou & Goedhart, 2021; Simanjuntak et al., 2021). Because each student learns best in his/her unique way (Prahani et al., 2021), it is reasonable to suppose that a range of multiple representation approaches such as text, formulae, computations, visuals, and interactive learning strategies, is necessary for students to develop a thorough understanding.

This implies that since students prefer a variety of representations, teaching using MR methods will make a difference in students' understanding (Dimas et al., 2018; Hartini et al., 2020; Mizayanti et al., 2020). Using a multi-representation approach, it has been shown that Physics students are more successful in problem-solving (Gestson et al., 2018), improving their comprehension skills (Bakri & Mulyati, 2018; Bakó-Biró et al., 2012), and can easily understand a variety of designs, such as formulae, calculations, diagrams, and abstract concepts (Dimas et al., 2018; Volkwyn, Airey, Gregorcic, & Linder, 2020).

1.2 CONTEXT OF THE STUDY

In Ethiopia, a fluid mechanics course has been offered for undergraduate Physics major students, with the course name "Fluid mechanics and thermodynamics". The course code: "Phys 232" has a course credit hour: of 3 as a compulsory course; and is a similar course offered at all Ethiopian universities. This is because the curriculum and all course programmes for the degree of Bachelor of Science in Physics at all universities are harmonized (MOE, 2018). The course has been semester-based and would take four months, or 16 weeks, to complete. The fluid mechanics' course consists of Archimedes' principle, Pascal's principle, the continuity equation, Bernoulli's principle, temperature, and the first law of thermodynamics; the kinetic theory of gases, heat engines, entropy, and the second law of thermodynamics. The course is taught by the lecture method, and students are assessed through assignments, examinations, quizzes, midterms, and final exams (MOE, 2013). The course's content descriptions are provided (see Section 2.2). These problems are particularly prevalent in Ethiopia, where this study was conducted. The researcher found that the students' knowledge was insufficient in the basic concepts of fluid mechanics and that their misconceptions were not resolved after traditional instruction.

This is due to the gap in the school curriculum. Regarding this, the report from the Ministry of Education shows that in Ethiopia, there is no one standard policy regarding curricula. For instance, Technology University has its curriculum and there is not one coherent curriculum for the entire country (MOE, 2018). In addition this is due to the fact that the school curriculum has failed to provide students with an opportunity to use their multiple thoughts to improve their understanding of learning fluid mechanics concepts (Wondemetegegn, 2016). As a result, this study focuses on using a Multiple Representation Approach to improve the learning of fluid mechanics, specifically Archimedes' principle and buoyant force, Pascal's principle, the continuity equation of fluid dynamics (moving fluids), and Bernoulli's principle, in undergraduate Physics classes in Ethiopia.

When learning fluid mechanics, first-year university Physics students in Ethiopia are expected to be able to explain the notions of fluid dynamics, floating, and pressure variation, as well as the effect of buoyancy forces and the Archimedes' principle. Therefore, in this study, the intervention was developed on the basis of Multiple Representations (MR's) instructional approaches. This was done to show students how using different teaching materials would be a beneficial approach to learning fluid mechanics' concepts.

1.3 PROBLEM STATEMENT

Different problems have been identified in Ethiopia namely the deterioration of the quality of education, the dominance of traditional methods of teaching, conceptual learning difficulties in Physics, lack of motivation or interest in Physics learning, and enduring alternative conceptions in conceptual learning.

The quality of education in Ethiopia is deteriorating as it does not meet international standards in terms of laboratory quality, class size, textbook preparation, school building infrastructure standards, and instructor quality. Moreover, lack of motivation or interest in Physics learning for students is also one of the factors that were dealt with in this study. Studies show that up to 50% of elementary school students have a low interest in Science. As these problems develop in the minds of students at the grassroots level, they can be challenging for secondary and higher education levels in the future (Saleh, 2014).

To address this issue, Ethiopia introduced a new education policy in 2008, and 70% of students enrolled in higher education were trained in Science and Technology (MOE, 2016). This indicates that the country is interested in improving its Science and Technology education, but it has not been possible to improve quality by increasing the number of graduates. As a result, this effort to provide education has not improved the quality of education. In a study by Sitotaw and Tadele (2016), students from high schools and elementary schools were found to prefer Physics education. The study involved high school and primary school students from Dire Dawa City Administration (Ethiopia). According to that study, students had developed a negative attitude towards Physics because they viewed it as a difficult subject and indicated that they had not learned much from the Physics teacher's approach. Additionally, the results suggest that female students were more likely to lose interest in Physics near the end of the 9th and 11th grades.

Studies show that attitudes change in many ways, and many factors can influence a person's attitudes, including experiences and social influences (Cracker, 2006). Undergraduates have a poor attitude towards Science and Mathematics, and a lack of interest has a negative impact and can cause problems in students' understanding (Jesse et al., 2006).

The concern is far more serious in Physics, as students consider Physics to be the most challenging subject in Science. Therefore, even in higher education, students prefer to study other subjects compared to Physics (Sitotaw & Tadele, 2016). Further, research on Physics teaching to undergraduate students indicates that Physics is not a subject of choice for students, and the number of students applying for the programme is also very low (Erdemir, 2009; MOE, 2016). As the number of students attracted to this subject is dwindling, so is the number of scholars involved in the field (Cracker, 2006). This can cause problems in student understanding (Jesse et al., 2006).

The Ethiopian Higher Education initiated a project (MOE, 2018) to establish what the scenario is with Mathematics and Science students. The study found that the Physics enrolment rates were low, indicating that Physics applicants had lower scores than other groups in the Ethiopian National Higher Education Entrance Examination. There is an unprecedented gender gap in enrolment and graduation rates. The explanation for the low enrolment rates is inadequate pre-university preparation; lack of job opportunities outside the teaching profession; and a lack of teacher competency and content knowledge (Semela, 2010).

The reality on the ground in Ethiopia is that students who score very low on the Ethiopian Higher Education Entrance Examination (EHEEE) are unintentionally placed in the field of Physics. This student's unintentional placement in Physics makes the situation very difficult, leading to ongoing problems with student achievement (White & Tesfaye, 2010).

The other factor was the dominance of the traditional lecture method of teaching. The traditional lecture is a method of teaching many students in a classroom at the same time. Normally, this method uses chalk and talk (Chen & Gladding, 2014). Traditionally, lectures are dominated by the instructor, who provides information with minimal student interaction, whereas active learning models encourage student interaction. In traditional instruction methods, students move from a group learning environment to an individual learning environment. Thus, it minimises the results of an interactive learning environment where the educator guides the students in applying the concepts and the students also engage creatively with the subject.

A traditional lecture method is an approach, and it is said to be less effective than the modern approach (Geyer & Kuske-Janßen, 2019; Faleye & Mogari, 2010). Similarly, the study shows that using a traditional lecture approach was not fruitful in enhancing students' understanding of fluid mechanics and hindered their ability to solve problems (Chen & Gladding, 2014; Euler & Gregorcic, 2018). A study by Mohammad et al. (2012) found that the traditional method of teaching fluid courses is not an effective method of teaching. This is due to the fact that it leaves students with fewer opportunities to combine what they learn, how they learn, and how to improve their school performance. This is because students have no role in the teaching-learning process. In the traditional lecture, the teacher plays a vital role; he/she is the manager when the learning process relies heavily on enforcing the rules. In a broader sense, the traditional method gives the chance to promote a top-to-bottom approach.

Physics students have conceptual learning difficulties in understanding basic Physics concepts, i.e., they do not link the concepts of Physics to their daily life activities or experiences (Raissi et al., 2020). In addition, many undergraduate Physics students do not fully understand the concepts of fluid mechanics (Faleye & Mogari, 2010; Minichiello et al., 2020).

First-year undergraduate Physics students have great trouble understanding that buoyancy force equals trust pressure and the Archimedes' principle (Ornek et al., 2008; Robertson & Schaffer, 2016). This could mean that students are unable to relate the concepts of Physics to their daily activities or experiences (Raissi et al., 2020). Furthermore, when students were asked to answer questions about pressure and temperature problems, they were unable to do so correctly even after instruction (Akis, 2011; Hartini & Sinensis, 2019; Prahani, et al., 2021). Loverude, Kautz, and Heron (2003) conducted a study on undergraduate first-year students' learning difficulties in the tertiary-level context of fluid mechanics. They found that many students did not recognise the crucial role of displaced volume in determining the buoyant force and shared confusion about pressure and Archimedes' principles.

According to Misaiko and Vesenka (2013), undergraduate students at New England University have alternative conceptions of Bernoulli's principle and the kinetic theory. In Spain, undergraduate students have misconceptions about molecular interaction and temperature (Romero & Martnez, 2013). A study conducted at Midwestern University in the United States observed that around 80% of their undergraduate students had alternative conceptions of velocity and pressure while learning kinetic energy (Meltzer, 2008). In South Africa, it was found that students had misconceptions about the relationships between pressure, temperature, velocity, and cross-sectional areas in fluid flow (Faleye & Mogari, 2010). Moreover, Fraser, Romero and Martnez (2013) indicated that most Physics students still have difficulty understanding fluid mechanics even after instruction.

In every phase of learning in school or at the tertiary level, students need to adhere to the prescribed curriculum. A curriculum provides information about the content, rules, and principles associated with a specific topic as well as a determined time range in the classroom (Van den Akker et al., 2003). A curriculum indicates what students need to learn, while a successful curriculum is based on proper implementation that can achieve the designed objectives and goals (Van den Akker et al., 2003). However, the effective implementation of a curriculum depends on many factors, among which are the students' natures (readiness of understanding) and teachers' use of effective instructional approaches (Fredlund et al., 2015).

In Ethiopia, a study indicated that there is a mismatch between the progressions of the Mathematics required to do advanced Physics courses (Ayene, Kriek, & Damtie, 2010).

Therefore, the Ministry of Education becomes the principal producer of academic course materials without much concern being given to the role of other stakeholders. The traditional method does not take into account some pertinent factors that have an impact on the process of teaching fluid mechanisms.

The other factor was the teachers' factors. The impact of teacher characteristics (teacher factors) is important for Science education and students' learning outcomes in Science (Bal-Taştan et al., 2018). Teachers' factors are influenced by their experience level, school location (urban, semi-urban, or rural), and level of students' education (kindergarten, primary, or high school) (Kim & Seo, 2018; Milner, 2012).

However, Nkrumah (2018) investigated whether age, gender, teaching experience, and qualifications in tertiary education affect tertiary students. There were 40 teachers and 1,800 students involved in the study. The findings were diverse. For example, female teachers negatively influenced the learning of tertiary students in the first semester but positively influenced students in the second semester. As with the teaching experience, teachers with five to eight years of experience negatively impacted the first semester but positively impacted the second semester of the same course. Age and qualifications did not have any effect.

The researcher of this study is 35 years old, a male who has had 14 years of teaching experience and holds an M.Sc. in Physics. Based on these studies in both developed and developing countries, it can be concluded that learning fluid mechanics can be seen as an area of confusion for many students and appears to be difficult to grasp. This research is focused on the use of multiple representation approaches in enhancing the learning of fluid mechanics, namely: Archimedes' principle and buoyant force, Pascal's principle, the continuity equation of fluid dynamics (moving fluids), and Bernoulli's principle in undergraduate Physics classes in Ethiopia.

1.4 RATIONALE OF THE STUDY

The rationale for the study was twofold: firstly, it comes from my experience and, secondly, from identifying a gap in the literature. The researcher has been teaching Physics courses (fluid mechanics) for the last 14 years and has noted that undergraduate Physics students repeatedly have challenges understanding the concepts of buoyancy force, Pascal's principle, fluid dynamics, and Bernoulli's principles. The traditional lecture method that the lecturers have been using for their entire teaching careers does not facilitate understanding among undergraduate university Physics major students. Therefore, the researcher needed to seek possible alternative methods. The purpose of addressing this course is thus to explore the gap that students appear to face between school and university Physics teaching and the learning process framed by a non-calculus-based approach.

Secondly, previous researchers have shown that teachers focused on using different instructional approaches without considering students' prior understanding (intuitive conceptions) (Ling, 2012). Hence, it is important to assess students' prior understanding before starting the teaching/learning process, as this could contribute to the teachers' knowledge of how to approach their learners to facilitate students' conceptual understanding (Linder, Fraser & Pang, 2015).

There was a need to categorise students on the basis of their conceptual understanding of fluid mechanics. This was done before using the instructional approach. From my research point of view, no previous studies have embarked on the categorising of students' understanding of fluid mechanics. Therefore, the topics of fluid mechanics that were addressed include: The Archimedes' principle (buoyancy force); Pascal's principle; fluid dynamics (the continuity equation); Bernoulli's equation and their applications.

To address students' conceptual understanding of fluid mechanics, it is imperative to find the most applicable teaching intervention. Therefore, a focused teaching intervention using the MR approach was developed. The MR approach has been shown to be effective in some other Physics concepts, such as mechanics (Hartini, Liliasari, Agus & Ramalis, 2020). Therefore, it was decided to develop the MR approach for the Physics concepts listed above.

The MR approach has been used in different studies. Researchers found that the use of an MR approach can increase students' conceptual understanding of basic concepts of Physics. This was seen from the data tables of experimental group results, which used videos, figures, verbal explanations, and mathematical equations (Bakri & Mulyati, 2018). One study used the MR approach without interactive computer simulations, and the results showed that the MR approach was effective in developing an understanding of the concepts of introductory Physics (Lusiyana, 2019). Hartini and Sinensis (2019) and Volkwyn et al. (2020) indicate that using a variety of designs, such as formulae, calculations, and diagrams, has been effective in enhancing the understanding of abstract concepts in Physics. However, students still had difficulty, for example, in using graphs; finding mathematical equations from graphs; and drawing conclusions from the lesson (Dimas, Superarmi, Sarwanto & Nugraha, 2018).

Scholars have used 3 or 4 representations (Hartini & Sinensis, 2019; Volkwyn et al., 2020). However, the current study was conducted on the basis of eight representations to determine the effectiveness of teaching fluid mechanics in producing more than just this study.

1.5 OBJECTIVES OF THE STUDY

The study filled these gaps by first establishing what the student's prior understanding of fluid mechanics was and then categorising their understanding. Secondly, more focused teaching approaches were developed using multiple representations to address students' alternative conceptions. The MR approach was designed and used based on the framework of variation theory (Ling, 2012). The focus of this study was to investigate the use of multiple representation approaches to enhance the learning of fluid mechanics in undergraduate Physics classes.

1.6 RESEARCH QUESTIONS

The study attempted to answer the following research questions:

- What are the categories of students' understanding of fluid mechanics concepts?
- Which category of students' understanding is dominant in fluid mechanics concepts?
- What are the effects of multiple representation approaches on students' understanding of fluid mechanics concepts?
- What are students' attitudes toward multiple representation approaches in fluid mechanics concepts?
- Is there any significant difference between Iteration 1 and Iteration 2 in the experimental group in terms of student understanding of multiple representation approaches in fluid mechanics concepts?

1.7 SIGNIFICANCE OF THE STUDY

Primarily, the research findings can help policymakers and curriculum designers establish effective instructional approaches to teaching fluid mechanics. This enables practitioners to provide students with the opportunity to improve their understanding of fluid mechanics.

Secondly, describing every lesson using MR approaches can assist other researchers and higher education academics to use these lessons or change them according to their context. By providing examples of lessons, academics would not have to start from the beginning. Furthermore, describing every lesson using MR approaches can assist other researchers.

Finally, categorising students' understanding of fluid mechanics can provide other researchers with insight into research topics and come up with sound findings useful to support students' understanding of learning fluid mechanics.

1.8 LIMITATIONS OF THE STUDY

The progress of this research was influenced by four major limitations:

The first was that the majority of students were not assigned to the Physics department based on their interests. This influenced the students' interest in and capacity for conceptual learning in Physics courses. Through OEQs, it was difficult to obtain in-depth qualitative conceptual information from such students.

Secondly, the country's serious and ongoing security environment disrupted the teaching and learning process and made students feel frightened. This had an impact on the data-gathering sessions in particular. It was difficult to collect data from students who were uncertain because of security issues. The disruption to the teaching-learning process influenced the students' development of conceptual learning abilities, as well as the completion of the study according to schedule.

Thirdly, it would be good if the number of MRs that changed from 4 to 8 were again increased from 8 to 12, then to 16, and so on. By using these MR representations, it is feasible to obtain in-depth information regarding the conceptual challenges and enhance the learning of fluid mechanics concepts among undergraduate Physics students.

1.9 DEFINITION OF KEY TERMS

The meanings and descriptions of the terminologies used for the study are:

- Archimedes' principle (buoyancy force) in fluids states that "any object that is partially or completely submerged in liquid experiences a buoyancy force equals up trust pressure acting on the object in the opposite direction to the submerged object and pushes it upward".

- Bernoulli's principle deals with the relationship between the velocity and pressure of a fluid. Bernoulli's principle states that swiftly moving fluids exert less pressure than slowly moving fluids. This principle is essential in our daily lives. For example, this principle is the main principle that leads to the lifting of an aeroplane wing and permits an aeroplane to fly.

- Common Alternative Conception Model: Students' comprehension is a haphazardly organised knowledge structure that is occasionally correct and occasionally incorrect (Bao & Redish, 2006).

- The conception Model means the characterisation of the concept in a student's mind that is observed from their response to the items (Bao & Redish, 2006).

- Conceptual understanding refers to an integrated and functional understanding of ideas in a transferrable way, as it enables students to take what they learn in class and apply it across various domains (Holme, Luxford & Brandriet, 2015).

- Correct Expert Conception Model: According to Bao and Redish (2006), the correct expert conception model is based on scientifically accepted understanding.

- Fluid flow can be expressed in mathematical equations: "the product of the area and the fluid speed at all points along a tube is constant for an incompressible fluid". One can observe this by holding a finger over the outlet of a garden hose.

- Fluid mechanics is a fundamental topic that is usually taught at the undergraduate level in Physics and Engineering classes. It is one of the branches of Physics that deals with the interaction mechanics of fluids in dynamics, fluids in motion, and static fluids at rest and the forces applied to this interaction. Fluids are physical states of matter that comprise gases and liquids.

- Multiple representations are the expression of a concept in many ways, such as text (verbal and textual descriptions), sketches, diagrams, graphs and mathematical equations (Airey, Lindqvist, & Kung, 2019; Eichenlaub & Redish, 2019; Euler & Gregorcic, 2018; Franke et al., 2019; Geyer & Kuske-Janßen, 2019).

- Null Conception Model: students' understanding that is intuitive and scientifically unaccepted (Bandyopadhyay, Kuma, & Bhabha, 2010; Bao & Redish, 2006).

- Pascal's Principle (pressure measurement) states that pressure applied to a confined fluid in a container is transmitted equally to all regions of the fluid and the walls of the container. An important application of Pascal's principle is the hydraulic press.

- Students are undergraduate Physics students who are enrolled in fluid mechanics Physics courses at Ethiopian universities.

1.10 THE CONTRIBUTION OF THE STUDY TO PRACTICE

This research utilised the Variation Learning Theory (VLT) to define and address how students build the notion of fluid mechanics, as well as the major problems they experience while teaching fluid mechanics. This can help teachers to choose the best learning design. The strategy was used to identify the MR teaching approach in this study, and its effectiveness was assessed in the classroom.

The research came up with additional information on how to design a more interactive fluid mechanics teaching-learning approach to enhance students' understanding of the topic under investigation. This research is new of its kind. The researcher used an integrative instructional approach, which involved three learning theories, namely, cognitive learning theory developed by Piaget; Variation Learning Theory developed by Ling; and multiple intelligence theory developed by Gardner. The researcher was able to develop a Multiple Representation Approach to teaching fluid mechanics by combining the three theories. The method helped the researcher to address the students' multiple sense organs in learning fluid mechanics by providing them with pictures, computational activities, audio-visual activities, and virtual laboratory activities.

Piagetian-Based Constructivism is traditionally considered, and focuses on how people make meaning of or construct knowledge when interacting with content knowledge and the active processes of this interaction. This can happen both individually as an "epistemic knowing agent" (as Piaget refers to the knower, learner, and constructor of knowledge) or in a group of peers or more expert others. For Piagetian constructivists, the focus is on the knower and peer relations, equalizing power and relationships to create optimal challenges and support for investigating the knowledge. The process of the construction of meaning, learning, and knowledge development involves active engagement with the objects and people in the environment, a sense-making reminiscent of the child as a philosopher or a scientist (Dewey 1933; Papert 1999; Kohlberg 1968).

James Mark Baldwin's fundamental conceptualisations of knowledge creation, on which Piaget so heavily relied, were grounded prominently in the dynamic interaction between the person and their social and physical environment. Baldwin states, "The individual is found to be a social product, a complex result, having its genetic conditions in actual social life. Individuals act collectively, not individually" (Baldwin, 1909: 211).

Piagetian-based constructivism uses the processes of assimilation, accommodation, and equilibration (borrowed from evolutionary Biology as the mechanism by which increasingly complex understandings are created). This is also called "intellectual adaptation" and involves the "fit" between a knower's current understandings, knowing system, view, or lens (all terms used interchangeably by Piagetian-based theorists) through which she interprets the world and her engaged experience.

1.11 AN OVERVIEW OF THE THESIS

The thesis is organised into eight chapters. The first chapter provides an introduction and explains why this study is necessary, supported by the research questions. Chapter 2 provides an overview of relevant literature. The third chapter deals with the theoretical framework and the reasons for using the chosen theoretical framework. The fourth chapter describes the research design and methodology, as well as the intervention utilised in this study. After being exposed to the typical schooling described in Chapter 5, the students' understanding was described. The first part of the educational intervention was conceptualised, created, and implemented, as labelled in Chapter 6. In Chapter 7, the usefulness of learning interventions in addressing students' conceptual understanding is discussed. Finally, Chapter 8 provides a summary of the main findings, conclusions, implications, and recommendations of the study.

1.12 SUMMARY OF CHAPTER 1

This chapter describes the background of the study, with statements of the problem that focuses on the motivation for the study. The research questions, the significance of the study, definitions of operational terms and the organisation of the study are included. The main focus of this study was to investigate the use of Multiple Representation (MRs) approaches to enhance the learning of fluid mechanics in undergraduate Physics classes.

The study shows the motivation for the importance of the study as there was a gap in the literature and therefore a need to explore and then categorise students' conceptual understanding of fluid mechanics before using the instructional approach. The study is based on both developed and developing countries. Further, fluid mechanics is an area of confusion for many students and appears to be difficult to grasp, as this is also prevalent in Ethiopia where this study was conducted.

Four topics of fluid mechanics topics are addressed: Archimedes' principle (buoyancy force); Pascal's principle, fluid dynamics (the continuity equation), Bernoulli's equation and their applications. The studies in Physics education used either 3 or 4 MR representations, however this current study presents eight representations to explore fluid mechanics. The study adds that it fills the gap by first establishing students' prior understanding of fluid mechanics and then categorising their understanding. Secondly, the study addresses the issue of teaching approaches to addressing students' alternative conceptions incorporating the MR approach based on the variation theory. The study defines Multiple Representations as the expression of a concept in many ways, such as text (verbal descriptions), sketches, diagrams, graphs and mathematical equations This research uses the VTL (Variation Learning Theory) to define and address how students build the notion of fluid mechanics as well as the major problems they experience while learning. VTL was used to identify and communicate critical components of each of the five basic and significant fluid mechanics' ideas. This information can be used to build classrooms for fluid mechanics lectures. The researcher adds that the outcomes of this study may help students grasp and express Physics topics better and enhance the knowledge of the scientific research community.

CHAPTER 2: REVIEW OF LITERATURE

2.0 INTRODUCTION

The study focused on solving students' conceptual problems in fluid mechanics Physics through interventional instruction. It begins with an explanation of the history of fluid mechanics Physics (Section 2.1). A section on Physics education research issues follows (Section 2.2). Detailed descriptions are given of the challenges that Physics students face when acquiring a conceptual understanding of Physics concepts (Section 2.3). Furthermore, teaching approaches used to address students' conceptual difficulties in fluid mechanics are discussed (Section 2.4). Lastly, the Multiple Representation teaching approaches are defined and discussed with their successes and challenges (Section 2.5).

2.1 THE DEVELOPMENT AND HISTORY OF FLUID MECHANICS

According to Pal (2019), "fluid mechanics is the study of the motion of fluids and forces in fluids" (p. 1). Students need to visualise and understand the motion of fluids and the forces in fluids. For example, they need to understand concepts such as pressure, viscosity, pressure distribution, velocity gradient, velocity distribution, normal and shear stresses, pressure loss, mechanical energy dissipation, and the inflow of fluids due to friction. Fluid mechanics quantities can be directly measured in most cases. According to Serway (2004), instruments are available to directly measure pressure, flow rate, pressure drop, local velocity, and normal and shear stresses. In this study, the focus is on basic concepts in fluid mechanics, namely: internal force, pressure measurement, fluid flow, and Bernoulli's principle.

Fluid mechanics is typically taught in lectures and through laboratory experiments in most undergraduate Engineering programmes (chemical, mechanical, civil, etc.). For example, Pal (2019) reports that students are expected to perform pipeline flow experiments involving measuring pressure loss as a function of flow rate for pipes of different diameters. Flow metres and pressure transducers are used to measure flow rate and pressure drop, respectively. Usually, water is used for the experiment, and the experiments are conducted at room temperature. Sometimes the calculated numbers were compared with the theoretical relations. As an example, friction factor vs. Reynolds' number is calculated when dealing with pressure drop vs. flow rate experimental data, and compared to theoretical and empirical relationships.

In undergraduate fluid mechanics experiments, there is no relationship between pipeline flow experiments and the second law of thermodynamics, namely entropy and entropy generation in pipeline flows (Walker, et al., 2014).

2.1.1 A Brief History 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, the hydraulics part is concerned with experimental studies, and hydrodynamics is concerned with the theory of fluid flow. Therefore, the study on fluid mechanics resulted from the combination of hydraulics and hydrodynamics.

As hydraulics evolved, it became a purely experimental Science with practical applications. Mostly, in the Great Rift Valley regions, including the Nile Valley and the Tigris and Euphrates River Valleys, people have developed irrigation agriculture backed by a continuous stream of the proper amount of water used to produce their food. In particular, Egypt and Mesopotamia played a significant role in developing irrigation Technology about 8, 000 years ago. Since then, irrigation systems have been used to irrigate agricultural land to produce crops and vegetables to support household demands. Therefore, hydraulics is believed to have originated in water channels and floating ships. In due course, the history of fluid mechanics was transferred to the highest stage and began to support the success of people's day-to-day lives (Nguyen et al., 2019).

Meanwhile, the theory of viscous flow has been unexploited. Navier (1785–1836) and Stokes (1819–1903) added to the Newtonian viscous terms to provide the equations of motion. The equations developed by Navier-Stokes were difficult to analyse for arbitrary flows. The most important paper on fluid mechanics was written by a German engineer, Ludwig Prandtl (1875–1953). The sense of dividing water and air and the identification of their flow with small viscosity was discovered by Prandtl, who attempted to divide the layer between water and air by applying the Bernoulli and Euler equations. Since then, the boundary layer theory has been a leading tool in the analysis of flows. Theodore von Kármán (1881-1963) and Sir Geoffrey I.

Taylor (1886-1975) are among the scientists who laid the foundation for fluid mechanics as we know it today.

2.2 PHYSICS EDUCATION RESEARCH AND ITS IMPACT ON STUDENTS' CONCEPTUAL UNDERSTANDING

If a student has an alternative conception, it is sometimes known as a misconception (McDermott, 1997; Suprapto 2020). In other words, this alternative conception can interfere with students' understanding and make it challenging for them to develop scientifically accepted concepts (Ling, 2012; Ow, 2014). However, this is often not only due to ignorance of the past but could also be because of difficulties in connecting and relating previous knowledge to the correct concept (Christensen & Thompson, 2012). It, therefore, undermines the students' ability to solve problems and prevents them from understanding the concept (Alao & Gutherie, 1999; Light & Cox, 2001).

2.3 PHYSICS EDUCATION RESEARCH AND ITS IMPACT ON STUDENTS' CONCEPTUAL UNDERSTANDING OF FLUID MECHANICS

In response to scientific concepts, student responses are determined by prior knowledge (Chinn & Brewer, 1993). Students' prior knowledge provides an indication of their alternative conceptions as well as their scientific conceptions (Hewson & Hewson, 1983; p. 731). Prior knowledge means knowledge that students have because of what they have learned before or due to their intuition.

Prior knowledge can have a significant impact on what students learn (Maxwell, Lambeth & Cox, 2015). Hewson and Hewson (1983) established that significantly greater progress in understanding scientific conceptions was found when the teaching approaches dealt with students' alternative conceptions.

Therefore, teachers need to know what students' prior knowledge of a specific topic is, as this will assist them in knowing what to focus on in the lesson (Lo, 2012). "Such a challenge can affect the designing of instructional approaches that are used in the interventions" (Kriek & Coetzee, 2016, p. 723). Consequently, knowing the student's understanding could assist in designing focused teaching approaches and could allow students to conceptually understand what the teacher is teaching (Fredlund, Airey & Linder, 2015).

2.4 DEFINITIONS OF FUNDAMENTAL FLUID MECHANICS CONCEPTS

In every phase of learning, such as primary education, secondary education, or the tertiary level, students need to follow the designed curriculum. Thus, a curriculum provides information about the content, rules, and principles associated with a specific topic as well as a determined time range in the classroom (van den Akker, Kuiper & Hameyer 2003). A curriculum indicates what students need to learn, while a successful curriculum is based on proper implementation that can achieve the designed objectives and goals (Van den Akker et al., 2003). However, the effective implementation of a curriculum depends on many factors, among which are the student's nature (readiness of understanding) and teachers' use of effective instructional approaches (Fredlund et al., 2015).

This study used Ethiopia's prescribed curriculum for its fluid mechanics' course for Physics major undergraduates (MOE, 2018). There are four basic topics in fluid mechanics' undergraduate programmes. These are the Archimedes' principle, or buoyant force, Pascal's principle, fluid dynamics (moving fluids and continuity equation), and Bernoulli's principle. The next section lays out these four concepts in detail.

2.4.1 Archimedes' Principle

The first topic in fluid mechanics is Archimedes' principle (buoyancy force). The Archimedes' principles were developed around 250 B. by the Greek mathematician Archimedes, which describes that "any object that is partially or completely submerged in fluid experiences a buoyancy force equals up trust pressure exerted on the object in the opposite direction to the submerged object and pushes it upward." This is the reason that objects appear to weigh less while submerged in a liquid. Moreover, Archimedes' principle can be further expanded to mean that when an object is submerged completely in a liquid, the weight of the displaced fluid equals the weight of the submerged object. Likewise, Archimedes' principle can be an expression in the mathematical equation which is presented in Figure 2.1 below.

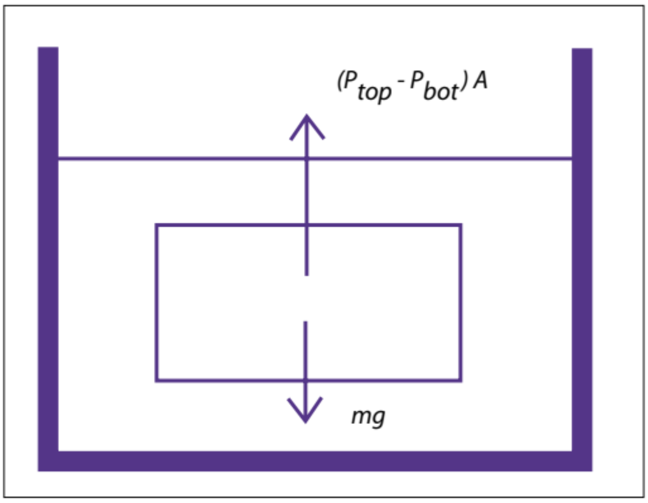

Figure 2.1: A submerged object surrounded by a fluid

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

The surface area of an object is A, its mass is m, and the surface pressure is P. As shown in Figure 2.1, buoyancy occurs when there is a difference in fluid pressure between the top and bottom of the object. Assuming that the force, due to fluid pressure on the vertical surfaces, cancels everything out and that atmospheric pressure effects are negligible, the free-body diagram for the object shown in Figure 2.1 would show three forces: a weight force down of magnitude mg, a force up of magnitude PbotA, and a force down of magnitude PtopA where A represents the block's cross-sectional area, while p_{top} and p_{bot} are the fluid pressures at the object's bottom and top, respectively. The pressure at the bottom is x times greater than the pressure at the top, where h is the block's height and p is the fluid density, resulting in a net upward force owing to the surrounding fluid. $(P_{bot}–P_{top})$ A is the total force attributable to fluid pressure, which is proven to equal the weight of the displaced fluid. In other words, buoyancy is the force that surrounds us that causes us to move upward when we float.

Figure 2.2 illustrates how a normal force between the surface and an object replaces the fluid force on the bottom of an object, resulting in the same buoyant force as in Figure 2.1. The force exerted by the fluid on the bottom of the container in Figure 2.1 is based on the depth and density of the fluid, not the container.

$$F_{buoyant} = W_{fluid} = \rho_{fluid} V_{\substack{displaced \\ fluid}} g \quad \text{.......................................2.1}$$

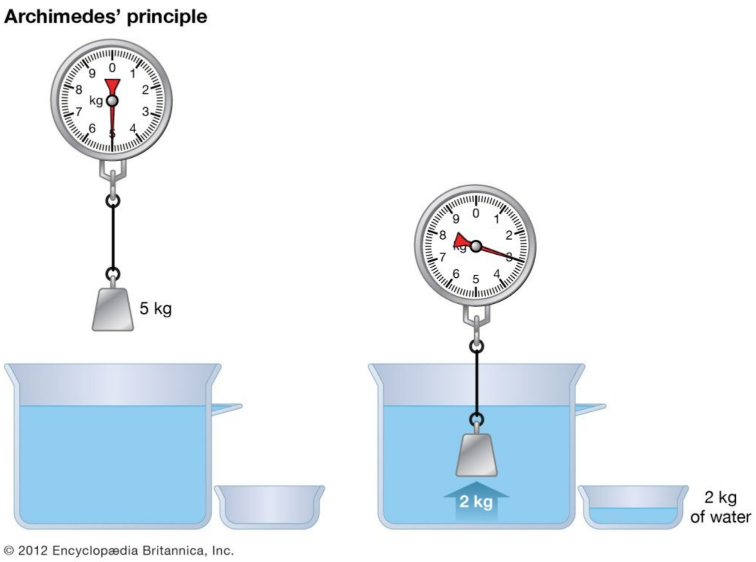

Figure 2.2: Archimedes' principle

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

2.4.2 Pascal's Principle

The second topic is Pascal's principle, which states that pressure applied to an enclosed fluid is equally transmitted throughout the fluid and all areas of the walls of the container. The hydraulic press is an important application of Pascal's principle (Figure 2.3).

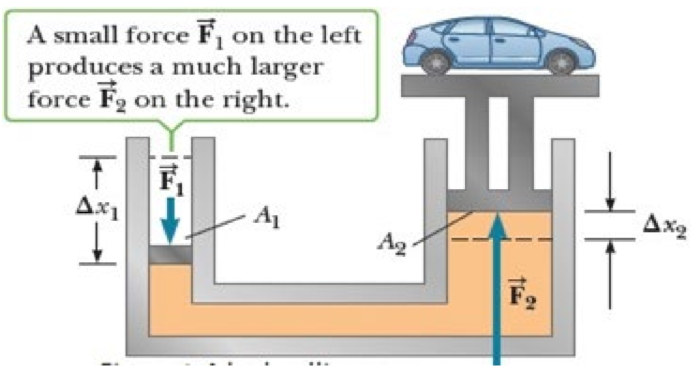

Figure 2.3: Hydraulic press

Source: (Serway 2004 p. 393).

A force $\overrightarrow{F_1}$ is applied downward on a small piston having an area of A_1 and causes the pressure of P_1. Mathematically, this can be presented as:

$$P = F1/A1.......2.2$$

There was no change in pressure because the pressure was distributed throughout the container and reached the larger piston on the opposite side without being affected.

When the fluid moves from the smaller piston to the larger, it can push the larger piston. The force exerted on the larger piston is equal to $\vec{F}_2$ having the pressure of P_2. Mathematically, these can be explained as:

$$P_2 = \frac{\vec{F}_2}{A_2} \text{ ……………….2.3}$$

According to Pascal's principle, even though the forces exerted are different, the two pressures are equal. This can imply that:

$$\frac{\vec{F}_1}{A_1} = \frac{\vec{F}_2}{A_2} \text{……….2.4}$$

The hydraulic press that was used indoors and in other openings is one of the main applications of Pascal's principle.

2.4.3 Fluid Dynamics

The above two concepts deal with fluids at rest or static fluids. The third topic is hydrodynamic fluids or fluids in motion. Fluids in motion can be categorised into different sections, such as a constant flow of the fluid whose velocity is constant at all times. When a fluid is flowing through one area, it keeps the same velocity. It can be classified as compressible or incompressible, depending on the nature of the flow being compressed or not. The other classification can be a non-viscous or viscous fluid, depending on its flow nature. A viscous fluid, such as butter, does not flow and a non-viscous fluid, such as water, can flow easily.

The equation of continuity is about the conservation of mass of an incompressible fluid. As a result of this, all cross-sectional areas will have the same amount of fluid flowing through them. This can be expressed in the mathematical equation: "the product of the area and the fluid speed at all points along a tube is constant for an incompressible fluid".

$$Flow\ rate\ = \frac{volume}{time} = Av = \ constant \text{ ……………………………..2.5}$$

One can observe this by holding a finger over the outlet of a garden hose. When the cross-sectional area decreases, the rate of flow increases. According to this principle, when the cross-sectional area decreases, the velocity of the water will increase. This shows the condition of the principle. According to this, when no water leaks occur at any interval of time, the volume of water that leaves the tube at one end equals the volume that enters it at the other end. In addition, undergraduate Physics students study steady flows of incompressible, non-viscous fluids.

2.4.4 Bernoulli's Principle

The fourth topic in this course is Bernoulli's principle. This principle was developed in the 18th century by Daniel Bernoulli, who was a physicist. In this equation, velocity and pressure are related, as Bernoulli's principle states that fluids moving rapidly exert less pressure than fluids moving slowly. It is expressed mathematically as follows:

$$P + \frac{1}{2}\rho v^2 + \rho g y = constant \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.6$$

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

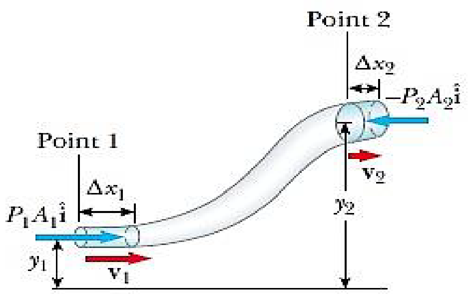

Figure 2.4: Fluids flowing steadily through pipes of varying cross-sectional areas

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

2.5 CONCEPTUAL DIFFICULTIES WITH FLUID MECHANICS CONCEPTS

Students' lack of understanding of fluid mechanics can affect their understanding of some everyday life situations or their prior understanding if they further their studies in Physics (see Sections 1.1 and 1.2). Common alternative concepts in fluid mechanics (internal force, pressure measurement, fluid flow, and the principle of Bernoulli) are presented.

2.5.1 Conceptual Difficulties in Understanding Archimedes' Principle

The Archimedes' principle (buoyancy force) can be explained by considering Archimedes' principle. Studies show that undergraduate students find it difficult to explain and analyse

Archimedes' principle (Chen & Gladding, 2014), and students find it difficult to calculate and explain the sinking and floating behaviour of simple objects (Loverude et al., 2003). They are confused when they have to explain the difference between the weight and density of the material inserted into a fluid. In addition, undergraduate students fail to distinguish between density and volume (Hewitt, 2009).

Furthermore, most undergraduate students have difficulty distinguishing between internal force and pressure (Wagner, Cohen & Moyer, 2009). In the same manner, undergraduates are confused when they have to identify the difference between the mass and volume of the material inserted into a fluid (Loverude, Heron & Kautz, 2010).

Students find it difficult to accurately evaluate and provide mathematical calculations when a substance is partially or completely submerged in a fluid (Heron & Christian, 2003; Loverude et al., 2003). It is difficult to understand the difference in calculations when an object is completely immersed, partially or completely immersed, or floated in a fluid, and students often use the same formula when describing all three cases. They find it difficult to describe two or more related physical terms, and this results in their inability to solve and calculate problems about internal force. Furthermore, they find it difficult to analyse the results of the problems and what they conclude after solving them.

2.5.2 Conceptual Difficulties in Understanding Pascal's Principles

Tire pressure, water pressure, and gas stations all use pressure measurement (Walker et al., 2014, 2004). Therefore, from elementary to high school, the pressure concept is dealt with in general Science, and later it forms part of the Physics course in fluid mechanics. Introducing it at an early age could help students learn and understand the fundamental concepts of pressure. At the undergraduate level, students are expected to provide some analysis and explanation of pressure measurement. However, undergraduate students are confused about pressure differences at different heights and are more likely confused about pressure variations at different temperatures. Similarly, there is confusion among students about pressure and volume (Aksit, 2011; Minichiello, et al., 2020). However, this problem is not only seen in students but also teachers (Taylor & Lucas, 2000).

Undergraduate students have difficulty explaining the difference between weight and pressure (Raissi et al., 2020). Students also find it difficult to distinguish between pressure and temperature (Loverude et al., 2003). Studies also show that there is difficulty with pressure and volume detection (de Berg, 1995; Psillos, 1999), as well as a difference between pressure and force (Misaiko & Vesenka, 2014). The concept of compressed air for undergraduate students has been explored, and it was established that students do not understand size and pressure (de Berg, 1995).

For undergraduate students (Goszewski et al., 2013), the relationship between pressure and height is difficult to analyse. Increasing the height between two points of reference increases the pressure change while decreasing the height between the two points decreases the pressure change (Serway, Moses & Moyer, 2004). Not understanding proportional reasoning could be challenging too. Sometimes undergraduate students find it difficult to understand elementary concepts such as the relationship between pressure and height. They indicate that when height decreases, the pressure of the fluid increases. They also find it difficult to explain how pressure interacts with density. Furthermore, many undergraduate students have difficulty remembering the pressure unit and have problems using and understanding formulae to describe density and weight (Akis, 2011).

2.5.3 Conceptual Difficulties in Understanding Fluid Dynamics

Fluid flow involves the motion of a fluid subjected to unbalanced forces. This motion continues as long as unbalanced forces are applied (Jewett, & Serway, 2008). Therefore, fluid flow is a function of the rate at which fluids flow in a tube, such as speed and volume. Everyday examples include drinking juice from a straw and having a garden hose connected to a tap that can be opened and closed.

Students find it difficult to understand constant velocity and volume while learning fluid mechanics (Raissi, et al., 2020). Studies show that alternative conceptions of fluid flow exist at the undergraduate level. This includes the linking of different concepts, confusion of physical variables, and difficulty identifying related variables (such as pressure and temperature as well as area and volume), which makes it difficult to understand the fluid flow concept (Besson & Viennot, 2004; Hartini & Sinensis, 2019).

2.5.4 Conceptual Difficulties in Understanding the Bernoulli Principle

Bernoulli's principle is a very important concept in our lives. This includes the use of Bernoulli principles, such as air travel, wing design, ballooning, parachute fighter jets, bombers, and so on.

Bernoulli’s principle states that “an increase in a fluid’s speed occurs simultaneously with a decrease in its static pressure or potential energy” (Walker et al., 2014, p. 553). At any point in time in the subsurface, the total energy per unit mass of flowing fluid is equal to a constant value. Thus, kinetic, potential, and fluid-pressure energies are all included (Jewett & Serway, 2008, p. 432). It should not come as a surprise that Physics and Engineering students have difficulty understanding or explaining questions about Bernoulli’s principles (Chen & Gladding, 2014; Loverude et al., 2000).

2.6 TEACHING APPROACHES USED IN FLUID MECHANICS

It is possible to teach fluid mechanics using multiple representations, i.e., combining two or more representations in a way that helps students understand Physics concepts. For most students, the independent learning style or dependent learning is the most effective way to enhance the learning of fluid mechanics concepts. An independent learner is considered as one who does not limit his learning to the immediate environment and provided materials, and can extend his/her experience to the wider environment. While a dependent learner is a learner who is mostly dependent on the materials given to him/her in his environment (Abdurrahman, Setyaningsih, & Jalmo, 2019).

For this purpose, the use of Multiple Representation teaching materials is crucial, which contain MR-based content based on four fluid mechanics concepts. Furthermore, a student worksheet is provided for students to use to ask questions based on the indicators and objectives of the MR-based lectures. A combination of both qualitative and quantitative approaches is also recommended to get a clearer picture of the implementation of MR to enhance students' understanding.

The fluid mechanics' course is composed of different laboratory practical activities that require the application of several teaching approaches. Teachers are expected to provide students with various lab assignments and explain their responsibilities. They need to be able to maintain the labs as well as lab materials; enhance their knowledge of the manipulation of scientific-technical equipment; and achieve the objectives of classroom teaching-learning activities. Here, the student-centred approach helps students improve their experience of how to act in class and manage laboratory activities. The use of a student-centred approach affords students the chance to be addressed equally, to be active participants in lab activities, and to show their subject mastery to the teacher. However, teaching fluid mechanics in a lab setting needs some careful technical approaches. This is because of the mismatch between lab experiment sessions and the time allotted to them. In addition, there may be a contradiction between lab experiment sessions and the students' exam time. This may divert students' efforts and attention from their studies (El-Hajj & Budny, 2019).

In contrast, using multiple contextual approaches is an effective way of teaching fluid mechanics courses. They use multimedia devices such as videos, concept maps, and figures; charts of data tables; data tables of experimental results; verbal explanations, textual; mathematical equations; problems; and solutions as a basis for exercises. This involves relating, experiencing, transferring, applying, and cooperating. The method enables teachers to teach fluid mechanics courses using modern technological inputs such as information and communication technologies (internet and devices) to support and enhance learning in institutions. The method needs high competence in the use of ICT Technology in classroom affairs (Bakri & Mulyati, 2018).

There is also an individual work approach used by the teachers to create an environment for innovative activities. Here, students are expected to identify concerns, develop projects, and conduct individual research. In due course, they can improve their competence in associating concepts, ideas, views, opinions, and the organisation of documents (Alvermann & Hague, 1989). It is a subsection of the learner-centred approach, which is one of the major conditions for students' self-organisation in mastering the methods of professional activity. This enables them to be efficient in dealing with complex and innovative Engineering challenges using their fluid mechanics skills and knowledge. The method reduces the role of the subject teacher, while it increases the role of the students in problem-solving activities. Students obtain favourable conditions to organise the learning conditions that ensure the management of learning activities in the absence of a teacher, which enhance the process of learning-by-doing and helps students acquire long-lasting knowledge. However, the method is less applicable to teaching fluid mechanics courses, which need cooperative work and a close interactive approach between students and subject teachers in line with the academic demands of the 21st century (Guseinova, 2018).

2.6.1 Traditional Teaching Approaches in Fluid Mechanics

In traditional instruction methods, students move from a group learning environment to an individual learning environment. Thus, it minimises the results of an interactive learning environment where the educator guides the students in applying the concepts and the students also engage creatively with the subject. The traditional lecture is a method of teaching many students in a classroom at the same time. Normally, this method uses chalk and talk (Chen & Gladding, 2014). A traditional lecture method is an approach, and it is said to be less effective than the modern approach (Geyer & Kuske-Janßen, 2019; Faleye & Mogari, 2010). Similarly, the study shows that using a traditional lecture approach is not fruitful in enhancing students' understanding of fluid mechanics and hinders their ability to solve problems (Chen & Gladding, 2014; Euler & Gregorcic, 2018). In Engineering, most instructors use a lecture-based pedagogical model. Among these reasons is the persistence of this model, which requires a lesser amount of resources and time than traditional fluid mechanics courses. However, the method is applicable if it is complemented with visual graphics of the related materials (Wayan & Kartini, 2020). Here, students are predicted to be at the centre of the teaching-learning process. They decide what to learn and how to select and organise content and materials. In addition, they learn how to integrate fluid mechanics with other disciplines. Furthermore, how to manipulate computational aspects of the course, how solve problems, conduct class activities, and manage activities to finally achieve the end with little intervention from the subject teacher. However, the method is less likely to solve more complex ideas and concepts that need demonstration, explanation, and guidance as expected from the subject teacher (Shaheen, 2015).

A study by Mohammad et al. (2012) found that the traditional method of teaching fluid courses is not an effective method of teaching. This is due to the fact that it leaves students with fewer opportunities to combine what they learn, how they learn, and how to improve their school performance. This is because students have no role in the teaching-learning process. As a result, the teacher plays a vital role; he is the manager when the learning process relies heavily on enforcing the rules. In a broader sense, the traditional method gives the chance to promote a top-to-bottom approach.

The Ministry of Education becomes the principal producer of academic course materials, without much concern being given to the role of other stakeholders. The traditional method does not take into account some important factors that have an impact on the process of teaching fluid mechanisms. Many factors influence whether a child performs well in school. This includes family background, materials, teaching methods, homework, class schedule, classroom activities, students' intelligence and motivation, a teacher's level of knowledge and experience, educational facilities, and the number of students in a class. Therefore, it is essential to use an efficient teaching-learning approach when teaching fluid mechanics courses. This helps students to be active, reactive, responsive, innovative, creative, and respectful of the teacher, who is the organiser of the procedure for teaching fluid mechanics concepts.

2.6.2 Contemporary vs. Traditional Teaching Methods

In the current study, the researcher selected a modern teaching approach called the MR approach. As a form of learning development, MRs can be used to teach fluid mechanics by combining two or more representations as a form of teaching that helps students understand Physics concepts. Allowing for a range of cognitive styles is a supportive approach to improving students' understanding of their field. A crucial method to achieve this objective is the use of modules, which contain MR-based content encompassing gravity, particle system dynamics, rigid body rotation, and rigid body rotation in three dimensions. Additionally, a student worksheet (LKM) is essential to pose questions based on the indicators and objectives of MR-based lectures which are undertaken by students. In addition, descriptive, qualitative, and quantitative research methods should also be employed to obtain a clear picture of how MR is implemented using the cognitive styles of FD and FI (Hartini et al., 2021).

2.6.2.1 Cooperative learning vs. traditional instruction

A cooperative learning strategy is a method through which a group of students work together on a common project. In collaborative learning, students can work together on a variety of issues, ranging from simple mathematic problems to large assignments, such as recommending environmental solutions nationwide. As a teaching methodology, students collaborate on a meaningful project or a significant question. In America, cooperative learning dates back to John Dewey's philosophy of social learning (Palmer, Peters & Streetman, 2017). Cooperative learning and group work are frequently used in the classroom to introduce a change or provide students with variety in their instruction; it keeps students engaged and allows the teacher to reach a larger audience. Besides changing students' and teachers' roles, cooperative learning makes teachers more like coaches on the side, and it encourages students to take responsibility of their learning.

The study reveals that the cooperative instructional approach, which is an innovative teaching method, enables students to be active participants in the peer instruction system. The method provides students with the opportunity to learn fluid mechanics courses through peer-based problem-solving techniques. Thus, students enrich their understanding of the concepts by receiving peer instruction, which enables them to benefit from hearing another perspective on the concepts that are not offered in the traditional approach. There is also the possibility to use both cooperative and traditional approaches to teach fluid mechanics courses. Students are engaged in group activities, master learning objectives, and develop knowledge based on what they already know. An active learning system is essential for learning fluid mechanics concepts, engaging in actual problem-solving techniques, and achieving objectives.

In literature, cooperative learning is differently phrased. It is also called the "active learning method," which helps students do meaningful learning activities and think about how they are engaging in classroom activities while learning fluid mechanics. The method is used to provide learners with different classroom as well as home-based assignments to enhance their independence as well as cooperative work. Thus, the method also allows teachers to use a traditional instructional approach, i.e., the provision of traditional work such as homework activities. Despite that, students are expected to be active learners and follow practices that are introduced in the classroom by the subject teacher. Unlike the traditional approach, the cooperative method paves the way for the students to be the owners of the teaching-learning process, and they learn the concepts of fluid mechanics through the use of their multiple sense organs. Therefore, in contrast to the traditional method, the cooperative approach is an important method for teaching courses in fluid mechanics. It reduces the role of the teacher to that of a facilitator vis-à-vis the student's involvement in the teaching-learning process (Caabate et al., 2020).

Cooperative learning, as part of a student-based teaching approach, enables students to solve complex fluid mechanics problems. As part of a clear shift from the traditional approach, students have greater influence over the direction their learning takes within a given academic framework when using the cooperative fluid mechanics approach. Using a cooperative teaching method improves students' learning outcomes compared to using the traditional method of teaching fluid mechanics concepts. This means the cooperative teaching method allows the subject teachers to provide students with various problem-based and project-based learning experiences. This increases the student's motivation for learning, competence, and knowledge retention while helping them understand and resolve activities in fluid mechanics. This is, thus, more effective than using the traditional approach (AbdelSattar & Labib Francis, 2020). The cooperative teaching approach is a type of student-centred pedagogy, which is the opposite of a traditional lecture-based course that is supposed to lead to sustainable improvements in student attitudes and performance in learning the concepts of fluid mechanics. Unlike the traditional approach, the cooperative instructional method is part of the 21st-century pedagogical shift from a passive moralistic teacher-centred approach to an active student-centred approach. It provides students with the opportunity to learn about the principles and practical aspects of fluid mechanics. This can help in a more interactive manner that occurs outside the traditional classroom setting. Therefore, the cooperative teaching method is said to put students' interests first in teaching fluid mechanics courses.

This method gives students the choice of what to learn, how to learn, and how to assess what they learn. As a result, fluid mechanics is taught from the perspective of the students instead of the teacher. In other words, the cooperative teaching method is a synonym for the active learning method. Students take ownership of the teaching-learning process, which includes a variety of classroom activities such as problem-solving, answering questions, formulating questions, discussions, explanations, debating, brainstorming, and so on. Therefore, the method, unlike the traditional approach, helps students develop a sense of team spirit, and interdependence, and learn the course material in the context of addressing the challenges (Rizvi, 2015).

The cooperative learning method enables students to learn how to deal with fluid mechanics courses through the use of team-approach or collaborative learning skills, and the method prepares them for problem-solving levels. Initially, the method allows students to identify a problem relevant to applications of fluid mechanics that would address a societal need. As a type of cooperative method, the functional-based approach provides a suitable teaching-learning environment. It can help students learn to play various roles and develop the skills required to complete a complex task using teamwork. Thus, this is the foundation for knowing how to control and use different complementary ideas, develop effective communication skills, and solve the challenges of learning fluid mechanics. Here, students are not only learning how to solve problems, but they are also learning how to build a team that facilitates the exchange of ideas within the learning process. In dealing with fluid mechanics courses, the subject teacher must assist students in developing a positive attitude towards teamwork or cooperative learning and must determine whether the teaching-learning process achieved its goal or not (Jorgensen et al., 2020).

Using the student-centred approach in teaching fluid mechanics concepts indeed helps students to improve their initiation, participation, engagement, creativity, critical thinking, and collaborative learning skills in learning fluid mechanics courses. Likewise, using the inquiry-guided instruction method is a vital way to teach students essential skills and knowledge of fluid mechanics, backed by the provision of close assistance or guidance by the subject teacher. Therefore, the inquiry method, like the student-centred approach, is believed to provide students with an innovation-driven learning experience compared to the use of traditional instructional methods. Utilising this method, teachers are expected to use several alternative methods in teaching fluid mechanics courses and provide guidance to their students. This can make them creative learners, critical thinkers, and interactive learners of fluid mechanics through the use of an inquiry-guided instruction method, which reduces the role of teachers to that of facilitators of learning. Here, teachers need to build an environment where students feel comfortable and learn fluid mechanics using an open or discovery learning process. However, this is not possible while using the traditional instructional method because, in a traditional approach, students do not learn fluid mechanics courses in a more structured approach. Furthermore, it gives the teacher more authority to control the whole instructional process. So, the student is considered less responsive, less creative, less interactive, and less able to use their multiple sense organs in learning fluid mechanics. Therefore, the inquiry-guided instructional approach is a process of transferring authority from a facilitator of learning to the actual learners (Arce-Trigatti & Anderson, 2020).

By contrast, guided inquiry does not rely on traditional methods of teaching, but rather gives students the ability to visualise and experiment with flow fields in real time. It also allows the teacher to show students how to learn about the flow of fluid substances. Therefore, students can improve their ability to use active engagement and discovery learning from fluid mechanics lessons, regardless of whether they are formal or informal. In a guided inquiry method, the students can discover certain fundamental principles of fluid mechanics concepts, as opposed to a traditional method in which the teacher is the primary instructor. A guided inquiry approach allows the subject teacher to organise teams and provide each team with separate class activities and conduct formative assessments to ensure that each team member contributes to the outcome. Rafferty (2010) found that when fluid mechanics courses were taught through inquiry, students scored higher than when they were taught the traditional way. This was because students had been provided with the chance to do classroom and outdoor activities by themselves with minimal intervention from the teacher.

Like the cooperative method, the inquiry-guided approach gives the first position to the students, and they play a more central role in learning fluid mechanics concepts. They are also facilitators of the inquiry process, moving forward and exploring key topics of the content in more depth. To build confidence, students are expected to emphasise the existence of different approaches to team formation. The most important one is the functional-based approach, which is an effective way to organise members and is closely coupled to the functions needed to complete a task. The team members need to act in accordance with a mutual agreement to achieve the objectives. Therefore, the inquiry-guided approach, unlike the traditional method, is an effective self-teaching method through which students can learn on their own. The method provides students with a conducive learning environment in which they can hone their skills and knowledge of how to use innovative Technology to achieve their goals (Jorgensen et al., 2020).

2.6.2.2 Interactive computer-simulation vs. traditional instruction

The interactive computer-simulation approach has become a viable alternative instructional approach compared to the traditional approach. In recent years, the traditional approach has become a much less favoured instructional method. This is because technological innovations have transformed the academic system, and most academic institutions have had to transform their teaching and learning processes, such as computer-based learning because Technology adoption is part of the new paradigm of education. This includes online learning in the natural Science field of studies, including Physics, which supports classroom instruction. Some physical quantities are not directly accessible, requiring semiotic representations through observation and direct or indirect measurements of the objects of study, which can be accomplished using computer simulations (Campos et al., 2020).

The interactive computer-simulation approach is believed to have produced better learning outcomes than teaching fluid mechanics using the traditional approach because the traditional approach is a weak method to improve student engagement, perceptions, achievement, enthusiasm, and stimulation, leading to the overall effectiveness of the fluid mechanics' course (Webster, Kadel & Newstetter, 2020).

With modern Technology, students can learn from online content, which allows them to be aware that each experiment has a finite number of setups, motivating them to do all the assigned experiments. These can be done in any order. In contrast to the traditional approach, the computer-simulation method is an efficient instructional approach in providing learners with the chance to learn autonomously. This can be achieved by having the autonomy to decide the best learning approach for them to progress through the course (Russo et al., 2020).

At the beginning of the 21st century, information, and computer technologies provided teachers with a favourable teaching-learning classroom environment in which to teach fluid mechanics courses and develop cognitive skills. Instructional resources emerged that are based on computer technologies and minimised the use of traditional approaches. The computer-simulation teaching method enhances the student's ability to acquire knowledge while carrying out experiments. It is also a useful approach to provide students with the opportunity to revisit classroom content to strengthen their knowledge. On the other hand, computer simulation and traditional approaches can be used simultaneously to teach fluid mechanics concepts. However, it is advisable to use the computer-based teaching method when there is a need to accommodate all forms of learning. It has the benefit of making content and activities accessible electronically or digitally.

The use of computer Technology to teach fluid mechanics courses is also highly dependent on the manipulation of technological materials compared with traditional methods. The downside of computer Technology is that access to technological resources (adequate ICT infrastructure, innovative tools for learning, media information, and its literature) may be limited. At such times, the traditional approach is more effective in teaching fluid mechanics concepts (Bakri & Mulyat, 2018).

2.6.2.3 Traditional instruction vs. video and animation methods

Traditionally, lectures are dominated by the instructor, who provides information with minimal student interaction, whereas active learning models encourage student interaction. Video models are preferred to reduce the problems related to the use of traditional models. This is less likely to lead to the creation of tutorials for each topic and in-class activities (Herreid & Schiller, 2013). This is a phenomenon that has not been commonly seen in traditional teaching methods. Video instruction systems have facilitated the creation of focused instruction on a specific topic. The videos can be reviewed as many times as needed, which will help students embed the concepts into their thinking. Such repetition is not possible with traditional teaching approaches. Furthermore, once created, the teacher no longer has the burden of creating new lessons all the time and can focus on facilitation rather than lecturing. This, of course, does not mean that the videos may not need to be adapted, which could be quite time-consuming. However, the teacher can also select well-prepared videos from the internet. The video system creates interest and is a favourable way of teaching fluid mechanics concepts.

Video tutorials and online homework systems are incorporated into the online system, which makes teaching fluid mechanics courses more effective than a traditional lecture method that does not incorporate these features (Fuqua et al., 2019). The 21st century has facilitated the process of teaching-learning activities. For example, the use of internet Technology has multiple advantages. One is the reduction of distance and the provision of visual practical activities in class, and students get the opportunity to enhance their learning through their multiple sense organs. Nowadays, teachers have more opportunities to teach students using technological instructional materials such as PowerPoint, video, photos, laboratory apparatus, etc. These technological instruments play a significant role in teaching fluid mechanics, which requires the use of technological instruments, unlike teaching the same subject through the traditional approach. As a result, teachers are urged to promote a more interactive flow of visualisation and analysis activities. This includes computational fluid dynamics (CFD), particle-image velocimetry (PIV), and scientific computing modelling tools that will enhance student outcomes, which are impossible to accomplish through traditional instruction methods. Because fundamental fluid mechanics is composed of time-dependent flow structures that are very complex to solve analytically, traditional instructional methods are inefficient for teaching fundamental fluid mechanics concepts (Minichiello et al., 2020).

Unlike the traditional approach, a video-based instruction system enables teachers to cover more content because it is a cost-effective approach and enables teachers to save contact hours for higher-level interaction. The method is efficient for teaching students to show step-by-step experimental activities. Students have the freedom to perform experiments based on their choice through the adoption of the blended learning approach. This is done in the presence of the teacher as a vital means to discuss the topics and exercises through the use of online services. In addition, students can ask questions and get a timely response from the subject teacher (Minichello et al. 2020; Yaacob & Velte, 2021).

Therefore, a video-based instruction system is a supportive method to provide students with online teaching materials and their corresponding exercises, helping them to better comprehend the purpose of the experiment and acquire the rationale behind the experimental procedure. Besides helping to instruct the students in setting up the equipment and properly performing the first measurement, these videos also guided them in performing basic data processing operations correctly, as well as shutting down the equipment safely after completing the experiment. Video-based instruction is one of several recent technological inventions that facilitate the student-centred approach, which enables students to learn more about the concepts of fluid mechanics (Yacoob & Velte, 2021; Minichiello et al., 2020).

The video animation method is a fairly recent instruction system. In contrast to the traditional approach to learning, the video instructional technique is part of digital learning strategies that encompass more than just online learning environments (Anaraki, 2004). In fluid mechanics courses, the use of new technologies as useful academic inputs promotes active or student-centred learning. In this case, the video animation teaching method allowed teachers to present fluid mechanics in a scientific context instead of lecturing (Permana et al., 2021). It is part of online learning approaches such as quizzes, collaborative activities before the classroom, or reading. This method of video animation allows students to watch a video of the content before class and get a sense of what to expect. The students can then participate in facilitated activities in preparation for their assignments. The idea is a reaction to the most prevalent teaching and learning method in Engineering education, which is textbook-based instruction delivered through lectures, tutorials, and laboratories in conjunction with small exercises (AbdelSattar & Labib Francis, 2020).

2.7 THE TEACHING APPROACH BASED ON MULTIPLE REPRESENTATIONS

2.7.1 The Meaning of Multiple Representations

Researchers in the area agree that using an instructional approach based on variation theory can successfully enhance teaching (Fredlund et al., 2015). This has been found in Physics (Fraser et al., 2006); Engineering (Bernhard, 2010; Ingerman, Berge, & Booth, 2009; Romero & Martnez, 2012); Chemistry (Lo, 2012); Mathematics (Runesson, 2005); Language (Marton et al., 2010); and Economics (Pang, Linder & Fraser, 2006). Since students have different gifts or intelligence, the use of this variation theory can affect a student's knowledge positively (Lo, 2012; Lo & Marton, 2011).

Multiple representations are the expression of a concept in many ways, such as text (verbal descriptions), sketches, diagrams, graphs, and mathematical equations (Airey, Lindqvist, & Kung, 2019; Eichenlaub & Redish, 2019; Euler & Gregorcic, 2018; Franke et al., 2019; Geyer & Kuske-Janßen, 2019). The methods of MRs are described in the next section.

2.7.2 Using a Multiple Representation-Based Teaching Sequence

Multiple representations are the expression of a concept in many ways, such as text (verbal descriptions), sketches, diagrams, graphs, and mathematical equations (Airey, Lindqvist, & Kung, 2019; Eichenlaub & Redish, 2019; Franke et al., 2019; Euler & Gregorcic, 2018; Geyer & Kuske-Janßen, 2019; Skrabankova et al., 2020). These are discussed in more detail below.

2.7.2.1 The use of the text description approach

Several studies have indicated that written representation has many benefits, such as covering a wide range of educational content over a limited time (Martnez & Rebello, 2012; Wong et al., 2011). This method of representation helps students to understand the differences between abstract concepts that are closely related and those that could be misleading and can be used when other strategies cannot be used (Duffen et al., 2007).

Learning to write is also effective in interpreting concepts; therefore, a focus needs to be on teaching learners to write, then read, and then correct their own mistakes (Barton & Heidema, 2002). Studies have shown that the use of written methods to explain complex concepts in Physics is effective in enhancing learning (Duffen et al., 1997). Moreover, it helps to transform and interpret the concepts of Physics from one representation to another, so that it can create the necessary connections between the representations. For example, it helps to translate graphs and equations to explain their interpretation (Kozhevnikov, Motes & Hegarty, 2007). It is also associated with other methods of representation, such as simplifying the content of the curriculum and assisting students to understand the concept (Alverman, Smith & Readance, 1985; Hynd & Aleverman, 1989).

Furthermore, written representations are an easy-to-use method that can be used anytime and anywhere and can assist students to develop problem-solving skills (Kohl & Finkelstein, 2006; Wong et al., 2011). In addition, text representation is a technique used by many students. Students are accustomed to this method as they use this approach at school (Fredlund et al., 2015; Kuo, Stokes, & Nobre, 2012; Linder, 2013; Uhden et al., 2012). The use of written representation is inexpensive and does not necessarily require Technology, so it can be used to improve the conceptual understanding of all grades (Barton & Heidema, 2002).

Although text (written descriptions) is useful, it does have some disadvantages. The effectiveness of a method depends on how many students are in a class (Meh, 1997). As some students prefer to listen rather than read (Wong et al., 2011), not all students will learn in the same way, and some methods may not work for all students (Claston & Booth, 1997; Tao, 2001). When used in conjunction with algorithms to solve problems, text representations cannot completely replace the concept of algorithms (Wong et al., 2011). In earlier years (1985–2000), it was necessary to understand the concept by drawing and making graphic representations of the text (Alverman et al., 1985; Einsworth, 1998; Hynd & Alverman, 1989; Tarver, 1996). If students' previous knowledge is poor, the effectiveness of this method will be compromised to some extent.

There are differences between pictures, design, and a graphical representation, and each is discussed separately below. A picture is the whole-body representation of an object, whereas a drawing is the skeleton of the picture.

2.7.2.2 The picture representation approach

Picture representation refers to the use of charts and illustrations to visually display, analyse, and interpret numerical data, functions, and other qualitative structures. It visualises a non-algorithmic concept and is useful when a formula cannot be used and the concept is difficult to express in another representation. This representation allows students to use alternative conceptions to better understand the facts about the concept they are learning (Tabachneck, Leonardo & Simon, 2019). Although formulae and graphs play an important role in the success of Physics education, they are not effective without pictures (Gilbert, 2005).

In recent years (2000 to the present), studies have shown that the use of pictures has been a major tool in helping students who are visual learners. This method also conveys the concept better compared to many representations, with one picture being worth a thousand words (Tyler, 2013). Moreover, picture representation allows students to understand concepts that are not directly related to Mathematics (Kohl & Finkelstein, 2005a). The picture could contribute to conceptual development in Physics (Kozma & Russell, 2005; Gooding, 2004), and help students easily understand and remember the concepts they have been taught (Kozhevnikov et al., 2007). Picture concepts help students to easily connect with previous knowledge (Tao, 2001). In addition, viewing images could contribute to students' understanding of problems as it is a method of recognising differences in the same picture (Friedlund et al., 2015; Linder, 2013). The picture can help students to visually understand concepts more easily (Gooding,

2004) as it helps them to see and understand the realities of the problem (Tabachnek et al., 2019).

Picture representation can support imaginary logic because of its ability to "read" images compared to reading algorithms (Gilbert, 2005). Students often like to learn by drawing (Fredlund, et al., 2015; Linder, 2013), and it could assist in developing a positive attitude towards learning. It assists students in the understanding of kinematics, with particular attention to picture representations of position-, velocity-, and acceleration-versus-time graphs (Christensen & Thompson, 2012).

Ivanjek et al. (2016) investigated undergraduate university students' graph interpretation strategies at the Faculty of Science, University of Zagreb. It was found that students' strategies for picture interpretation were largely context-dependent. It seems that, in Physics, students prefer to use formulae rather than pictures. In this investigation, students' answers indicated the presence of slope-height confusion and interval-point confusion. Finally, it was concluded that students' reasoning about graphs varies from context to context.

In addition, findings from students who were enrolled in laboratory-based preparatory Physics courses indicated that there were some common errors exhibited in interpreting pictures (Brahmia et al., 2020; Christensen & Thompson, 2012; Eichenlaub & Redish, 2019; Euler & Gregorcic, 2018; McDermott, Rosenquist, & Van Zee, 1987). There are also limitations when using picture representations. For example, if a student's previous knowledge is poor, the effectiveness of this method could be compromised (Weinstein, Madan & Sumeracki, 2018). Holdsworth, Turner and Scott-Young (2018) maintain that students' experiences are critical to their resilience.

2.7.2.3 *The* ***diagram representation*** *approach*

Students' use of diagrams helps them solve problems in Physics (Kuo et al., 2012; Linder, 2013) as it helps them understand the concepts they are learning. It is a method often used to teach and learn Physics. For example, in the topic mechanics, free-body diagrams are used and then used again in optics and ray diagrams. Diagrammatic representations assist in explaining concepts that are not easily expressed in writing and mathematical representations (Martínez & Rebello, 2012). In addition, this approach is believed to be a good method for visually impaired students (de Cock, 2012). Another good thing about diagram representation is that a diagram can represent a concept without using many words (Linder, 2013; Simon, 1997). A study conducted with undergraduate students during an introductory Physics course about their understanding and problem-solving showed that the use of diagrams is effective in teaching electrical circuit concepts. In their study, they found differences in how experts and novices solve the problems and observed that experts would look back at the circuit while solving the problem but not the novices (Skrabankova et al., 2020). Using a diagram to analyse an issue can assist a student to solve it (Bakó-Biró et al., 2012; Duffer et al., 2007). Christensen, Meltzer and Ogilvie (2009) and Huvelen (1991) concluded that diagrammatic representation is a good way to express non-algorithmic concepts. It is also easy to use in the classroom and can be used to help solve problems and answer questions correctly (Christensen et al., 2009; Huvelen 1991). This method also solves real problems by developing student creativity (Bicer, 2021). The one disadvantage of diagrammatic representations is that students need experience in the use of these representations (Christensen et al., 2009).

2.7.2.4 The representation of the mathematical equations approach

Physics is often described as symbolic equations and numerical formulae. Therefore, knowing and applying mathematical equations can assist students in succeeding in Physics. Mathematical representations strengthen written and numerical relationships and provide creative problem-solving ideas (Romero & Martnez, 2013).

Kuo (2013) explained that Mathematics is a method of expressing concepts using formulae, equations, and numbers, and is a way of expressing laws, theories, and principles using letters, and is an important factor in learning and teaching Science (Kozma & Russell, 2005). A mathematical equation is the backbone of Science education, is uniquely represented in Physics (Christensen & Thompson, 2012), and assists when students need to solve numerical problems (Chi et al., 2010).

The use of Technology-integrated lessons could influence students' conceptual understanding of fluid mechanics (Kriek & Coetzee, 2016). Possible technologies are discussed in the following sections.

2.7.2.5 The computer-simulation approach

Computer simulations are a popular and widely used teaching method (Chen & Glading, 2014; Fredlund et al., 2015) in teaching Physics to all ages (Romero & Martnez, 2013). However, the method is a very time-consuming educational approach (Fraser, 2013), as it takes time to select the most appropriate simulations for the topic to be taught (Kriek & Coetzee, 2021).

Simulations support laboratory work, and it is important to use them in conjunction with other approaches (Gregorcic & Bodin 2017). They are effective in teaching students the principles of gas and burners (Misaiko & Vesenka, 2014), as they do not directly involve students in person, and they do not need to touch dangerous apparatus.

Koehler, Martens and Pries (2007) suggest that computer-simulation is an effective method in the teaching and learning of Physics. They were used to show students about abstract concepts, which were used as a method to develop students' conceptual understandings. Computer-simulation allows students to better understand the effects of forces and pressures in fluid mechanics (Mensah & Larson, 2017). Similarly, it improves the understanding of the difference between size and pressure (Rollnick & Rutherford, 1993) and is effective when teaching speed and flow rate (Kriek & Coetzee, 2016). By using computer simulations interactively, students can engage in critical thinking (Samuelsson, Elmgren & Haglund, 2019).

2.7.2.6 The virtual laboratory approach

The virtual laboratory is a simulated learning environment where students can conduct experiments and investigate concepts and theories without ever having to set foot in a lab. The virtual lab is a way of demonstrating theoretical concepts through practical activities (Bao, 2004). Using virtual experiments and relevant teaching methods can produce good results (Ya-feng Li, 2015) and enhance students' conceptual understanding (Allie et al., 2003).

Research shows that virtual laboratory-based learning impacts students' scientific thinking significantly. It was shown in a study conducted in Indonesia that the use of virtual laboratories develops students' critical thinking, creativity, conceptual understanding, laboratory skills, motivation, and interest (Ramadhan & Irwanto, 2017). The fluid mechanics' course is composed of different practical laboratory activities that require the application of several teaching approaches. Teachers are expected to provide students with various lab assignments and explain their responsibilities. This can enable them to maintain the labs as well as lab materials, enhance their knowledge of the manipulation of scientific-technical equipment, and achieve the objectives of classroom teaching-learning activities. Here, the student-centred approach helps students improve their behaviour in class and manage laboratory activities. The use of a student-centred method provides learners with the chance to be addressed equally, to be active participants in lab activities, and to show their subject mastery efficiently to the teacher. However, teaching fluid mechanics in a lab setting needs careful and technical approaches. This is because of the mismatch between lab experiment sessions and the time allotted for the same purpose. In addition, there may be a contradiction between lab experiment sessions and the students' exam time. This may divert students' efforts and attention from their studies (El-Hajj & Budny, 2019).

In another study, findings indicated that virtual laboratory exercises from the Physics Laboratory have a positive effect on students' perceptions and that students had positive comments about virtual Physics laboratory practices (Aşıksoy & Islek, 2015).

Scholars found that using virtual labs when teaching atmospheric pressure, for example, is a good approach that helps students understand the concepts better (Aksit, 2011; diSessa, 2008), and indicated that virtual labs are more effective when teaching this topic compared to traditional lectures (Bernhard, 2010; Pontiga & Gaytán, 2005).

On the other hand, using virtual labs can hinder the potential to use a real lab. Lack of knowledge of how to use virtual laboratories could be a hindrance, and it is necessary to have internet access when using virtual laboratories, which is not always possible in a developing country such as Ethiopia.

2.7.2.7 The teamwork approach

Observation shows that although students have prior knowledge concerning some typical functions within a team, their understanding of the roles is limited or shows several misconceptions. Jorgenson et al. (2020) recorded observations of teamwork during a two-hour laboratory session using the lab kit as a basis for the course activities. These activities were developed and used to expose students to the importance of the concepts behind developing and performing as a functional team. One important aspect was the identification of typical functions required in a team to achieve a team goal. Furthermore, the training focused on the identification of roles necessary for success within the context of the challenge and the appropriate selection of team members for the roles identified. A useful set of tools to achieve the distributed selection and identification of specific member functions was a functional resume. The creation and implementation of a strong AOR and an appropriate rubric for evaluation within the responsibilities outlined by the AOR are effective.

Fluid mechanics courses were devoted to knowledge acquisition within a functionally organised team (Dixon & Hall, 2013). Within this training, small, arbitrary teams of three students were asked to identify roles that they considered most appropriate for generating a prototype of innovative Technology in the context of a then-unidentified challenge within fluid mechanics that might have some level of societal impact. However, during this phase of the training, the focus was on the functions or roles that a team member should demonstrate or possess to contribute effectively to the success of the team. Once the arbitrary teams developed titles and descriptions of the roles they thought were most important, they were ready to develop a prototype of innovative Technology based on fluid mechanics concepts. In this case, students were asked to transfer the knowledge they acquired individually as well as through these arbitrary teams. This was done to develop a mutually agreed list of roles pertinent to the development of a prototype of innovative Technology that used fluid mechanics concepts. The purpose of this process was to instigate student ownership of the different functions needed to successfully achieve a team goal.

After undergoing the rigorous training described above, students were tasked with implementing activities. This is the step in which they were fully immersed in the identification of a challenge. This required the application of knowledge of fluid mechanics to a real-world, societally relevant challenge and progressing through knowledge acquisition and knowledge transfer to develop their prototype of innovative Technology to address that challenge. Each week, the facilitator of learning was available to students for discussions regarding their direction and how to redirect, if necessary, through activities within the elements of the model. At the end of the 15-week semester, students were to present the results of their prototypes of innovative Technology via a poster presentation. This was effective for teamwork (Jorgensen et al., 2020).

2.7.2.8 The video approach

Video representation describes the sequence, structure, and content of frames that make up a video, as well as any audio or text information (closed captioning). The video representation teaching method is a method of teaching students to visualise a concept (Jaeger et al., 2009). This approach is a useful teaching method for students who learn best by using sight and defining abstract concepts better than by using words and formulae. Videos allow students to view how something works and to understand the applicable concepts (Chen & Gladding, 2014). It has also been suggested that video tutorials are a fast, effective, and efficient method of acquiring knowledge (Marek & Aleksander, 2005). Studies show that the use of videos helps to improve students' creative skills (Gilbert & Watts, 1983).

Videos contribute greatly to the creation of a self-reliant and problem-solving generation. The use of video projects can increase students' curiosity and is very effective compared to the traditional approach (Chaco et al., 2009). The use of videos can address abstract concepts in Physics and fluid mechanics (Chen & Gladding, 2014; Geyer & Kuske-Janßen, 2019).

2.6.2.9 The use of animated pictures and the video approach

Video tutorials and online homework systems are incorporated into the online system, which makes teaching fluid mechanics courses more effective than a traditional lecture method that does not incorporate these features (Fuqua et al., 2019). Advances in Technology have facilitated the process of teaching and learning. For example, the use of internet Technology has multiple advantages; for example, the reduction of geographical distance, the provision of visual practical activities in class, and providing students with the opportunity to enhance their learning through their multiple sense organs. Nowadays, teachers have more opportunities to teach students using technological instructional materials such as PowerPoint, video, photos, and laboratory apparatus. These technological instruments play a significant role in teaching fluid mechanics, which requires the use of technological instruments. As a result, teachers can promote a more interactive flow of visualisation and analysis activities. This includes CFD, PIV, and scientific computing modelling tools that enhance student outcomes, which is impossible to accomplish through traditional instruction methods. Because fundamental fluid mechanics is composed of time-dependent flow structures that are very complex to solve analytically, traditional instructional methods are inefficient for teaching fundamental fluid mechanics concepts without the assistance of Technology (Minichiello et al., 2020).

Unlike the traditional approach, a video-based instruction system enables teachers to cover more content because it is a cost-effective approach and enables teachers to save more contact hours for higher-level interactions. The method is efficient for teaching students to show step-by-step experimental activities. Students have the freedom to perform experiments based on the adoption of the blended learning approach. The teacher becomes involved in discussing the topics and exercises virtually in an online environment. In addition, students can ask questions and get a timely response from the subject teacher (Minichello et al. 2020; Yacoob & Velte, 2021).

Therefore, a video-based instruction system is a supportive method that provides students with online teaching materials and their corresponding exercises, helping them to better comprehend the purpose of the experiment and understand the rationale behind the experimental procedure.

Besides helping to instruct the students in setting up the equipment and properly performing the first measurement, these videos also guided them in performing basic data processing correctly as well as shutting down the equipment safely after finishing the experiment. Therefore, unlike the traditional approach, video-based instruction is one of the recent technological inventions that has facilitated the student-centred approach, enabling students to have a better understanding of fluid mechanics (Minichiello et al., 2020; Yacoob & Velte, 2021).

The video animation method is a recently introduced instructional system. In contrast to the traditional approach to learning, the video instructional technique is one of the digital learning strategies that encompass more than just online learning environments. The video animation teaching method allows teachers to present fluid mechanics in a scientific context instead of lecturing. It uses online learning approaches such as quizzes, collaborative activities before the classroom, or reading. This method of video animation allows students to watch a video of the content before class and get a sense of what to expect. The class is used more for learning activities, where the students participate in facilitated activities in preparation for their assignments. The idea is a reaction to the most prevalent teaching and learning method in Engineering education, which is textbook-based instruction delivered through lectures, tutorials, and laboratories in conjunction with small exercises (AbdelSattar & Labib Francis, 2020).

2.8 SUCCESSES AND CHALLENGES OF MULTIPLE REPRESENTATIONS

Multiple representations are a unique learning approach conducive to all students. These approaches are multifaceted, for example, with one student excelling at using words, images, and Maths while another excels at only one (Sewell, 2002). According to Bakri and Mulyati (2018), MRs are appropriate teaching methods that have been applied to the design and teaching of basic Physics. This includes concept maps, videos, figures, data tables, charts of data tables, verbal explanations, equations, problems, and solution examples and exercises. The representations of contextual learning can be categorised into stages as follows: relating, experiencing, applying, transferring, and cooperating. Physics education as part of natural Science indeed deals with the study of matter. It is also concerned with the study of interconnections between the elements within it. Hence, MRs play an integral role in learning Physics. They offer the opportunity to manage fluid mechanics questions. In addition, they can provide students with the opportunity to learn more about Physics concepts, including text and animated images, diagrams, tables and graphs, algebra notation, as well as tables and mathematical equations (Bakri & Mulyati, 2018). In most cases, the process of learning Physics is successful when teachers are interested in using the MR approach. Moreover, using MRs helps students to improve their problem-solving skills, develop their creative thinking, and understand how to build their knowledge through experience and context rather than being taught. Therefore, the use of multiple representations in teaching Physics is an effective method to develop students' ability to learn cooperatively, respond to other learners in class, and communicate with them (Bakri & Mulyati, 2018). Hartini and Sinensis (2019) argue that MRs are important teaching-learning techniques that enable classroom teachers to improve the students' learning outcomes, which are consolidated through the provision of different ideas and technical equipment that enhance the students' learning in Physics.

Developing concepts by using different representations improves students' understanding (Meltzer, 2008), as it assists students to organise their knowledge (Khol & Finkelstein, 2005; 2006). It also helps the student to develop a dynamic understanding of the concept (Martnez & Rebelo, 2012; Distrik, Supardi & Jatmiko, 2021). The MR approach is suitable for teaching Physics and covers topics ranging from geoPhysics to medicine (Wiyarsi et al., 2018). Moreover, findings from a material Science training study show teachers need to use a variety of examples in their teaching practices, such as drawing, descriptions, compositions, and numeracy, to improve students' problem-solving skills (Rice, Lowenthal & Woodley, 2020). Researchers have indicated that combining numerical and written expressions using multiple representations enriches the experience and makes learning easier. For example, you can easily describe the concept of melting graphically, using a video or using mathematical equations (Frederick et al., 2015). In this way, students can analyse and understand concepts derived from algebra and algebraic representations to help them answer various Physics questions efficiently. In many cultures, using MRs seems to be successful when solving Physics problems (West et al., 2013). Therefore, to learn, interpret, and build different physical and scientific knowledge structures, there must be a variety of representations in the Physics class. Building knowledge through MRs develops students' comprehension skills (Kohl, Rosengrant, & Finkelstein, 2007).

Representing difficulties in several ways helps students to increase their chances of solving equations by combining quality and numerical expressions that give students a deeper understanding of pressure and frequency (Barton & Heidema, 2002; de Cock, 2012). It can produce better results by teaching Physics better in many representations (Barton & Heidema, 2002; Linder, 2013). Using a variety of representations could assist the student in developing an understanding by choosing different representations of the same concept (Gooding, 2004; Kohl & Finkelstein, 2005a; Kozma & Russell, 2005). Algebraic representations are difficult to analyse and solve real problems (Duffen et al., 2007; Martnez & Rebello, 2012; Kohl & Finkelstein, 2005a; Christensen & Thompson, 2012). A study examining the effectiveness of students' use of different types of representations shows that this improves their ability to easily solve complex Physics questions (Franke et al., 2019).

However, simulations can sometimes be a barrier to student learning. Simulations could create conceptual confusion and need to be designed to expand students' understanding (Fraser, 2015). Furthermore, using MRs is difficult and expensive, while having a variety of representations to explain one concept is even time-consuming and needs technological advancements to be implemented in a class (Dufer et al., 2007; Martnez & Rebello, 2012). It may not be effective for all subjects. Furthermore, it requires money, time, energy, and Technology (Bakó-Biró et al., 2012). Another obstacle to using this method is that students do not understand MRs in advance. In addition, students have ambiguities while using MRs simultaneously (Kohl & Finkelstein, 2006).

On the other hand, Lusiyana (2019) indicates that teaching Physics is a very challenging academic task because learning Physics concepts needs detailed mathematical equation-solving skills and knowledge. Thus, students require the use of various methods in understanding and translating different words, tables, graphs, equations, and diagrams. For this purpose, students are expected to solve mathematical equations, which are vital prerequisite skills in understanding Physics; otherwise, learning Physics is an unthinkable attempt without having adequate mathematical skills.

In this regard, studies reveal that students are required to know basic concepts of Physics and Mathematics because there is a close relationship between the two academic disciplines. Therefore, teaching students about the concepts of Physics by using their mathematical abilities is an important approach. It seems to be very difficult to learn Physics without having mathematical problem-solving knowledge because the two fields of study are reciprocally supported, i.e., students who learn Mathematics may be better able to solve Physics problems. According to Prahani et al. (2021), students are interested in learning Physics because it provides people with skills and knowledge that can be used to solve complex life-related problems. According to the authors, the MRs approach is a poor teaching method for satisfying the interests of all students. It is said that the method is suitable for teaching students who have active learning skills. This means the method needs the use of multiple learning domains such as cognitive and psychomotor so that Physics learning is more meaningful. Here, Physics teachers need to modify their approaches depending on the information on the students' social, cultural, academic, and language backgrounds to improve their learning abilities. This creates an additional work burden for them. On the other hand, in learning Physics, students need to know the laws, principles, and theories. Students who lack such knowledge are less likely to learn Physics through the application of the MRs approach (Destini, 2020).

MR could be an important teaching method in fluid mechanics as it enables teachers to use Multiple Representation techniques. This, in turn, can help students to learn more about the concepts of fluid mechanics using their different abilities. However, MR is not free from limitations, such as shortage of time, lack of technological inputs, class size etc. Despite that, the researcher used MR to enable the students' understanding of fluid mechanics concepts.

2.9 REASONS FOR SELECTING THE MULTIPLE REPRESENTATION APPROACH

Students find it difficult to meaningfully connect different representational forms in a given task or problem and to extract the intended conceptual understanding (Volkwyn et al., 2019). For that reason, it does not come as a surprise that studies show that an MR teaching approach helps students learn Physics more effectively (Brahmia et al., 2020; Saleh, 2014). It is thus important to use a diversity of tools, such as text, formulae, calculations, illustrations, and interactive learning techniques that can create a better understanding for students. Studies show that it is important for undergraduates to be taught in a variety of ways (Kohl & Finkelstein, 2006; Volkwyn et al., 2020), as it can improve their comprehension skills (Bakó-Biró et al., 2012). Therefore, since students prefer a variety of representations, researchers in the field of fluid mechanics agree that teaching using MR methods could make a difference (Minichiello, et al., 2020; Hartini, et al., 2020). In addition, studies in the field have shown that Physics students are more successful in problem-solving when using MR principles (Gestson et al., 2018), as their ways of understanding may differ because of the different ways they might approach a problem (Bako, 2012; de Cock, 2012; Fredlund et al., 2015). Therefore, it is a good idea to use all kinds of representations to engage students, and this allows students to be more successful in understanding basic Physics using MRs (Abdurrahman et al., 2019). Another advantage of using MRs is that students can easily understand a variety of designs, such as formulae, calculations, diagrams, and abstract concepts (Lin, 2014).

2.10 CHAPTER SUMMARY

This chapter presented the student's understanding of fluid mechanics, as well as possible explanations for the observed alternative conceptions in the topic. The MRs teaching approaches were discussed, and the challenges and successes of using the approaches were presented. The next chapter presents the theoretical framework for the study. Chapter 2 begins with an explanation of the history of fluid mechanics Physics. A section on Physics education research issues follows. Detailed descriptions are presented of the challenges that Physics students face when acquiring a conceptual understanding of Physics concepts. Furthermore, teaching approaches used to address students' conceptual difficulties in fluid mechanics are discussed. Lastly, the Multiple Representation teaching approaches are defined and discussed with their successes and challenges. Fluid mechanics in this study is defined as the motion of fluids and forces in fluids. Therefore, students need to visualise and understand the motion of fluids and the forces in fluids through concepts such as pressure, viscosity, pressure distribution, velocity gradient, velocity distribution, normal and shear stresses, pressure loss, mechanical energy dissipation, and the inflow of fluids due to friction. The Ethiopian university teaching context of Physics and fluid mechanics is discussed in detail.

A brief history of fluid mechanics was discussed, and the foundation was presented. Section 2.2 on Physics education research and its impact on students' conceptual understanding was discussed. Section 2.3.2 presented the difficulties with fluid mechanics concepts. In Section 2.4, teaching approaches used in fluid mechanics were discussed. Then the independent learning style or dependent learning style is the most effective way to enhance fluid mechanics concepts. This section adequately covered the different teaching styles, from traditional to video, and some related to fluid mechanics.

In Section 2.5, the teaching approach based on multiple representations was discussed. "Students obtain favourable conditions to organise the learning conditions that ensure the management of learning activities in the absence of a teacher, which enhances the process of learning-by-doing and helps students acquire long-lasting knowledge." In Section 2.5.3 Successes and Challenges of Multiple Representations, the researcher elaborates on multiple representations as a unique learning approach conducive to all students presented and discussed. For instance, MRs are appropriate teaching methods that have been applied to the design and teaching of basic Physics, including concept maps, videos, figures, data tables, charts of data tables, verbal explanations, equations, problems, and solution examples and exercises were discussed. The study takes a critical stance and adds that MRs are difficult and costly. While having a variety of representations to explain one concept was time-consuming and needed technological advancements to implement in a class, it may not be effective for all subjects and teachers might find it difficult to use. The study also discusses, in Section 2.5.4, several valid reasons for selecting the Multiple Representation Approach and connects MR to research in the field of fluid mechanics, as the research concurs that teaching using MR methods could make a difference. Finally, the MRs teaching approaches were discussed, and the challenges and successes of using the approaches were also presented.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 INTRODUCTION

This chapter covers the study's theoretical foundation. This encompasses the theories of cognitive learning, multiple intelligences, and learning variety. The chapter gives specifics on the research approach taken to carry out this investigation. The cognitive learning hypothesis is discussed (see Section 3.1). The description of the variation theory (Section 3.3) and the multiple intelligence theory (Section 3.2) follow. Gardner's eight types of intelligence were thoroughly addressed in relation to the Multiple Intelligence Theory (MI), and the researcher presents a case that learning happens in various ways. He uses these eight types of multiple intelligence to teach Physics and fluid mechanics as a result. According to the researcher, the Variation Theory of Learning (VTL), which is related to CT and MI, provides a theoretical framework from which potential variations in experience and the ensuing variances in learning and understanding are investigated.

3.2 COGNITIVE LEARNING THEORY

Piaget's (1936) theory of cognitive development explains how a child constructs a mental model of the world. Piaget's cognitive development theory posits that children move through four different stages of mental development (sensorimotor stage: birth to 2 years; preoperational stage: ages 2 to 7; concrete operational stage: ages 7 to 11; formal operational stage: ages 12 and up). His theory focuses not only on understanding how children acquire knowledge but also on understanding the nature of intelligence. The concept of cognitive development is defined by Piaget (1936) as how a child builds a mental model of the world.

Cognitive development occurs because of cognitive maturity and interaction with the environment, not because intelligence is a permanent feature. It is at an intermittent rather than gradual stage that children begin to understand, think and solve problems in the world. To better understand cognitive development, we should first examine some important ideas and concepts introduced by Piaget. One of the most important concepts is that of a schema which involves mental and physical activities and is a process of interpreting and understanding the world around us. In more simple terms, Piaget and Cook (1952) call the schema the basic building block of intelligent behaviour.

A new schema may be modified, added to, or modified as a result of new experiences. For example, children who only know small dogs may assume that all dogs are small, hairy, and four-legged. However, suppose a boy owns a dog that is large and furry. The child will modify their previous schema to incorporate these new perspectives. In the so-called Piaget method, Piaget (2001) believes that children strive to strike a balance between integration and accommodation. Adaptation processes that enable the transition from one stage to another involve equilibrium (i.e., a state of cognitive (mental) balance), assimilation (i.e., using an existing schema to deal with a new object or situation), and accommodation (this happens when the existing schema (knowledge) does not work and needs to be changed to deal with a new object or situation. Furthermore, Piaget posited that children learn best through doing and actively exploring and that acquiring knowledge is a process of maturation. He maintains that learning depends on a state of readiness without which it is not possible to understand information or concepts. The cognitive theory posits that students should form relationships between concepts in their long-term memory – this brings them to a state of readiness to learn the next concept. Sweller (2016) makes the argument that meaningful learning has occurred when there is an association between previous and newly learned knowledge. This enables students to memorise the new material and save it in their long memory (Bretz, 2001; Sweller, 2016).

There are also cognitive theories such as Bruner and Ausubel with variations in descriptions of cognitive development in each (Lawton, Saunders & Muhs, 1980). Cognitive learning theories include Vygotsky's (1978) sociocultural theory, which postulates that social interaction is a necessary ingredient for cognitive development, and the information processing theory (Simon, 1978), based on the association between long-term, short-term, and working memory.

Moreover, due to the existence of a clear and well-organised cognitive structure, Ausubel (1968, p. 68) believes that "the most important independent variable influences a student's ability to achieve". The most important single concept in Ausubel's theory is meaningful learning. Meaningful learning occurs when new knowledge is actively connected with a student's existing concepts or preconceived notions. In addition, "Bruner's cognitive learning theory (1966) was concerned with how knowledge is represented and organised through different modes of thinking (or representation)" (Berk, 2002, p. 212). From a cognitive theory point of view, the acquisition of new knowledge is only possible if cognitive structures are efficient (Tsai & Huang, 2002).

Relating cognitive theory to the learning of fluid mechanics, a systematic approach is needed to build the students' cognitive skills. Concepts need to be taught and understood sequentially because they build on one another to create the necessary schemata – one cannot, for example, learn about fluid dynamics without first having understood the Archimedes principle. In other words, students must develop their abstract thinking about fluid mechanics by first understanding the basic concepts. If not, it will be hard for educators to teach fluid mechanics concepts and for students to understand these (Temel & Özcan, 2020). Thus, cognitive theory can be used as a basis for designing fluid mechanics courses (Ifenthaler, Masduki & Seel, 2009).

Constructivism is a scientific and meta-theory which defines the possibility and limitations of daily life theories in the formation of humanity. The meaning of constructivism varies according to one's perspective and position. Constructivists are observers in a way, observing reality being formed in daily life or Science (Ültanir, 2012). Furthermore, constructivism is an epistemology, a learning or meaning-making theory that offers an explanation of the nature of knowledge and how human beings learn. It holds that people create or construct their new understandings or knowledge by interacting with what they already believe and the ideas, events, and activities with which they come into contact. The teacher is a guide, facilitator, and co-explorer who encourages learners to question, challenge and formulate their ideas, opinions, and conclusions (Ciot, 2009; Richardson, 1997), while the role of the community in the development of understanding requires active engagement on the part of the learner.

In theory, constructivism means that theories depend on observation and when directly translated, the theory has the meaning of observation (Siebert, 2002). In practice, this means that a careful observer structures the problem and how to comprehend it him or herself. Constructivism has been transformed into a role in which the intensive power of the teacher has been lifted.

For Piagetian constructivists, the focus is on the knower and peer relations. This equalizes power and relationships to create optimal challenges and support for investigating the knowledge. The process of construction of meaning, learning, and knowledge development involves active engagement with objects and people (Dewey 1933; Papert 1999; Kohlberg 1968).

Piaget's theories of knowledge creation were grounded prominently in the dynamic interaction between the person and their social and physical environment. Baldwin states, "The individual is found to be a social product, a complex result, having its genetic conditions in actual social life" (Baldwin 1909, p. 211).

Piagetian-based constructivism is a theory of the mind that uses the processes of assimilation, accommodation, and equilibration to create increasingly complex understandings. This is also called "intellectual adaptation" and involves the "fit" between a knower's current understandings, knowing system, view, or lens (Schrader, 2015).

Constructivism as an educational theory holds that teachers should first consider their students' knowledge and allow them to put that knowledge into practice. Mvududu and Thiel-Burgess (2012) represent the constructivist view as one of the leading theoretical positions in education. Since there is no universal definition of constructivism, some researchers consider it as a theory of learning (Mvududu & Thiel-Burgess, 2012). Constructivist perspectives on learning have become so influential in the past twenty years that they represent a major shift in knowledge and theory of learning.

Most of the interpretations of the constructivist theory agree that it involves a dramatic change in the focus of teaching and puts the students' efforts to understanding at the centre of the educational enterprise (Prawat, 1992). Constructivist teaching promotes learners' motivation and critical thinking and encourages them to learn independently. It is based on the learning that occurs through learners' involvement in the construction of meaning and knowledge (Gray, 1997).

3.3 THE MULTIPLE INTELLIGENCE THEORY

Gardner says that “to his mind, human intellectual competence must entail a set of skills for problem-solving, enabling the individual to resolve genuine problems or difficulties that he encounters and, when appropriate, to create an effective product or service, and must also entail the potential for finding or creating problems—thereby laying the groundwork for the acquisition of new knowledge. These prerequisites represent my effort to focus on those intellectual strengths that prove some importance within a cultural context. At the same time, I recognise that the ideal of what is valued will differ markedly, sometimes even radically, across human cultures, with the creation of new products or the posing of new questions being of relatively little importance in some settings” (Gardner, 2011, pp. 65).

Gardner (1983) divides intelligence into eight categories, stating that everyone has their natural inclinations and talents, and they learn in different ways. Therefore, it is effective to teach students based on their talents as their inclinations and talents motivate them. Using a variety of teaching methods will make it easier for them to understand concepts as shown in the discussion on MRs.

Gardner's eight bits of intelligence are discussed in the following sections.

3.3.1 Visual-Spatial Intelligence

Visual acuity is the ability to perceive things visually, and those who are gifted or intelligent are better able to understand their surroundings using visual representations. Students who are visual-spatial intelligent like to solve puzzles and understand parables because they have the skills to solve written problems. They can draw and understand pictures and prefer to learn by drawing. They can also analyse graphs and interpret designs, making it easier to learn by graphical representation.

3.3.2 Deep Vocabulary Intelligence

Deep vocabulary intelligence is the ability to understand, e.g., ideas, issues, and features in writing. People who are gifted or intelligent in this area are better able to express themselves in words. This means that they can understand the ideas expressed. They also can understand speech and the ability to understand what is presented in writing. Students who have vocabulary intelligence can understand what is presented in words, so they can easily ask questions either face-to-face or in class if they do not understand something. They can teach themselves by reading.

3.3.3 Numbers Intelligence

The use of numbers is the ability to work with and understand numbers and formulae. People who are gifted or intelligent in this area have strong cognitive skills in using numbers and can understand and analyse mathematical expressions. Students who are competent in this area may understand complex formulae and do multifaceted experiments. Therefore, students who are knowledgeable in this space like to learn to use mathematical representations.

3.3.4 Art-Beauty Intelligence

Artistic intelligence is the ability to easily understand what is described in art, and people who are gifted or intelligent in this space are better able to understand what is described in the art world. People in this area like beautiful things to look at and are capable of body development and exercise. They like to learn by touch, so they are comfortable with using laboratory experimentation or other representations such as animations and simulations.

3.3.5 Melodic Intelligence

Melodic intelligence is the ability to learn from sound. People with melodic intelligence are eager to listen to people and are interested in hearing from and listening to their friends and other people.

3.3.6 Communication Intelligence

Communication intelligence is the ability of people to understand and understand things by interacting with other people. People who are gifted or intelligent in this area are better able to communicate with their friends or teachers. They also have a strong motivation and desire to communicate with the people around them and can learn from their friends. As a result, they are well-received in the community.

3.3.7 Self-Control or Personal Intelligence

The art of self-control is the ability to understand and correct one's self-discipline. People who are gifted or intelligent in this space are the ones who can review their actions or decisions and correct themselves when they make mistakes. These individuals can create and control their own emotions and motivations. They can also learn from associations with other people and integrate efficiently. They also influence their friends and have the talent to understand themselves.

3.3.8 Naturalistic Intelligence

Naturalistic intelligence is the ability to understand and comprehend things in nature. People who are gifted or intelligent in this space are interested in natural phenomena.

These eight categories of multiple intelligence are used to teach fluid mechanics and Physics. In his book, Gardner states the educational implications of the theory. "It is concerned with how the theory of multiple intelligences might be used to inform, and perhaps alter, policies implemented by people who are responsible for education, childcare, and human development" (Gardner, 2011, p. 336).

3.4 VARIATION THEORY OF LEARNING

It is important to focus our attention on using a variety of representations to make sure that students understand, in our case, fluid mechanics in a scientifically acceptable way. Variation Theory of Learning (VTL) offers a theoretical framework from which to explore possible variations in experience and the resulting differences in learning and understanding. According to variation theory, there are a limited number of features of a given phenomenon to which we can pay attention at any given time. Our experience of that phenomenon depends on the specific features to which we direct our attention. Two individuals who experience the same phenomenon may focus on different features and, thus, come to understand the phenomenon differently (Bussey, Orgill & Crippen, 2013; Orgill, 2012). The best way to learn is to understand the similarities and differences between the concepts. Therefore, when students cannot recognise the similarities and differences between concepts, the learning process will be challenging (Michael & Modell, 2003).

Students are taught fluid mechanics courses through the use of the variation method, which enables them to learn how to analyse effectively, create by synthesising information, and evaluate using existing data. In addition to keeping track of required tasks, completing classwork and homework, and studying for exams, a detailed understanding of variations among various objects is a strong predictor of school performance related to general academic skills. According to scholars, it is impossible to discern differences because only what varies against an invariant background can be noticed. The VTL, states a learner must distinguish between critical aspects of an object of learning. Thus, to help students understand fluid mechanics concepts, using the variation method is essential so that they can see both similarities and differences between various aspects of the subject (Ling, 2012).

Teachers also need to use various methods to plan and analyse teaching and learning. It allows them to design and structure classroom activities ranging from simple to complex, and it allows students to distinguish between them. Teachers are also expected to maintain various conditions in teaching fluid mechanics concepts, use various presentations of techniques, and provide students with a problem that could be solved in different ways. In each case, it is possible to maintain the patterns of variation and invariance. It is also possible to revise past lessons in terms of the patterns of variation and invariance. Therefore, during their presentation or revision, fluid mechanics course experts should provide examples of how certain things can vary. The method has provided teachers with favourable environments to support their revision with serial observations of communication patterns and language; for example, when they need to observe if previous patterns and perspectives continue to be applicable in the present lesson (Osbeck et al., 2018).

Using variation methods in teaching fluid mechanics concepts is a vital alternative to helping students see things in distinctly new ways. It enables students to see an object from different perspectives or dimensions. Consequently, they are able to develop an understanding of a concept through application or practice that can only come from explaining the various dimensions of an object. This can be turned into tangible knowledge when students are simultaneously provided with the chance to see the similarities that exist between objects. Therefore, students at the introductory levels of Physics need to be able to define a system consisting of bodies moving in an inertial frame of reference, as well as a system in a non-inertial frame of reference. Such a differentiation calls for the discernment of relevant disciplinary aspects of the system under study. In such cases, students can discern each dimension or the distinct aspect of a moving object with constant velocity, and they can also identify several features that need to be discerned. When exploring language and communication patterns, sequential observation is an invaluable tool, particularly when studying weather patterns and perspectives that have been established in previous lessons and have continued to be used (Altman et al., 2021).

Large class sizes do not permit to conduct direct supervision of the students' work (Pascarella & Terenzini, 2005). Additionally, fluid mechanics teachers can provide a broad range of topics with a large emphasis placed on exam performance, which often requires intensive study styles for successful performance (Putnam, Sungkhasettee & Roediger, 2016). Studies reveal that variation is a broad concept, which is difficult to see from a single angle. Fluid mechanics teachers are expected to have knowledge of the students' conceptions and assist them accordingly to focus on learning the content. Having knowledge about the students' understanding allows them to develop learning activities (Vansteenkiste, Lens & Deci, 2006).

It is important to recognise that students differ in terms of their social, economic, and cultural factors, which can have an impact on their ability to develop independent academic skills, verbal abilities, and mathematical abilities. There are also variations among students in their academic backgrounds. They may not have been provided with equitable academic opportunities that were free from the challenges of gender, and ethnicity. This is because large disparities exist in gaining access to high-quality core educational experiences and sizeable differences in access to optional educational experiences such as elective coursework, after-school school/extracurricular programming, and at-home learning resources. Similarly, variation can be seen in grading standards across high schools. Allensworth and Clark (2020) also indicate that this is one of the most significant predictors of undergraduate students' fluid mechanics course academic performance. Teachers need to know how to use different methods of teaching fluid mechanics and how to help students develop academic work skills. Putnam et al. (2016) suggest that teachers include a broad range of topics in their lessons so that they can inspire students to have intensive studying habits to achieve success (Putnam et al., 2016).

3.4.1 Object of Learning

In VTL, the object of learning is a special term. Learning objectives refer to the end product of the learning process and the predetermined learning outcomes. The object of learning, however, points towards the process rather than the outcome of learning. As a dynamic process, it can change over the course of learning (Kerlind, 2015, 2018; Marton & Tsui, 2004). The object of learning is not the same as the notes, texts or teaching materials teachers use in their lessons (Cheng, 2016; Runesson, 2005).

Objects of learning are the things the students need to learn in order to achieve the desired learning objectives. In a sense, it points to the beginning of the learning journey rather than the end.

Understanding an object involves more than what we can see and feel. For instance, if we see a pair of moving antlers in a forest, we will not mistake them for antlers that have flown by themselves. Based on our prior experience with deer, we understand that although we see only the antlers, a deer is running through the trees. In the same way, when we hear a car horn behind us, without looking back, we know that an approaching car is behind us. This is called "representation" in phenomenological terminology. Application is the fact that although phenomena are, as a rule, only partially exposed to us, we do not experience the parts separately, but as part of a larger whole to which the parts contribute. Thus, our experience also includes the external horizon in which the parts are anchored (Marton & Booth, 1997). The external horizon provides meaning to objects of learning. Using a jigsaw puzzle as an analogy, Marton and Booth (1997) wrote that “to make a picture distinct, the pieces need to be found and fitted into place” (p. 180).

Exploring the world and gaining knowledge about it is also part of how we constitute it. Our learning experiences are influenced by the world around us. We build a shared language and culture. Learning brings our world closer to the world known by other people. The experienced world, which is made up of people, also influences our understanding of it.

Each learning situation has its objectives and limitations. A school's objective might be to prepare students to contribute to society. Students' overall understanding of an object of learning can be influenced by its context, as the external environment influences their association with it and whether it has any relevance for them. Learning objects do not exist in isolation. Teachers must first clarify the position of an object within the system of objects to which it belongs and its relationship to other objects in the system. The parts of this system are not the learning object itself, but are closely related to it and belong to the external horizon of the learning object.

VTL states that when students attempt to grasp fluid mechanics through laboratory work, the concept remains constant for them. When students do experiments for the first time, they may not be able to grasp the whole and parts of the topic well. However, each time the students conduct an experiment, different concepts will become apparent. Students' understanding of the full topic will be impacted by focusing on the parts of the whole. Through the repeated performance of the experiment, different aspects of the concepts will become clearer and the students' understanding of the entire topic will become deeper. Repetition such as this differs from the mechanical memorisation characteristic of rote learning.

3.4.2 Critical Aspects and Features of the Object of Learning

To be able to see objects in the same way, people must also be able to focus on the same features. A certain way of seeing an object requires us to pay attention to its critical features as an object (Bussey et al., 2013).

A teacher needs to know critical features in order for students to comprehend the object of learning in an intended way (Ling Lo, 2012). In addition to knowing a topic in-depth, teachers must also know how this topic relates to other topics within a subject, how the topic relates to other subjects within the discipline, how the topic is represented within the discipline and the nature of the discipline as a whole. Furthermore, teachers must identify what features are most likely to lead to student learning difficulties. In the majority of cases, those that are difficult for teachers to discern present the biggest barriers to student learning (Orgill, 2012). It may be difficult for teachers to recognise the critical features that pose challenges to students if they have difficulty recognising those features. In such a case, teachers may unwittingly ignore certain features of a lesson, leading to a knowledge gap (Fredlund, 2015).

Teachers tend to assume students who can identify difficult critical features independently have a deeper understanding of the teaching topic and are viewed as students with higher ability. It is difficult for students who are not able to discern the features by themselves to be considered high-level thinkers. Because of the relationship of critical features to one another and the whole, such students may not progress in their learning. The best way to comprehend a learning object is to discern all of its critical features and their relationships simultaneously (Bransford, Brown & Cocking, 2000).

3.4.3 Application of the Variation Theory in the Study

There is no single effective instructional approach. However, recent studies state that effective learning can be achieved by using a range of methods (Marton & Pang, 2008).

The teaching of fluid mechanics courses requires a strong understanding of Mathematics. The course prepares students for such tasks as interpreting graphs and tables, quickly solving problems or solving equations, conceptualising the function of mathematical operations, and computing a standard deviation. Studies have shown that mathematical ability predicts performance in introductory Science courses (Hazari & Sadler, 2007). There is a need to create interdisciplinary relationships and work cooperatively to overcome obstacles in the process of teaching fluid mechanics. There is an argument that indicates Physics and Mathematics departments need to design their courses and socialise their students into their disciplines. These enable teachers to maintain the horizontal relationship between Mathematics and Physics, which helps with academic disciplines and uses various alternatives to improve school performance (Linder et al., 2014). It is known that departments differ in a variety of ways, such as academic policy formulation and personal communication. Thus, it is advisable to develop the habit of integrative action, which gives deep insight into a department based on its disciplinary identity. It is important to identify the impact of one discipline on the other and develop a common approach to improving academic school performance in teaching fluid mechanics courses (Reinholz et al., 2019).

The objective of an analytical tool for exploring, from a qualitative perspective, how students learn in interactive environments is to gain additional insight into the learning challenges students face in highly complex courses such as Physics. Student engagement with Physics tasks can be studied using social semiotics. “Social semiotics is an approach to the analysis of popular culture that distinctively emphasises social dimensions of meaning, systematically crossing major boundaries that are often taken to constitute different forms of popular culture” (Hodge, 2014). In social semiotics, meanings are constructed, shared, interpreted and remanufactured employing a range of representational and communicational techniques, language being one of these. Although social semiotics has been widely applied across a wide range of contexts, they have not been applied in an interactive Physics learning context. This transformative approach is referred to as “social semiotic multimodal transcription” (Eriksson, Eriksson & Linder, 2010, p. 1). The course and classroom practice for Physics has been developed by a particular group of people. The social semiotics perspective we employ is a tool in Physics Education Research (PER) that seeks to understand specialised systems of meaning-making in particular sections of society. An example from the Physics student lab can be seen in Volkwyn et al. (2018). Meaning-making is situated within a particular collection of semiotic systems (such as equations, graphs, diagrams, pictures, and apparatus). In Physics, semiotic resources are typically drawn from the following systems: spoken and written language, Mathematics, diagrams, gestures, and apparatus (Eriksson et al., 2020).

Secondly, based on the successes in various subjects, the VTL can be implemented in designing teaching activities to enhance learning in fluid mechanics. However, further investigation should be conducted to evaluate teaching sequences (Fredlund et al., 2015). The current study has used the VTL following the five main stages of the theory, as depicted in Figure 3.1 and explained briefly in Table 3.1.

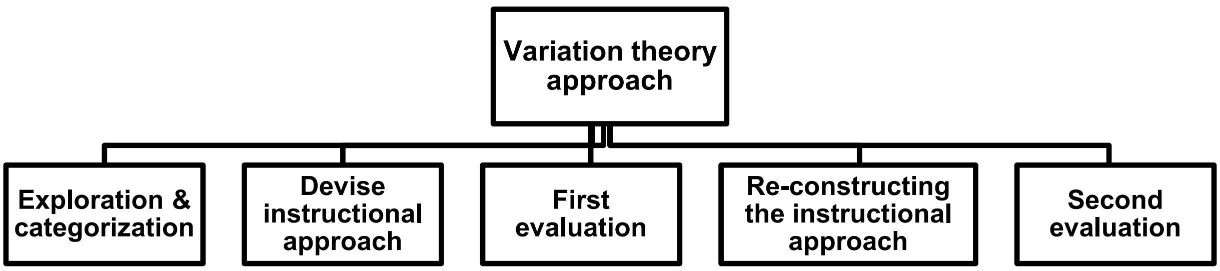

Figure 3.1: The stages in the VTL approach.

Source: (Ling, 2012, p. 33)

3.4.4 Disciplinary-Relevant Aspects

The researcher in this study refers to various Physics-related concepts as disciplinary-relevant concepts. Compared to the "quantities on which (physical) events may be considered to depend" are disciplinary-relevant features (Maxwell, 1871). Using the definitions from Fredlund (2015) and Fredlund et al. (2015), we will define disciplinary-relevant characteristics as those Physics concepts that are especially relevant for completing a given task. Therefore, Physics' disciplinary-relevant aspects are those that physicists would use to address a specific issue or explain a specific phenomenon.

3.4.5 Learning from Representations

In the literature on Science education, there has been a lot of focus on the connection between learning and representations. The emphasis in Physics has frequently been on helping students develop "representational competence" or "fluency" with representations (see, for instance, Kohl & Finkelstein, 2005; Linder et al., 2014; See, for example, Airey & Linder 2009; De Cock 2012). In this regard, a variety of representations have been examined, including language, gestures, arithmetic (e.g., Bing & Redish, 2009), graphs (e.g., Christensen & Thompson, 2012), and graphs (e.g., Scherr, 2008). (e.g. Brookes, 2006).

Distinct representations "highlight different parts of a notion," according to McDermott (1990, p. 19). McDermott (1990, p. 19) suggests that "different representations emphasise different aspects of a concept". Here, Podolefsky and Finkelstein (2007) claim that the "surface features" of representations are particularly important for how they are used by Physics students.

Building on this work, Fredlund et al. (2012) show how different representations of the same Physics phenomenon provide access to different disciplinary-relevant aspects. They termed such access the "disciplinary affordance" (p. 658) of a given representation.

3.4.6 Variation and Learning

According to the Variation Theory of Learning, possibilities for learning are optimized when those aspects that students need to notice are changed against an unchanging background (Marton & Booth, 1997; Booth & Hultén, 2003; Marton & Tsui, 2004; Marton & Pang, 2013; Marton, 2015). Thereafter, people notice the changes.

Initially, variation should be organised so that as few aspects as possible are varied at one time. Only later should several aspects be varied simultaneously. This strategy has been described in terms of creating a "pattern of variation and invariance" (Marton & Pang, 2013, p. 30). The variation approach has been successfully applied in a wide range of disciplines. For example, Mathematics (Runesson, 2005), Economics (Pang et al., 2006), Chemistry (Lo, 2012), and Language (Marton et al., 2010). There are also several examples from undergraduate Physics and Engineering (see, for example, Linder et al., 2006; Ingerman et al., 2009; and Bernhard, 2010). Evidently, the success of the variation approach calls for insight into what to vary. In three aspects of representational learning in what follows, we further present and exemplify each of these factors using everyday examples before doing the same with an illustrative Physics example taken from fluid mechanics.

3.4.7 Using the Three Factors in Physics

Having presented the three factors using examples from everyday settings, we will now illustrate how they can be applied to enhance the possibilities for learning in a Physics education context. The Physics problem we have chosen for this illustration is a qualitative explanation of Archimedes principle.

3.4.8 Identifying Disciplinary-Relevant Aspects

Because a wide range of aspects is potentially associated with every Physics phenomenon, each Physics situation that students encounter requires a choice to be made about which aspects are disciplinary-relevant. For example, when solving a problem related to pressure buoyancy, a physicist might conceivably deem any of the aspects as relevant.

To solve a particular problem or explain a given part of the phenomenon, only a subset of these aspects will be relevant. Teachers' knowledge of what these disciplinary-relevant aspects are, for the learning goal at hand, may often be tacit (Polanyi, 1967).

This study analyses students' understanding of fluid mechanics concepts in the context of developing focused teaching strategies.

Table 3.1: Brief explanation of the phases of the research

Stage	Explanation
Stage I: Exploration and categorisation are the first two stages of the process	Students' conceptual understanding was examined and classified. This was done to understand the students' background knowledge (pre-conception).

Stage II: Develop an instructional approach	Different representations were explored during the teaching approach to address all eight multiple intelligences.
Stage III: First evaluation (Iteration I)	The effectiveness of the planned and implemented teaching method was evaluated.
Stage IV: Reconstructing the instructional approach	The instructional approach was reconstructed for further effectiveness.
Stage V: Second evaluation (Iteration II)	The effectiveness of the reconstructed approach was evaluated.

3.5 CHAPTER SUMMARY

The chapter discussed the theoretical framework of the study. This includes cognitive learning theory, multiple intelligence theory, and the Variation Theory of Learning. The next chapter provides the details of the research methodology used in conducting this study. In this chapter, cognitive learning theory (Section 3.1) is described. Thereafter, the multiple intelligence theory (Section 3.2) and the variation theory (Section 3.2) are described.

The researcher relates cognitive theory to the learning of fluid mechanics as he argues that a systematic approach is needed to build the students' cognitive skills and, thus, it can be used as a basis for designing fluid mechanics courses.

For Multiple Intelligence Theory (MI), Gardner's eight categories of intelligence were discussed in-depth, and the researcher argues that learning occurs in different ways. Therefore, he applies these eight categories of multiple intelligence to teach fluid mechanics and Physics. Related to CT and MI, the student suggests that the Variation Theory of Learning (VTL) offers a theoretical framework from which to explore possible variations in experience and the resulting differences in learning and understanding. The objects and critical aspects of the objects of learning were explained. The student diagrammatically shows how VTL is applied and follows the five main stages of the theory as depicted in Figure 3.1 and explained briefly in Table 3.1. This helped to connect the theory with the methods.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 INTRODUCTION

In chapter 4 the research approach, methodologies, and learning theory are discussed. The chapter also presents a discussion of the research design, which is subdivided into subheadings Case Study and Quasi-Experimental Research Design. The interpretive paradigm underpinned the quantitative and qualitative methodologies. An exploratory case study design was used to categorise undergraduate Physics students' conceptual understanding. Purposive sampling was used to select the students. Three research instruments were utilised to collect data, namely, Open-Ended Questionnaires (OEQ) (Appendix D); the Fluid Mechanics Conceptual Inventory (FMCI) test (Appendix E); and the Students' Attitude towards Multiple Representation Questionnaire (SAMRQ) (Appendix F). The nature of learning could be explained using the Variation Theory of Learning (VTL). The ethical considerations and trustworthiness of this study are also discussed.

4.2 RESEARCH DESIGN

Both case study research design and quasi-experimental research design were utilised in different phases of the study depending on the objectives.

4.2.1 Case Study Research Design

The study used a case study research design to explore how students understand the learning objectives. The reason for selecting an exploratory case study rather than a descriptive or explanatory one is that it acts as a pilot and can be used and tested in larger experiments (Cohen, Manion & Morrison, 2009; Yin, 1994; Yin & Moore, 1988).

Different types of data were used to evaluate this sample of students' understanding of fluid mechanics. Stake (1994) would describe this study as an instrumental case study, as it investigates a particular case to gain insights into an issue or a theory. However, the focus of the study was to understand ideas more clearly in a tertiary-level environment, rather than simply present abstract theories or principles. Consequently, an exploratory case study research design was used in the first phase of the study.

The type of data to be collected (qualitative or quantitative), its source (population and sample), and the data collection and analysis techniques are all covered (Ejigu, 2014). This study was conducted using an exploratory case study research approach. It is a qualitative research design that aims to find out how undergraduate Physics students comprehend and express the fundamental concepts of fluid mechanics. The exploratory case study research was designed using a three-phase qualitative technique.

In an exploratory case, when researchers consider the research issues that will be investigated in subsequent phases of a study, a case study is appropriate (Yin, 2014; 2018). The qualitative technique was used to investigate undergraduate Physics students' conceptual knowledge and representations of fluid mechanics. Two groups of students were chosen from a public university in Ethiopia.

In the first phase, after students had been exposed to traditional teaching methods, in-depth evaluation was used to identify the students' conceptual challenges. In the second phase, the Multiple Representation method for the second group of students was used. The effectiveness of these methods in reducing conceptual challenges was investigated in the third phase. To present it another way, an educational problem was recognised in the first phase and the problem was explored in later phases. This is the central tenet of the qualitative research approach which aligns with the exploratory case study research design (Section 2.7.3).

4.2.2 Quasi-Experimental Research Design

As part of the second phase, MRs were used to design lessons in fluid mechanics, while in Phase 3, their effects were explored. Therefore, in the third phase, an experimental design was used (Alao & Gutherie, 1999). A random sample of participants was selected for each group. One group of participants received treatment and was called the experimental group. An MR intervention was used to teach fluid mechanics to them as part of their treatment. In the second group, no treatment was given, and it was referred to as the control group. The first group is represented by O1, where X1 indicates the intervention in the experimental group (MR), and O2 represents the effect of the intervention on the experimental group. The second group is represented by O3 and received no treatment (X2) but only traditional teaching, while O4 represents the influence of traditional teaching on the control group.

$$O_1 \text{----} X_1 \text{----} O_2$$

$$O_3 \text{----} X_2 \text{-----} O_4$$

4.3 PARTICIPANTS AND SAMPLING METHOD

4.3.1 Participants in the Study

Participants in the study were first-year undergraduate Physics majors and students at two universities in Ethiopia. In Ethiopia, students are assigned to universities based on their results in the final year school examinations called the Ethiopian school leaving examination (ESLCE) conducted by the Ministry of Education, and no other criteria are used for enrolment. Accordingly, there was only one class at each of these two universities selected as sites for the research. There were 32 students selected in each class – a total of 64 undergraduate students. As the researcher taught at one university, the students at this university made up the experimental group, while students at the other university made up the control group. In the experimental group, students were taught using multiple representations, whereas, in the control group, students did not receive any other treatment than traditional lectures. The universities were similar in the academic rank of teachers, and the laboratory equipment and facilities are the same. However, they are in different regions and therefore different locations.

4.3.2 The Sample Size of Students

In the first phase, the sample of students was selected from first-year undergraduate Physics major students who had taken the introductory fluid mechanics course. The researcher used traditional teaching methods to present this course to the students for the last 14 years. So, he planned to investigate students' conceptual understanding in-depth. A small sample size was thus appropriate. Purposive sampling was used to select 32 students (80% of 40 students) from each class (Trigwell et al., 2000), totaling 64 students. Thus, in Iteration I, 64 students were selected as a sample, and in Iteration II, an additional 64 students were used as a sample. Therefore, the total sample size of the research was 128. Using a sample size of 30–40 students is acceptable in case study research (Cohen et al., 2009).

Based on academic achievement, a variable sampling strategy was developed (Patton, 2002). Students were selected based on their previous academic achievements (high, medium, and low).

The students who were selected for this study were those who were enrolled at the researcher's home university in the 2017–2018 academic years because the researcher could access them easily. Furthermore, online resources were available at the university. Using these resources from the researcher's home university was accessible compared to using the resources of other universities because this saved time and money. However, it must be stated that this could have held ethical implications and that the researcher could have been biased. However, data collection and analysis were done using a second researcher to ensure that there was no bias. In addition, the Physics students were assigned equitably (medium to lower achievers) to Ethiopian public universities (Section 1.4). Because the universities are equivalent, each university in Ethiopia has used the same curriculum and they have similar academic resources.

These universities were specifically selected because the researcher has been teaching at one university for more than ten years, and the second university was chosen as it was within a reachable distance from the researcher. The second reason is, that these universities are comparable in terms of academic offerings and the citizens are of the same social economic background. Therefore, the selection was based on purposive sampling as the researcher was able to study and monitor the teaching of the Physics students at both universities.

4.4 RESEARCH INSTRUMENTS

There were three research instruments used to gather data, namely, Open-Ended Questionnaires (OEQ) (Appendix D); the Fluid Mechanics Conceptual Inventory (FMCI) test (Appendix E); and the Students' Attitude towards Multiple Representation Questionnaire (SAMRQ) (Appendix F). Both qualitative and quantitative data were collected from the selected participants. Pre-intervention and post-intervention data were gathered from the research sample using the OEQ and FMCI. Furthermore, the SAMRQ was used to gather data in the second and third phases of the intervention in the experimental group. Researchers used the OEQ and FMCI to obtain information about students' "previous objects of learning" (See chapter 5).

4.4.1 Open-Ended Questionnaires

The OEQ was developed from the validated thermal transport conceptual inventory (TTCI) at the University of Colorado and reviews the students' fluid mechanics and heat flow knowledge and concepts (see Appendix D). The researcher communicated via e-mail with Professor Ron Miller who was the principal investigator of the TTCI on their research team. The researcher requested Professor Miller to use the TTCI instrument to collect data from the target group of students.

The researcher then developed an OEQ that comprised 12 items, of which (10 items) 83.23% were from the TTCI. The remaining two items included the fourth fluid mechanics concept, namely, Bernoulli's principle based on his teaching experiences and the content coverage required in the fluid mechanics' course.

This was to establish if the students had any alternative conceptions that were not scientifically acceptable. The fluid mechanics OEQ was used firstly to assess their prior knowledge before any intervention in the third and final phases. The face and content validity and reliability of the OEQ are discussed in the following sections. The final version of the OEQ, which was used in data collection, is available in Appendix E.

4.4.2 Fluid Mechanics Conceptual Inventory

The FMCI (version 3.3) was developed by Martin, Mitchell and Newell (2003) at the University of Colorado. The researcher wanted to use the FMCI research instrument to explore students' fluid mechanics' conceptions.

The researcher communicated via e-mail with Professor Martin, who was the principal investigator of the FMCI for their research team. Initially, he was not willing to share the FMCI research instrument. However, the researcher's supervisor provided another e-mail address for the researcher and told the researcher to communicate with the research group via e-mail by providing information about the researcher. Accordingly, the researcher, after repeated requests, sent an e-mail providing information about the researcher as a PhD candidate in Physics education at the University of South Africa. After being asked some questions, Prof. Miller sent me the FMCI survey via e-mail. The intellectual property rights of the University of Colorado are acknowledged in this thesis.

The FMCI (version 3.3) developed by Martin et al. (2003) had 28 questions. These contributed to 95% of the FMCI prepared from the items adopted. The researcher adopted 24 questions and added two questions on the Archimedes' principle. Thus, 5% of FMCI, namely, two items of the second fluid mechanics concept about Archimedes' principle, were developed and added by the researcher based on his teaching experience and the content of fluid mechanics in the curriculum. The fluid mechanics OEQ was used first to assess students' prior knowledge. This was to establish if the students had any alternative conceptions that were not scientifically acceptable before any intervention. Second, the researcher wanted to compare the results of the pre-test with the post-test after using the MRs approach to see if the observed alternative conceptions were addressed and if understanding of the concepts was improved. The face and content validity and reliability of the FMCI are discussed in the following sections.

Thus, the final version of the questions of the FMCI survey that was used for this research consists of 26 items and measures the concepts of fluid mechanics (Appendix E).

4.4.3 Students' Attitude Towards MR Questionnaire (SAMRQ)

The SAMRQ was developed by the researcher. This questionnaire comprises three parts. The first part was to establish the students' feelings towards the MR approach (5 items), and the second part was to determine the motivation and benefits of using the MR approach (7 items). The third part was about the interests of students towards the MR approach (6 items). See Appendix F.

4.5 THE VALIDITY AND RELIABILITY OF RESEARCH INSTRUMENTS

4.5.1 Content and Face Validity of the Open-Ended Questionnaire

The validity of the research instrument refers to the level of accuracy of its findings. Pilot tests of the Open-Ended Questionnaire were conducted with first-year Physics and Engineering students at the Colorado Institute of Mining Technology (Miller, Slawinski Blessing & Schwartz, 2006). The purpose of the questionnaire answers was to explore students' difficulties with fluid mechanics concepts.

The contents of fluid mechanics were analysed before the preparation of the first version of the questionnaire. Content breadth and depth were analysed and checked for content and face validity (Section 4.5.1).

To establish validity in the Ethiopian context, the questionnaire was given to three Physics faculty members to criticize, to see if it would test what it needed to test. They made some comments on the language used, the ambiguity of some questions and redundant content. Based on their suggestions, one question was corrected, and two questions were removed.

Checking face validity means ensuring that the prospective items measure what they are intended to measure according to the researcher's objectives. This was done to minimise the possibility of bias that could occur during data collection at the most granular level (Cohen et al., 2009).

The substantive content questions were modified using the responses from the pilot as a basis. The pilot was done on 20 students from another university who were not in the research sample before instruction on the relevant topics. One question was modified based on the comments given by the two Physics instructors. The final version of the questionnaire organised by the researcher is available in Appendix I.

4.5.2 Reliability of the Open-Ended Questionnaire

To establish the reliability of OEQ, before data collection was conducted, the questions were piloted on undergraduate students in another institution far from where the intervention was carried out. Based on the students' responses, the questions were modified. This includes checking and correcting the ambiguity in question wording, as well as the appropriateness of the questions. This helped the researcher set up a reliable open-ended conceptual exploration questionnaire research instrument.

4.5.3 Content and Face Validity of FMCI

The test has been validated by over 1 000 students at the University of Wisconsin and the University of Illinois. The contents of Fluid Mechanics were analysed before the preparation of the first version of the questionnaire. Content breadth and depth were analysed and checked for content and face validity (Section 3.5.1). Some of these items were also included in their classroom tests for the fluid mechanics' course.

In addition, face and content validity were established in the Ethiopian context curriculum by giving the FMCI test to three Physics educators to determine if the language used is suitable and if the questions test what they are supposed to test. The substantive content questions were modified using the responses from the pilot test. The questions were also modified based on the comments given by the two Physics instructors. The respondents were well-informed concerning the essence and objectives of the study before they answered the questionnaire.

The final version of the FMCI questions that were organised by the researcher is available in Appendix I.

4.5.4 Reliability of FMCI

Although reliability was established, it needed to be established before use in the Ethiopian context. The test was piloted with undergraduate Physics major students from another university far from where the intervention was conducted. This included checking and correcting the ambiguity in question wording as well as the appropriateness of the questions. Furthermore, based on the Kuder Richardson K-21 formula, a reliability coefficient of 0.854 was determined (see Appendix G-II). This is the most common Cronbach's alpha coefficient α. The value of α is determined by the rule of thumb according to George and Mallery (2003): thus if the value of α was > 0.9, it is excellent; if the value of α was > 0.8, it is good; if the value of α was > 0.7, it is acceptable; if the value of α was > 0.6, it is questionable. This helped the researcher to set up a reliable open-ended conceptual exploration questionnaire research instrument.

4.5.5 Validity of Students' Attitudes Towards MR Questionnaire (SAMRQ)

The validity of SAMRQ was established by giving it to three Physics faculty members to determine if the language used was suitable and if the questions tested what they were supposed to test. Furthermore, they gave recommendations on two questions to change, and these were accepted and changed accordingly.

4.5.6 Reliability of SAMRQ

Prior to data collection, the questions were tested on undergraduate students at another institution to ascertain the reliability of the SAMRQ. To verify the reliability of SAMRQ, the questions were pilot-tested on undergraduate students in another institution where the intervention was carried out before the data collection process began. As a result of the students' responses, the questions were modified. As part of this process, ambiguity in wording and suitable questions were checked and corrected. The researcher was thus able to create a reliable SAMRQ research instrument. Moreover, SPSS scale analysis was used to calculate the reliability coefficient, and Cronbach's alpha coefficient of internal consistency was 0.80 (Appendix G-III).

4.6 DATA COLLECTION

4.6.1 Data Collection in the First Phase

In the first phase, data were collected from 64 students before any interventions were made. First-year Physics students in both groups (experimental and control groups) were asked to complete an Open Ended Questionnaire in their Friday class and an FMCI inventory in their

Monday class according to the pre-planned schedule. The time required to finish this test was 90 minutes.

Data were collected from students to explore their prior understandings of fluid mechanics and then to use these results in designing an intervention that would be used in the second phase of the experimental group. The results and discussions of this phase are presented in Chapter 5.

4.6.2 Data Collection in the Second Phase

In the second phase, the results found in the first phase at pre-intervention were used as a basis to develop the intervention. The teaching activities that were used in the experimental group as an intervention were designed in MRs-based on including four approaches. For the control group, the teaching activities were prepared using the traditional lecture method. In this phase, first-year Physics students in both groups (experimental and control groups) were asked to complete an Open-Ended Questionnaire and an FMCI inventory post-test in class according to the pre-planned schedule. This was a suitable way to provide a foundation for determining the effectiveness of the intervention in improving students' conceptual understanding of fluid mechanics.

The number of students taking the post-test and the time required to complete this test were the same as the pre-test of this phase. The OEQ and FMCI were administered a week after the intervention was completed in the second phase. Moreover, in the experimental group, students completed SAMRQ in Likert scale form. This included 12 questions in two parts to assess their attitudes, perceptions, and feelings towards the interventions (see Appendix F).

The results and discussions of this phase are presented in Chapter 6.

4.6.3 Data Collection in the Third Phase

In the third phase, the results found in the second phase were used to reconstruct and develop the intervention.

The teaching activities that were used in the experimental group as an intervention were designed in MR and included eight approaches. For the control group, the teaching activities were prepared using the traditional lecture method. In this phase, first-year Physics students in both groups (experimental and control groups) were asked to complete an Open-Ended Questionnaire and an FMCI inventory post-test in class according to the pre-planned schedule.

This was a suitable way to explore the effectiveness of the intervention in changing students' conceptual understanding of fluid mechanics.

The number of students taking the post-test and the time required to complete this test were the same as the pre-test for this phase. The OEQ and FMCI were administered a week after the intervention was completed in the second phase.

Moreover, in the experimental group, students completed the SAMRQ in Likert scale form. These included 12 questions in two parts to assess their attitude, perceptions, and feelings towards the interventions (see Appendix F).

The results and discussions of this phase are presented in Chapter 7.

4.7 RESEARCH METHODOLOGY

Teachers should be able to build learning approaches and activities for students to strengthen their learning of the concept to be learned (Cheng, 2016).

The Ethiopian context offers fluid mechanics to first-year Physics and Engineering undergraduate students for three credit hours per week. The general objective of this course is to support students to understand and practise the basic principles and concepts of fluid mechanics as stipulated in the learning outcomes and course content. The topics selected in fluid mechanics were a buoyant force, Archimedes' principles, pressure variation with depth, fluid flow, and Bernoulli's principle. Learning activities were designed based on the variation theory to develop students' conceptual understanding using multiple instructional representations in the experimental group. The intervention consisted of four lessons and lasted two weeks (see Sections 5.3 and 5.5 and Appendix K and R). The duration of each lesson was 2 hours.

4.7.1 The Application of Variation Learning Theory

The overall work of the study was carried out in five main stages and is presented (see Section 4.7). To illustrate how the different stages were used, one example is presented.

Since students' perceptions can hinder their new learning path, how undergraduate Physics students understand fluid mechanics concepts (students' pre-existing understanding) was explored and categorised. Secondly, teaching activities were designed using multiple instructional representations to address the student's understanding. The MR approach includes four representations, namely, text, pictures, diagrams and mathematical equations. The teaching sequence consisted of four lessons for two weeks, and the duration of each lesson was two hours (see Section 5.5). Thirdly, the effectiveness of the approach was evaluated using the FMCI pre-test and post-test. Fourthly, based on the outcome of the previous stage, the instructional approach was reconstructed, and another four representations were added. Hence, the instructional approach included a total of eight representations, namely: text, pictures, and diagrams; mathematical equations; simulations; animation, video, and virtual lab. Finally, the effectiveness of the reconstructed approach was evaluated using the FMCI test. The same test was used after the first and second interventions as a pre-test and post-test. The results were compared to see if there was an improvement in the student's understanding of these fluid mechanics concepts. The results were compared with a control group (using the traditional approach) at another institution, during both interventions.

4.7.2 First Phase: Conceptual Understanding of Students at Pre-Intervention

The undergraduate students' fluid mechanics conceptual understanding was explored at the pre-intervention level. This took place between September 2019 and November 2019. The purpose of this study was to explore the understanding of the object of learning by students through an exploratory case study research design (see Section 4.1.1). The data were gathered by administering the OEQ and FMCI as a pre-test to both the experimental (N = 32) and control (N = 32) groups. Moreover, these results were also used to ascertain whether the two groups were comparable.

The results obtained in this step were used to design an instructional approach that was used as an intervention in the experimental group. After the analysis process, the categories of description were constructed. The data analysis and results obtained were discussed in the latter part of this thesis (see Chapter 5).

The VTL was used as a lens to analyse the learning process and its outcomes based on the categories of description. This analysis was done based on the critical aspects discerned by the students. The categories of description formed the basis for identifying the conceptual difficulties that the first group of students encountered during traditional instruction.

The instructional intervention was based on VTL as a research-based instruction aimed at helping students overcome their fluid dynamics conceptual difficulties in the first phase of pre-intervention. The MRs-based instructional approach using interactive tutorials was used. Students learn more deeply from videos and animations of this type when presented with text and pictures rather than with words alone (Mayer, 2003). While designing and developing instructional strategies based on VTL, the learners would be provided with the opportunity to discern various critical aspects of a disciplinary concept. Based on the VTL, critical aspects are necessary conditions for learning, which must be taken into consideration in developing instructions (see Section 2.8). If instruction is designed in this way, the "VTL is compatible with the majority of teaching strategies currently promoted" (Ling, 2012, p. 110). In this manner, the VTL provided a foundation for designing the MRs-based instructional approach with interactive learning tutorials (see Chapters 6 and 7).

4.7.3 Second Phase: Developing and Designing an Instructional Intervention

4.7.3.1 Iteration I: post-intervention

In this phase, undergraduate first-year Physics major students received instruction for two weeks for a total of 8 hours to learn the four concepts of introductory fluid mechanics Physics. The experimental group (Ex) consisted of 32 students, and the control group (Co) consisted of 32 students at two universities. The intervention took place between December 2018 and February 2019. The MRs-based approach was used to address students' different learning styles. In addition, this approach can ameliorate, and remedy students' conceptual difficulties.

For both experimental and control groups, instruction was given based on the course content outlined in Table 6.1 or Section 6.2.1. Lessons were developed and tested on the experimental students during Iteration I, using four representations. In Iteration I, instruction was delivered using the traditional lecture approach in the control group. After the instruction was carried out, both groups were given a post-test of OEQ and FMCI to determine the change in students' conceptual understanding of fluid mechanics. Moreover, the Likert scale semi-structured individual interviews were conducted to determine the students' level of agreement on the use of MR, which consisted of four representations.

Based on the findings after Iteration I, there was a recommendation to repeat the instructional approach in the experimental group and continue the process for Iteration II by adding four more additional representations. This was to address the video text, mathematical equation, and graph learning styles of the students.

Physics education, as part of natural Science, indeed deals with the study of matter. It is also concerned with the study of interconnections between the elements within it. For this purpose, MRs play a vital role in learning Physics. Because it can provide students with the opportunity to learn more about some Physics concepts such as enabling, animated images, text and diagrams, algebra notation and graphs, mathematical equations and tables (Bakri & Mulyati, 2018).

Most of the time, teaching Physics is successful when teachers use the MRs approach. As a result of using this method, students are better able to resolve problems, improve their creative thinking, and develop their understanding of how to build their knowledge through hands-on experience and outside the classroom environment. Therefore, the use of multiple representations in teaching Physics is important to help students acquire the habit of cooperating, responding to each other's comments and communicating with their classmates (Bakri & Mulyati, 2018).

Hartini and Sinensis (2019) argue that MRs are essential teaching-learning techniques that enable classroom teachers to improve the students' learning outcomes, which are consolidated through the provision of different ideas and technical equipment that enhance the students' learning in Physics. The authors demonstrated that the effectiveness of various representations can be measured by the emphasis placed on the "three basic things", namely, the learning aspects: the design parameters that are to learn with multiple representations; the function of multiple representations in support of learning and cognitive tasks performed by students who interact with a variety of representations. This implies that using the multiple representations approach in teaching Physics has become successful. Thus, when the teacher develops knowledge on how to plan and use the MR method in the context of the students' cognitive as well as psychomotor development levels, the teaching-learning process is more successful.

The students were provided with the designed MRs-based interactive fluid mechanics learning activities in small tutorial groups via the facilitation of the researcher (see Section 5.2.2 – 5.2.6). The researcher wanted to determine the students' understanding of fluid mechanics concepts using the MRs approach in the classrooms (Volkwyn et al., 2020). During the MRs-based interactive fluid mechanics learning activities, the students were provided with activities that were presented employing text, equations, graphs, diagrams and interactive simulations (see Section 2.6).

4.7.4 Third Phase: Effectiveness of the Instructional Intervention

4.7.4.1 The second iteration: pre-intervention

A new group of students formed part of Iteration II. Again, there were 32 students in the experimental group and there were 32 students in the control group. For the reasons mentioned in the context of this study (see Section 1.2), the number of students in each group was equivalent to the first phase. The intervention took place between December 2019 and February 2020. Moreover, both groups took the pre-test to establish if the students from the two universities were comparable.

The data were collected and analysed during pre-intervention to obtain information that was used to design an instructional intervention in the second phase (see Section 3.3.2.1). The results at pre-intervention for each of the four concepts of fluid mechanics are presented together with the results at post-intervention in the same table (see Chapters 6 and 7).

This presentation style makes it easy to understand the change in students' conceptual pathways because of the intervention. The categories of description represent the second group of students' different ways of conceptual understanding at pre-intervention (see Figure 3.1).

4.7.4.2 Second iteration: post-intervention

After the completion of the intervention with eight representations for the experimental group, both groups wrote the same post-test to establish the effect of the intervention. The data were collected through OEQ, and FMCI to gain more insight into students' conceptual understanding of fluid mechanics (see Section 3.5.4).

A model analysis approach was used to analyse the collected data (see Section 4.8.3.1). The VTL was used to analyse the conceptual learning process and the effects of the intervention. The researcher wanted to tell if there had been an improvement in students' conceptual understanding of fluid mechanics which could be attributed to the intervention's effectiveness.

This enhancement was explored based on the change in the number of research respondents discerning the critical and irrelevant aspects of each of the four fluid mechanics concepts at pre-, post-, and post-intervention (see Tables 6.1–6.5). The change in the number of non-respondent students from pre-to-post-intervention was also presented in these tables. The non-respondent students were students who did not respond at all to the OEQ. The results of the analysis are presented and discussed in Chapter 7.

4.8 DATA ANALYSIS

Before data analysis was done, the researcher provided descriptions of students' understanding categories. After the data were collected, it was analysed using both quantitative and qualitative methods of analysis. In both iteration phases, the pre-test and post-test results were compared. Finally, the results of iterations I and II were compared with each other by using ANOVA to determine the effectiveness of the MR-based instruction approach.

4.8.1 Descriptions of Categories of Students' Understanding

The researcher employed the students' difficult mental knowledge of fluid mechanics ideas as organising criteria in the hierarchical construction of the categories. The description categories are organised into three students' understanding. As a result, three sets of description categories were created for each of the four fluid mechanics ideas at these three locations (Bao & Redish, 2006). The researcher used the VTL to analyse the students' conceptual learning processes and results based on the categories in the description.

The three conception models are presented as follows:

- Model of Correct Conception (M1): According to this concept model, the students' response is correct and is based on a scientifically acceptable idea.
- A common alternative conception model (M2): This is when students provide responses which may be right or wrong. Students, therefore, have mixed and incomplete knowledge.
- Null conception model (M3): This is when the students respond incorrectly. The students may not know the answer or may be guessing. This is poorly organised knowledge, which leads to a lack of understanding. The data analysis methods of each research instrument are discussed in the next section.

4.8.2 Analysis of Data Collected Using the OEQ

Data collected from two sites were analysed using qualitative data analysis techniques. The data collected from students about fluid mechanics conceptual understanding during the pre- and post-intervention were analysed qualitatively. The OEQ was filled out by the study participants in the form of written texts.

In the current study, the content analysis technique of summative content analysis was used. Summative content analysis involves the counting and comparing of content or keywords, followed by an analysis of the underlying context (Hsieh & Shannon, 2005).

4.8.2.1 Qualitative content analysis

In summative content analysis, patterns are identified in a single piece of material (for instance, words or phrases) or numerous pieces of information or communication sources. In content analysis, large amounts of text are distilled into codes and then summarised into categories, so the data can be tabulated to find out the frequency of specific concepts or variables.

In summative content analysis, the frequency with which a concept is shared or discussed is determined; for example, how many times it is discussed. It is also possible to search for underlying meanings; such as phrases or words. In this way, the content analysis incorporates quantitative thinking into a qualitative process. In the summative content analysis process of this study, the following four steps were used:

- Step 1: Transform

This was the first step in qualitative analysis. The data collected from students were transferred from the students' questionnaire sheet to a word-format document. Moreover, it was the initial phase of data analysis, qualitatively, where the data were organised for further analysis.

- Step 2: Compilation

This was the second phase of the qualitative analysis, in which we organised the OEQ qualitative data to begin analysing it. At this stage, the text was read more carefully to discern similar and dissimilar thoughts. This stage was primarily concerned with organising the answers of the participants. This phase allowed data to be organised so that a framework could be established. It involves coding, identifying, and summarising the underlying themes and patterns in the data. The most valuable responses were selected throughout the process. In this study, the selected conceptions of fluid mechanics concepts were used as key phrases.

- Step 3: Categorise

In this stage, categories were reviewed to find connections and identify patterns. In this step, extracts that were relevant and significant to the study were chosen. This phase was intended to validate and compare the data used as the foundation for the study, which is a critical step. This was the phase in the data analysis process where the entire process was verified to ensure that the data were obtained without bias and following predetermined criteria. In this phase, the preliminary categories were compared to the initial list of categories of descriptions. The goal of this stage was to distinguish between the categories. These preliminary categories were re-evaluated to see if the categories with various labels communicated the same notion. As a result, the first list of categories in the description supplied in Step 2 was changed. The categorisation was examined again to confirm if the amended categories of description matched the various ways in which participants understood or not. After revising the categorisation, the main objective was to eliminate unnecessary, redundant or irrelevant responses from the participants. The researcher sought to understand the meaning of the data by seeking answers that seemed significant and by using explanations gleaned from the data. As a result, the key characteristics of the participants' responses were identified.

- Step 4: Determine the categories and reach a decision.

The goal of this stage was to name the categories based on their unique meanings. This is done to establish a relationship between the study objectives and the data that were analysed.

4.8.3 Analysis of Data Collected Using the FMCI

4.8.3.1 Model analysis method

To analyse the data that were collected by using the FMCI research instrument, the researcher used the model analysis method. The model analysis is a method of data analysis that is used in quantitative methods of data analysis by using the response probability of a single student for a single item to be measured (Bao & Redish, 2006).

The FMCI (see Appendix E) is composed of questions on four concepts: Archimedes's principle, Pascal's principle, fluid flow, and Bernoulli's principle. The answers are grouped into one of the three conception models (conceptual understanding category) as indicated in Figure 4.1.

The model density Matrix of the questions asked on the four fluid mechanical concepts was drafted based on the formula. As a result, the students' conception model state can be represented as a linear vector space concerning a set of conception models. Each conception model is associated with an element of the Matrix (orthonormal basis), which is presented as:

$$e_1 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} e_2 = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} e_3 = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \dots\dots \; e_w = \begin{pmatrix} 0 \\ 0 \\ . \\ w \end{pmatrix} \qquad 4.1$$

W- represents the total number of conception models considered, including a Null conception model to be considered in conjunction with the concept being investigated. The students' probability distribution vector is given as:

$$Q_k = \begin{pmatrix} q_1^k \\ q_2^k \\ . \\ q_w^k \end{pmatrix} = \frac{1}{m} \begin{pmatrix} n_1^k \\ n_2^k \\ . \\ n_w^k \end{pmatrix} \qquad 4.2$$

Whereas, $Q_{k\,=}$ is the coefficient of the students' response probability.

Moreover, the students' conception model state vector can be obtained as:

$$\lceil u_k \rangle = \frac{1}{\sqrt{m}} \begin{bmatrix} \sqrt{n_1^k} \\ \sqrt{n_2^k} \\ \sqrt{n_3^k} \end{bmatrix} - \qquad 4.3$$

In this case, the k^th student answers n_i^k questions using three conception models.

The conception model Matrix can be obtained by normalising the probability vector (Matrix 4.3):

$$D_1 = [u_{k\rangle}.\langle u_k] = \frac{1}{m}\begin{bmatrix} n_1^k & \sqrt{n_1^k n_2^k} & \sqrt{n_1^k n_3^k} \\ \sqrt{n_2^k n_1^k} & n_2^k & \sqrt{n_2^k n_3^k} \\ \sqrt{n_3^k n_1^k} & \sqrt{n_3^k n_2^k} & n_3^k \end{bmatrix} \qquad 4.4$$

Moreover, the average response of N students is determined by equation 4.5 below:

$$D_N = \frac{1}{N}\sum_{k=1}^{N} D_k = \frac{1}{N.m}\sum_{k=1}^{N}\begin{bmatrix} n_1^k & \sqrt{n_1^k n_2^k} & \sqrt{n_1^k n_3^k} \\ \sqrt{n_2^k n_1^k} & n_2^k & \sqrt{n_2^k n_3^k} \\ \sqrt{n_3^k n_1^k} & \sqrt{n_3^k n_2^k} & n_3^k \end{bmatrix} \qquad 4.5$$

One can measure and represent the student conception model state with Matrix 4.5 by using a set of questions related to a fluid mechanics concept. The student conception model Matrix represents the distribution of the students' understanding of the question, explaining the concept.

In Section 4.7.1, the category of students' conceptual model of the students is sequential: The diagonal element (see Matrix 4.5) represents the students' response to the incorrect conception model (M1), common alternative conception model (M2), and Null conception model (M3), respectively. This value runs from 0 to 1.

According to Bao and Redish (2006), the definitions of the three conception models are presented in Figure 4.1.

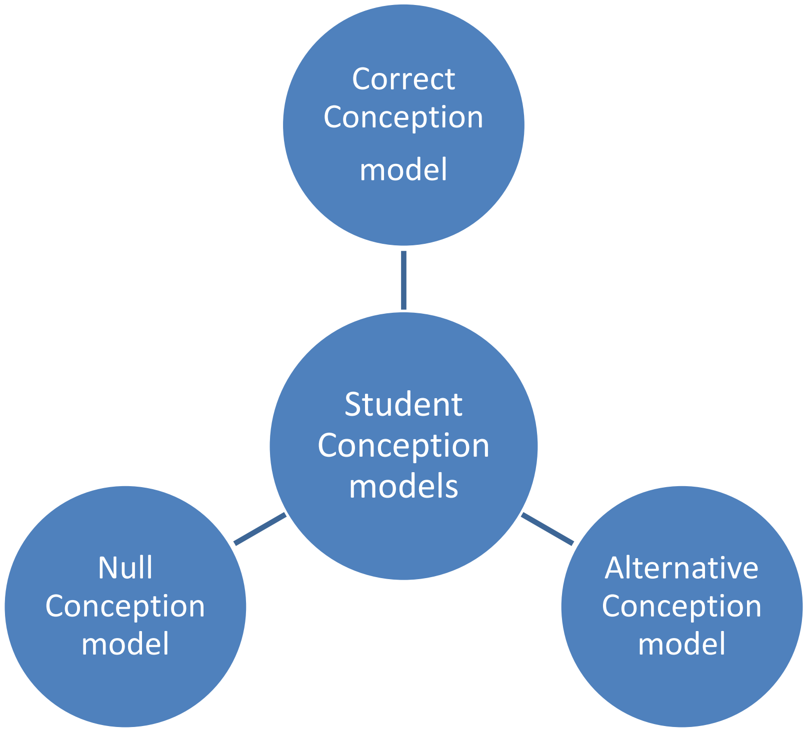

Figure 4.1 The categories of students' conception models

For example, the distribution below shows the results of one student's responses that were calculated by using the formula (see Matrix 4.5), and the students' conception model Matrix distribution in the three cases is presented below.

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.5 & 0 & 0 \\ 0 & 0.3 & 0 \\ 0 & 0 & 0.2 \end{bmatrix} \begin{bmatrix} 0.5 & 0.2 & 0.1 \\ 0.2 & 0.3 & 0.1 \\ 0.1 & 0.1 & 0.2 \end{bmatrix}$$

A B C

The density Matrix A is the distribution of students' responses when a student has a consistent response by using one model, i.e., 100% of the class used Model 1. Matrix distribution in B shows when students' consistent responses were using all models, i.e., 50% of the class were consistently categorised in M1, 30% were categorised in M2, and 20% were categorised in M3. Moreover, Matrix C represents the Matrix that shows students' answers using mixing and inconsistent categorisation into all models; i.e., each student is sometimes categorised into M1, sometimes M2, and sometimes M3.

4.8.4 Analysis of Data Collected Using the SAMRQ

Students' attitudes and feelings towards the MR approach were collected by using a Likert scale questionnaire. And the data were analysed by using SPSS and the mean and standard deviation were given. Moreover, the results in the first iteration were compared to Iteration II. The effect of the intervention on students' conceptual paths was studied using a comparative analysis approach (see Chapter 7).

4.8.5 Analysis of the Change in Students' Conceptual Pathways As a result of the Intervention

The paired-sample t-test was used to determine whether groups were the same before and after the interventions. Consequently, the similarity between the two groups (experimental and control) on both the OEQ and FMCI tests was assessed using a paired-sample t-test (see Section 5.2.2). The two groups needed to be similar before the intervention, as one group would receive treatment and the other not. To put it another way, the iteration reduction was compared to the final students' categories of description for a fluid mechanics topic.

The VTL is used in this study to determine the key and irrelevant features of a particular fluid mechanics idea that the students had identified (see Chapter 6).

After the intervention, the effectiveness of the approach was observed based on ANCOVA (see Section 6.4). The number of research participants who correctly identified each feature of a fluid mechanics concept in the pre-phase was compared to those who correctly identified each component in the post-and post-intervention phases. This was done only on those who were classified as M1 for both the OEQ and FMCI tests. The effectiveness of the approach (intervention) was observed on M1, i.e., how many students shifted (changed) from M2, and M3 to M1. Therefore, ANCOVA can determine the magnitude of the effect due to the intervention used. Therefore, the researcher was able to examine the impact of the intervention on the students' conceptual understanding of fluid mechanics and determine whether the intervention enhanced students' comprehension of fluid mechanics.

After thoroughly analysing the data in both phases of this study, the researcher carefully interpreted the findings to respond to the research questions (Kothari, 1985).

Interpretation, according to Kothari (1985), refers to drawing inferences from empirical evidence that has been analysed. Interpretation is, thus, a method of defining and explaining study findings.

4.9 THE TRUSTWORTHINESS OF THE STUDY

Validity and reliability are the most common phrases used to describe the trustworthiness of research. Both were generated from a positivist process, according to Kerlind (2005). This is a quantitative strategy for researching exterior, objective reality rather than the subjective reality that qualitative researchers explore.

Based on the qualitative approach reinforced by the interpretative paradigm, the study's trustworthiness criterion was defined and addressed. Because different paradigms have diverse worldviews, not all research paradigms have the same criteria for determining the trustworthiness of research (Lincoln & Guba, 1985; 2005). These researchers coined new concepts that are interchangeable with validity and reliability and are appropriate for qualitative research such as trustworthiness which comprises transferability, reliability, conformability, and believability. The purpose of trustworthiness is to convince the readers of the research report that the researcher can be trusted with their work during the research process. The external validity of a study's findings is similar to its transferability. The terms "dependability" and "reliability" are interchangeable. Dependability refers to the examination of findings for consistency.

In the context of an internal validity analysis, the data collection and findings were consistent and credible. These examples demonstrate the similarity in the reliability of interpretive and positivist perspectives.

Another approach to describing trustworthiness is for readers to be able to rely on the researcher's results to see if they are credible and valid. If the researcher conducted the investigation honestly from beginning to end, readers would be able to trust the results. Each criterion of trustworthiness is described in the sections that follow.

4.9.1 Credibility (Internal Validity)

Credibility is a trustworthiness criterion that allows readers to have faith in the veracity of qualitative research findings (Guba, 1981). According to Sandberg (2000), it is also known as "communicative validity" which justifies the researcher's interpretations. To acquire meaningful data, the researcher had long and systematic dialogues with the research participants during the interviews (see Section 4.9).

The researcher did not impose his opinions on the students during the translation, data analysis, or interpretation. The translated, processed and interpreted data were restricted to empirical data. The empirical data demonstrates the students' diverse approaches to conceptualising and representing fluid mechanics.

4.9.2 Transferability

This study used the transferability factor as the second measure of trustworthiness. According to Sandberg (2000), this refers to the extent to which one can apply the findings from one's study in a different setting. According to Sandberg, validity is also tested in qualitative research based on a researcher's reasoning. Another communicative validity criterion is that used to justify the entire research process and interpretations made by the researcher.

The findings of this study were distributed to stakeholders via papers and conferences, including the observed conceptual challenges, the intervention used to resolve them, and the critical features of a fluid mechanics idea discerned by students. Curriculum and classroom instruction developers and designers will benefit from this material. This study's conclusions are particularly useful for undergraduate Physics curriculum designers and fluid mechanics instructors.

4.9.3 Dependability (Reliability)

This is the study's third criterion for trustworthiness. Sandbergh (1997) describes dependability as interpretative awareness in qualitative research. This is a better fit for qualitative research than reliability, which is determined by the ability to replicate a study. The notion is that interpretative awareness, rather than inter-rater reliability, is more compatible with the relational features of the qualitative perspective. Sandberg (2000) claims that dependability is a measure of a researcher's interpretative awareness.

Bowden et al. (1992) and Sandbergh (1997) used dependability to determine whether the interpretation of a study's results had been effectively controlled and checked. These researchers believe that making the interpretive steps more evident to the readers is a superior, alternative kind of reliability that is ideal for qualitative studies. In the first phase, the researcher took great care in selecting a sample.

Based on their academic results, 32 students were chosen from a total of 49 students using a maximum variation sampling approach (Patton, 2002). This means that the study's sample included students with high, medium, and low academic achievements. All 32 students were selected as the sample in the second phase. The data were acquired methodically from the two major sources (the two samples) using verified devices (see Section 4.9). A pilot study was undertaken to validate the research instruments.

Three professors examined the research instruments as well (see Appendix IX). Participants' responses to interviews were audio-recorded and documented. By focusing on credible empirical evidence, the categories of description could be created. The seven steps of the qualitative data analysis procedure were completed before the development of the categories of description (see Section 4.7).

4.9.4 Conformability

Credible data were gathered from primary sources, as mentioned in Section 4.7. To ensure that the conclusions were a function of only the qualitative research participants, the analysis was focused on this credible data. The researcher attempted to avoid researcher bias, based on the theories of Guba (1981). As outlined in Section 4.7.2, the processes outlined in the qualitative data analysis process enabled the researcher to achieve these results. In the data analysis process, the researcher considered the dependability of the obtained data and the data analysis process using open-ended questionnaires.

4.10 ETHICAL CLEARANCE

Letters were written to the respective heads of the Ethiopian University departments to request permission to conduct research in their universities (see Appendix A). Permission from the respective heads was granted. Before adopting this instrument, the researcher communicated by e-mail and secured permission from professors at Colorado University and the University of Illinois to use the instruments. All students were permitted to participate in the study, and the Unisa Ethics Committee (see Appendix A) gave its ethical clearance with the code: 2014_CGS/ISTE_009.

4.11 CHAPTER SUMMARY

In this chapter, the research design, research instruments, study area and participants, data collection, and data analysis, as well as ethical considerations were addressed. Students in undergraduate Physics programmes participated in three phases of the study to enhance their learning of fluid mechanics using multiple representation approaches.

The sampling procedures and design were discussed and explained. Two groups of students were chosen from public universities in Ethiopia. There were 32 students in each class—a total of 64 undergraduate students. A random sample of participants was selected for each group. One group of participants received treatment and was called the experimental group. In the first phase, after students had been exposed to traditional teaching methods, in-depth evaluation was used to identify the students' conceptual challenges. In the second phase, different instruction methods for the second group of students were used, and as part of the second phase, MRs were used to design lessons in fluid mechanics. The effectiveness of these methods in reducing conceptual challenges was investigated in the third phase.

Three research instruments were used to gather data, namely, an Open Ended Questionnaire (OEQ) (Appendix D)—which was validated and reliable for the Ethiopian context; the FMCI test (Appendix E); and the Test of MR Approach Related Attitudes (SAMRQ) (Appendix F). Both qualitative and quantitative data were collected from the selected participants. Pre-intervention and post-intervention data were gathered from the research sample using the OEQ and FMCI. Furthermore, the SAMRQ was used to gather data in the second and third phases of the intervention in the experimental group. The Attitudes Related Scale Test (ARST) towards the MR approach was developed by the researcher.

All the instruments were well validated and the pilot study was noted. Communication to researchers from Colorado for permission to use the tests was a great effort by the researcher. In Section 4.6, the method of data collection was discussed for each of the 3 phases and described in detail. The topics selected in fluid mechanics were internal force, pressure measurement, fluid flow, and Bernoulli's principle. The methodology was discussed and learning activities were designed based on the variation theory to develop students' conceptual understanding using multiple instructional representations in the experimental group. The intervention consisted of four lessons and lasted for two weeks.

The discussion on trustworthiness and its 4 concepts were discussed in detail including the process of sampling and categories of data concerning the study. In this chapter, the research design, instruments, participants, data collection, data analysis, and summary are discussed. Table 4.1 is included to provide a summary of the chapter.

Table 4.1: A summary of the research questions, instruments, analysis, and references

Questions	**Instruments**	**Analysis**	**Sections**
What are the categories of students' understanding of fluid mechanics concepts?	OEQ and FMCI	Analytic content analysis, Model analysis method	Section 4.8.2.1 Section 4.8.3.1
Which category of students' understanding is dominant in fluid mechanics concepts?	OEQ and FMCI	Analytic content analysis, Model analysis method, paired-samples t-test.	Section 4.8.2.1 Section 4.8.3.1 Section 4.8.5
What are the effects of multiple representation approaches on students' understanding of fluid mechanics concepts?	Literature, Lesson plan, OEQ and FMCI	Synthesis, and discussion Analytic content analysis Model analysis, Paired-samples t-test, ANCOVA.	Section 2.4 Section 4.8.2.1 Section 4.8.3.1 Section 4.8.5
What are students' attitudes toward multiple representation approaches in fluid mechanics concepts?	SMARQA	Inferential statistics analysis	Section 4.8.4
Is there any significant difference between Iteration 1 and Iteration 2 in the experimental group in terms of student understanding of multiple representation approaches in fluid mechanics concepts?	OEQ and FMCI	Paired-samples t-test, ANCOVA	Section 4.8.4 Section 4.8.5

CHAPTER 5: ANALYSIS AND DISCUSSIONS OF RESULTS OF THE FIRST PHASE

5.1 INTRODUCTION

This chapter shows the results for the control and experimental groups before the interventions, which is the result of the first phase. This study examined and categorised the difficulties in understanding fluid mechanics courses of undergraduate university students with Physics majors. The data were collected using an OEQ (see Section 5.8), to which participants could respond in written text, drawings, equations, and other formats. The results of both groups of students' understanding of the four concepts of fluid mechanics were discussed. In addition, another research instrument, the FMCI was administered to investigate students' understanding of fluid mechanics. Both data collection instruments were used before commencing the fluid mechanics' course. The qualitative (OEQ) results and the quantitative (FMCI test) results were discussed in Sections 5.2 to 5.6.

The data collected and analysed were to answer the following research questions, namely:

- What are the categories of students' understanding of fluid mechanics concepts?
- Which category of students' understanding is dominant in fluid mechanics concepts?

The students' conceptual understanding of the four topics of fluid mechanics concepts was categorised according to the category of conception models (see Section 4.8.1). Sections 4.8.2 and 4.8.3 describe how the OEQ and FMCI data were thoroughly examined. These were carried out in light of the study's background and objectives to identify the most commonly used students' conceptual understandings, which were then written into text documents. The researcher questioned 32 undergraduate Physics students. Appendix I contains the OEQ with its guide.

The Microsoft Word document report included the non-verbal aspects of the responses, such as mathematical equations, graphs, diagrams, and textual explanations. These Open-Ended Questionnaire non-verbal expressions were given with their coded names from ES/OEQ_01 up to ES/OEQ/32 for one group, and CS/OEQ/01 up to CS/OEQ/32 for the other group.

The data for four concepts in fluid mechanics were analysed according to the qualitative data analysis method, which is presented in Sections 4.8.2.1.

Regarding the data collected from the FMCI test, undergraduate Physics major students (N = 64) from two groups were given the test to assess their prior knowledge before entering the fluid mechanics' courses. The categorisation of student understanding was compiled from the data collected from the FMCI.

The results were categorised into three categories of the conception models (see Section 4.8.1). Model analysis was used to analyse the data of FMCI (see Section 4.8.3).

The VLT was used to show how the differences occurred (see Sections 4.7.1). The students' conceptual understanding of each of the four concepts was shown in terms of the three categories of the concept model. Then the critical aspects (concentrated elements) of alternative methods used to show students' scientific understanding (see Section 3.2) were highlighted. Therefore, the findings from the first research question aided in the development of the instructional strategy.

5.2 CATEGORISATION OF STUDENTS' UNDERSTANDING OF ARCHIMEDES PRINCIPLE

In this part, the categorisation of students' understanding is compiled from data collected from the OEQ and FMCI tests, which were given at the beginning of the class (in the pre-intervention).

5.2.1 Results of OEQ Archimedes' Principle

The OEQ with 32 undergraduate students was conducted, and their responses were analysed qualitatively by using the content analysis method (see Section 4.8.2.1).

Students' conceptual understanding was explored and categorised using qualitative data analysis procedures described in Section 4.8.2. As a result, students' conceptions were categorised into three basic categories.

The next Section 5.2 presents results for the Archimedes' principle, one of the four sub-topics of fluid mechanics, where the percentage of students who were allocated in M1, M2, and M3 of OEQ about the Archimedes' principle is shown (see Table 5.1).

Table 5.1: Categories of students' responses on OEQ in Archimedes' Principle

Name of the Category	Descriptions of the categories	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The buoyancy force equals up trust pressures, which indicate internal forces. • The volume of an object is equal to the volume of displaced water.	10	31.25	11	34.75
Alternative conception model (M2)	• Boundary pressure equals buoyancy force. • The buoyancy force is a natural force that exists within the body. • The buoyancy force is volume.	14	43.75	13	40.62
Null conception model (M3)	• The buoyancy force equals the volume of an object. • An object's buoyancy force is equal to its mass. • The buoyancy force of an object equals its weight.	8	25	8	25

The students' responses to OEQ on the Archimedes Principle in fluid mechanics concept were presented in three categories (see Table, 5.1). In the category correct conception model, students in the control group outperformed the experimental group by 2.5%. Whereas students were categorised under the Alternative conception model, 3.13% of the students in the experimental group exceeded the control group students. Moreover, when comparing student responses in the Null conception model between the experimental and control groups, similar percentages were noted and there was no difference between the groups. This indicates the results were identical in both groups.

Studies suggest that undergraduate students have difficulty explaining Archimedes' principles and explaining the sinking and floating behaviour of objects (Aksit, 2011; Chen & Gladding, 2014; Loverude et al., 2003). Furthermore, students frequently used the same formula to describe all three cases and struggled to explain the differences in computations when an object is completely submerged, half immersed, or floating in a fluid. They had trouble describing the submerging cases by linking them with their daily experience, which made it difficult for them to understand and compute issues involving Archimedes' principle.

5.2.2 Results of FMCI for Archimedes' Principle

The distribution of students' responses in experimental and control groups in the FMCI on the Archimedes' concept is presented, according to the three conception models (see Table 5.2).

The diagonal elements of the Matrix (see Section 4.7.2) describe the density of students' responses in the three categories of conception. The diagonal elements of Matrix in the experimental group were given as 0.34, 0.42, and 0.25, and in the control group, 0.35, 0.40, and 0.25A. This is summarised in Table 5.2 below.

Table 5.2: Results of FMCI test regarding students' categories of understanding of Archimedes' Principle.

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.34	0.35
Alternative conception model (M2)	0.42	0.40
Null conception model (M3)	0.25	0.25

According to the comparison between experimental and control groups, 34% and 35% of students were classified as M1 respectively (see Table 5.2). This shows, in M1, there is a difference of 1% between the groups. Furthermore, the alternative conception model constituted 42% of the experimental group and 40% of the control group, indicating a 2% difference between the groups. Moreover, among the experimental and control group using the Null conception model, the difference was similar between the two groups, with 25%.

Table 5.3: FMCI pre-intervention-I paired-samples t-test result on Archimedes' Principle

		Paired differences				**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. error mean**	**95% confidence interval of the difference**				
				Lower	**Upper**			
Pair I	M1	-.00719	.01155	-.03074	.01636	-.623	31	.538
Pair II	M2	.01156	.01333	-.01562	.03875	.868	31	.392
Pair III	M3	-.00563	.01200	-.03009	.01884	-.469	31	.642

A paired-sample t-test was used to establish the similarity between the two groups for the three categories. As can be seen in Table 5.3, the experimental and control groups did not differ significantly between M1, M2, and M3 (t (31) =-0.623, p-value 0.538 (where p >0.05 at two-tailed); t (31) = 0.868, p-value 0.392 (where p > 0.005 at two-tailed); t (31) =-0.469, p-value 0.642 (where p > 0.005 at two-tailed) respectively. Therefore, there was no difference in average results between the experimental and control groups or across the three groups categorised as M1, M2, and M3.

5.3 THE DOMINANT CATEGORY OF STUDENTS' UNDERSTANDING OF ARCHIMEDES' PRINCIPLE

After analysing the data from the OEQ and FCMI, the results were categorised into different models. Sections 5.2.1 and 5.2.2, show the description of each category in the Archimedes principle. On average, more than 40% of undergraduate Physics students had an alternative conception regarding Archimedes' principle. Therefore, the dominant category of students' understanding of the Archimedes principle is in the alternative conception model.

Students had difficulty analysing the findings of the tasks and drawing conclusions once they had solved them. Furthermore, when a substance was partially or completely submerged in a fluid, students found it challenging to appropriately analyse and perform mathematical computations (Heron & Christian, 2003). When they had to explain the difference between the weight and density of the body inserted into a fluid, they became confused. The students could not tell the difference between density and volume (Hewitt, 2009). Similarly, students were confused when they needed to distinguish between the mass and volume of a substance introduced into a fluid (Loverude et al., 2010). Furthermore, most of the students struggled to distinguish between Archimedes' principle (buoyancy force) and pressure (Wagner et al., 2009).

Previous researchers found similar results and indicated that undergraduate students failed to make the connection between what they had learned in previous Physics classes and what they developed through their experiences with Archimedes' principle (Absi et al., 2011; Loverude et al., 2003). This difficulty was found not only at the undergraduate level but also in secondary schools. As an example, a study conducted to determine high school students' understanding of Archimedes' principles found that they had difficulty distinguishing hydrostatic pressure from Archimedes' ideas (Hanim et al., 2021; Kafiyani, Samsudin & Saepuzaman, 2019; Kusairi et al., 2020). Therefore, the observed alternative conceptions came from their background knowledge, i.e., from their high school learning. This was not only a problem of understanding; there was also a lack of ability in problem-solving. To overcome these obstacles, a variety of instructional scaffolding supports can be used. The recommendation is that teachers identify students' challenges so that they can provide scaffolding that is appropriate for them (Koes-H, Muhardjito & Wijaya, 2018).

5.4 CATEGORISATION OF STUDENTS' UNDERSTANDING OF PASCAL'S PRINCIPLE

This section provides results and a discussion on the students' understanding of Pascal's principle. Tire pressure, water flowing from the top of the mountain to the city, and petrol stations all use the Pascal principle (Walker et al., 2014). As a result, the pressure idea is covered in general Science from elementary through high school, and it eventually becomes part of the undergraduate Physics course in fluid mechanics.

Students should learn and grasp the essential ideas of pressure if they are introduced to it at a young age. Students are required to present some analyses and explanations concerning pressure measurement at the undergraduate level. However, undergraduate students are confused by pressure changes at various heights and are much more confused about pressure fluctuations at various temperatures.

5.4.1 Results from OEQ Regarding Pascal's Principle

The results of the data collected from OEQ regarding Pascal's principle (pressure measurement) were presented. Furthermore, it was discussed by comparing the experimental and control groups as categorised in the three conception models (see Table 5.4).

Table 5.4: Category of students' responses on OEQ in Pascal's principle

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The pressure in a liquid increases with depth. • The atmospheric pressure decreases with increasing altitude. • Independent of the shape of the container, the pressure is the same at all points with the same depth. • The density of a substance is its mass per unit volume.	10	31.25	9	28.13
Alternative conception model (M2)	• Water pressure decreases with depth. • The atmospheric pressure is independent of the altitude. • Sometimes the pressure P at a depth h below a point in the liquid is greater by a certain amount of pgh.	13	40.62	14	43.75
Null conception model (M3)	• At 0° C the densities of gases are equal to the densities of solids and liquids. • Atmospheric pressure is dependent on density.	9	28.13	9	28.13

As can be seen in the M1 of OEQ, the experimental group exceeds the control group of students by 3.12%. In the M2 category, the control group exceeded the experimental group by 3.13%. In the M3 category, the experimental group and the control groups of the students were equal.

According to Physics education research, fluid mechanics is difficult to learn conceptually. Undergraduate Physics and Engineering students, for example, struggle to grasp fluid mechanics concepts such as displaced volume and buoyant force at the secondary and tertiary levels (Distrik, Supardi & Jatmiko, 2021; Prahani, et al., 2021; Minichiello et al., 2020; Raissi et al., 2020).). This includes confusing the terms "pressure" and "temperature" (Hartini & Sinensis, 2019; Minichiello et al., 2020).

5.4.2 Results from FMCI Regarding Pascal's Principle

The results of the data collected from FMCI regarding Pascal's principle (pressure measurement) were presented by comparing the experimental and control groups as categorised in the three conception models (see Table 5.5a).

Table 5.5a: Distributions of the comparison results of students' responses on FMCI in Pascal's principle in the pre-test

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.33	0.30
Alternative conception model (M2)	0.48	0.46
Null conception model (M3)	0.19	0.24

From Table 5.5a, in M1 of the FMCI, the experimental group exceeded the control groups of the students by 3%. In M2 of the FMCI, the experimental group exceeded the control groups of the students by 2%. In M3 in the FMCI, the control groups exceeded the experimental groups of the students by 5%.

Table 5.5b: FMCI pre-intervention-I paired-samples t-test result on Pascal's principle

		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. deviation**	**Std. error mean**	**95% Confidence interval of the difference**				
					Lower	**Upper**			
Pair I	M1	.02625	.15957	.02821	-.03128	.08378	.931	31	.359
Pair II	M2	.02094	.20416	.03609	-.05267	.09454	.580	31	.566
Pair III	M3	-.04719	.19393	.03428	-.11711	.02273	-1.376	31	.179

A paired-sample t-test was used to establish the similarity between the experimental and control groups for the three categories. As shown in Table 5.5b, the experimental and control groups did not differ significantly between M1, M2, and M3 (t (31) =-0.931, p-value 0.359 (where $p > 0.05$ at two-tailed); t (31) = 0.580, p-value 0.566 (where $p > 0.005$ at two-tailed); t (31) =-1.376, p-value 0.179 (where $p > 0.005$ at two-tailed). Therefore, there was no difference in average results between the experimental and control groups or across the three groups categorised as M1, M2, and M3.

5.5 DOMINANT CATEGORY OF STUDENTS' UNDERSTANDING OF PASCAL'S PRINCIPLE

The results of the data collected from OEQ and FMCI regarding the dominant category of students' understanding of Pascal's principle are shown in Tables 5.5a and 5.5b.

In the M1 category, in the OEQ, there was an average of nearly one-third (29.69%) (31.25 + 28.13) of students. In FMCI, there was an average of 31.5% (33% + 30%) in the experimental and control groups in this category.

In the M2 category, in OEQ, there was an average of 42.19% (40.62% + 43.75%) of students and in the FMCI, an average of 47% (48% + 46%) of students. As a result, in the experimental and control groups, according to the data collected by the research instruments (OEQ and FMCI), there was an average of 44.60% of students in the M2 category.

In the M3 category, in the OEQ, there was an average of 28.13% (28.13% + 28.13%) of students in the M3 category. In FMCI, an average of 21.5% (19% + 24%) of students were in the M2 category.

In conclusion, the dominant category of the students' understanding of Pascal's principle was in the M2 category, with an average of 44.60%. The next section provides a discussion of the literature on the alternative conceptions of Pascal's principle.

Pascal's principle, pressure, and volume are difficult concepts for undergraduate students to grasp (Ornek et al., 2008; Robertson & Schaffer, 2016). This could indicate that students are unable to connect Physics topics to their everyday activities or experiences (Raissi et al., 2020). Furthermore, even after receiving instruction, pupils were unable to accurately answer questions about pressure and temperature difficulties (Hartini & Sinensis, 2019). Prahani et al., 2021, investigated undergraduate first-year students' learning challenges in the setting of fluid mechanics at the tertiary level.

The literature shows that students get confused by the terms “pressure” and “volume” (Aksit, 2011; Minichiello, et al., 2020). This issue, however, is not limited to students; it also affects teachers (Taylor & Lucas, 2000). Similarly, the study shows that undergraduate students have a hard time distinguishing between weight and pressure (Raissi et al., 2020). It is also difficult for students to tell the difference between pressure and temperature (Loverude et al., 2003). There is also an issue with pressure and volume detection (de Berg, 1995; Psillos, 1999), as well as the distinction between pressure and force (de Berg, 1995; Misaiko & Vesenka, 2014; Psillos, 1999; Minichiello et al., 2020). Undergraduate students’ conceptions of compressed air were investigated, and it was found that they did not comprehend the concepts of size and pressure (de Berg, 1995).

Undergraduate students, on the other hand, are perplexed by pressure changes at various heights and are much more perplexed by pressure variations at various temperatures. Similarly, kids are perplexed by the terms “pressure” and “volume” (Minichiello et al., 2020). However, this issue is not limited to pupils; it also affects teachers (Taylor & Lucas, 2000).

The link between pressure and height is challenging for undergraduate students to analyse (Goszewski et al., 2013). According to Pascal’s Law, "in an incompressible, static fluid of constant density, a change in pressure is linearly proportional to a change in height; doubling the height between the two points of reference will double the change in pressure while having the height between the two points will have a change in pressure” (Serway et al., 2004). It might also be difficult if a student does not comprehend proportional reasoning.

Basic concepts such as the link between pressure and height were difficult for undergraduate students to grasp. They assume that as the height of the fluid in the container lowers, the fluid pressure will rise. They also struggle to explain how density interacts with pressure. Furthermore, many college students have trouble memorising the pressure unit, as well as using and comprehending density and weight formulae (Akis, 2011).

5.6 CATEGORISATION OF STUDENTS’ UNDERSTANDING OF FLUID FLOW

The data on fluid flow was collected from OEQ and FMCI. This is discussed by comparing the experimental and control groups as categorised in the three conception models.

5.6.1 Results from OEQ Regarding Fluid Dynamics

Table 5.6: Distributions of the comparison results of students' responses of OEQ pre-test in fluid flow

Name of the Category		Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The equation of continuity for fluids states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid. • The product AV, which has the dimensions of volume per unit time, is called either the volume flux or the flow rate. • In steady flow, every fluid particle arriving at a given point in space has the same velocity. • The condition Av constant is equivalent to the statement that the volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval if no leaks are present.	10	31.25	9	28.13
Alternative conception model (M2)	• Equation of continuity for fluids states that the product of the area and the volume; • The product Av, is area times velocity; • In steady flow, the area and velocity are constant; • The condition Av constant is equivalent to the statement that the area and volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval.	13	40.62	13	40.62
Null conception model (M3)	• Equation of continuity for fluids states that the product of the pressure and temperature; • The product Av, is fluid statics; • In steady flow, the tube is similar; • The condition Av constant is fluid always passes in a tube.	9	28.13	10	31.25

As can be seen in Table 5.6 in the M1 of OEQ, the experimental groups of the students exceeded the control group of the students by 2%. In the M2 category, the experimental groups and the control group of the students were equal. In the M3 category, in the OEQ, the control groups of the students exceeded the experimental group by 3%.

5.6.2 Results from FMCI Regarding Fluid Flow

The data on fluid flow were collected from FMCI. This is discussed by comparing the experimental and control groups as categorised in the three conception models (see Table 5.7a).

Table 5.7a: Distributions of FMCI pre-test result categories of students' understanding of fluid flow

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.37	0.33
Alternative conception model (M2)	0.39	0.40
Null conception model (M3)	0.24	0.27

As shown in Table 5.7a, in M1 of the FMCI, the experimental group exceeded the control groups of the students by 4%. In M2 of the FMCI, the control groups exceeded the experimental groups of the students by 1%. In M3 in the FMCI, the control groups exceeded the experimental groups of the students by 3%.

Table 5.7b: FMCI pre-intervention-I Paired-samples t-test on fluid flow

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.04062	.17572	.03106	-.02273	.10398	1.308	31	.201
Pair II	M2	-.01250	.13854	.02449	-.06245	.03745	-.510	31	.613
Pair III	M3	-.02812	.15706	.02776	-.08475	.02850	-1.013	31	.319

A paired-sample t-test was used to establish the similarity between the experimental and control groups for the three categories. As shown in Table 5.7b, the experimental and control groups did not differ significantly between M1, M2, and M3 (t (31) =-0.931, p-value 0.359 (where p > 0.05 at two-tailed); t (31) = 0.580, p-value 0.566 (where p > 0.005 at two-tailed); t (31) =-1.376, p-value 0.179 (where p > 0.005 at two-tailed). Therefore, there was no difference in average results between the experimental and control groups or across the three groups categorised as M1, M2, and M3.

5.7 DOMINANT CATEGORY OF STUDENTS' UNDERSTANDING OF FLUID FLOW

The results of fluid flow data, which was collected from OEQ and FMCI, are discussed by comparing the experimental and control groups as classified in the three conception models (see Table 5.7a and 5.7b) as well as with the related literature.

As can be seen, in the M1 category, results in terms of fluid flow in the OEQ were an average of 29.69% (31.25 + 28.13). In the FMCI, there was an average of 35% (37% + 33%). Accordingly, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) indicated that an average of 32% of students were in the M1 category.

In the M2 category, in the OEQ, the mean score was 40.62% (40.62 + 40.62). In the FMCI, there was an average of 39.50% (39% + 40%). As a result, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) showed that an average of 40.06% of students were in the M2 category.

In the M3 category, in the OEQ, the mean score was 25% (28.13% + 31.25%). In the FMCI, the mean score was 25.50% (24% + 27%). Moreover, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) indicated that an average of 25.25% of students were in the M3 category.

In conclusion, the dominant category of students' understanding of fluid flow was in the M2 category; an average of 40.06% of students were in the M2 category.

"The motion of a fluid subjected to unbalanced forces is referred to as fluid flow”. As long as unbalanced forces are applied, this motion will persist (Serway et al., 2004, p. 428). As a result, fluid flow is determined by the rate at which fluids flow through a tube, as well as other factors such as speed and volume. A garden hose attached to a tap that may be opened and closed is a practical example. Similarly, when learning fluid mechanics, students have difficulty grasping constant velocity and volume (Raissi, et al., 2020). Alternative conceptions of fluid flow exist.

In Spain, undergraduate students have misconceptions about molecular interactions and temperature (Romero & Martnez, 2013). According to research (Meltzer, 2008), approximately 80% of undergraduate students at Midwestern University in the United States had alternate notions of velocity and pressure while learning kinetic energy. Students in South Africa have misconceptions about the links between pressure, temperature, velocity, and cross-sectional areas in fluid flow, according Faleye and Mogari’s (2010) study.

Based on the findings of research conducted in both developed and developing countries, it can be stated that fluid mechanics is a confusing subject for many students and looks to be difficult to master. When learning fluid Physics, students have a hard time grasping constant velocity and volume (Raissi et al., 2020). According to studies, alternative ideas about fluid flow occur at the undergraduate level.

According to various studies, the link between different concepts, confusion between physical variables, and difficulty identifying related variables (such as pressure, temperature, area, and volume) make understanding the fluid flow concept difficult (Besson & Viennot, 2004; Hartini & Sinensis, 2019). Students at the undergraduate level have this difficulty, and pre-service secondary Science teachers have alternative conceptions, such as fluid interactions (Oh, 2014). Because of these difficulties, students have developed negative attitudes towards Physics (Faour & Ayoubi, 2018).

5.8 CATEGORISATION OF STUDENTS' UNDERSTANDING OF THE BERNOULLI PRINCIPLE

The results from OEQ and FMCI were collected on Bernoulli's principle and presented in this section. The Bernoulli principle is a fundamental idea in our daily lives. These applications include air transport, wing design, ballooning, parachute fighter jets, bombers, and other applications of Bernoulli principles. According to Bernoulli's law in fluid dynamics (Walker et al., 2014, p. 553), "an increase in speed is concurrent with a decrease in static pressure or a decrease in a fluid's potential energy".

5.8.1 Results from OEQ Regarding the Bernoulli Principle

The results are discussed by comparing the response in each conception model in the experimental and control groups for the items of OEQ regarding the Bernoulli principle in the pre-test phase (see Table 5.8).

Table 5.8: Distributions of the comparison results of students' responses of OEQ pre-test in the Bernoulli principle

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The relationship between fluid speed, pressure, and elevation is the Bernoulli principle. • Bernoulli's equation shows that the pressure of a fluid decreases as the speed of the fluid increases. • The pressure decreases as the elevation increases.	10	31.25	12	37.50

	• The general behaviour of pressure with speed is true even for gases: as the speed increases, the pressure decreases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases.				
Alternative conception model (M2)	• As a fluid moves through a region where its speed or elevation above the Earth's surface changes, the pressure in the fluid is constant. • Bernoulli's equation shows that the pressure of a fluid increases as the speed of the fluid increases. • The pressure increases as the elevation increases. • According to the Bernoulli Effect, this higher-speed air exerts high pressure on the car than the slower-moving air on the other side of the car.	13	40.62	14	43.75
Null conception model (M3)	• Bernoulli's equation shows that as pressure increases, the speed of the fluid increases • The pressure does not depend on elevation • No answer • Silence	9	28.13	8	25

In the M1 in the OEQ, the control group's students had a difference of 6.25% more than the experimental group. In the M2 category, the control group of the students exceeded the experimental group by 3.13% in the OEQ. In the M3 category, the experimental group exceeded the control groups of the students by 3.13% in the OEQ.

5.8.2 Results from FMCI Regarding the Bernoulli Principle

The results are discussed by comparing the responses in each conception model in the experimental and control groups for the items of FMCI regarding the Bernoulli principle in the pre-test phase (see Table 5.9a).

Table 5.9a: Distributions of the comparison results of students' responses of the FMCI pre-test in the Bernoulli principle

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.33	0.30
Alternative conception model (M2)	0.40	0.40
Null conception model (M3)	0.27	0.24

According to Table 5.9a, in M1 of the FMCI, the experimental group exceeded the control groups of the students by 3%. In the M2 category, the experimental groups and the control group of the students were equal. In M3 in the FMCI, the experimental group exceeded the control groups of the students by 3%.

Table 5.9b: FMCI pre-intervention-I paired-samples t-test results on Bernoulli's principle

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.03719	.16183	.02861	-.02116	.09553	1.300	31	.203
Pair II	M2	.00344	.20963	.03706	-.07214	.07902	.093	31	.927
Pair III	M3	-.03594	.17610	.03113	-.09943	.02755	-1.154	31	.257

A paired-sample t-test was used to establish the similarity between the experimental and control groups for the three categories. As shown in Table 5.9b, the experimental and control groups did not differ significantly between M1, M2, and M3 (t (31) =-0.931, p-value 0.359 (where p > 0.05 at two-tailed); t (31) = 0.580, p-value 0.566 (where p > 0.005 at two-tailed); t (31) =-1.376, p-value 0.179 (where p > 0.005 at two-tailed); Therefore, there was no difference in average results between the experimental and control groups or across the three groups categorised as M1, M2, and M3.

5.9 DOMINANT CATEGORY OF STUDENTS' UNDERSTANDING OF BERNOULLI'S PRINCIPLE

The results from Bernoulli's principle, which were collected from OEQ and FMCI are presented. The dominant category of the students' understanding of Bernoulli's principle is shown in Tables 5.9a and 5.9b. As can be seen, the M1 category had results in terms of Bernoulli's principle in the OEQ that were an average of 33% (30% + 36%). In the FMCI, there was an average of 31.5% (33% + 30%). Accordingly, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) indicated that an average of 32% of students were in the M1 category.

In the M2 category, in the OEQ, the mean score was 39% (38% + 40%) in the FMCI with a mean score of 40% (40% + 40%). As a result, in the experimental and control groups, according to the data collected by the research instruments (OEQ and FMCI), an average of 39.5% of students were in the M2 category.

In the M3 category, in the OEQ, the mean score was 25% (26% + 24%). In the FMCI, the mean score was 25.5% (27% + 24%). Moreover, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) indicated that an average of 25.25% of students were in the M3 category.

In conclusion, the dominant category of students' understanding of Bernoulli's principle was in the M2 category; an average of 39.5% of students were in the M2 category.

The Bernoulli principle is a fundamental idea in our daily lives. These applications include air transport, wing design, ballooning, parachute fighter jets, bombers, and other applications of Bernoulli principles.

According to Bernoulli's law in fluid dynamics (Halliday & Resnick, 2004, p. 553), "an increase in speed is concurrent with a decrease in static pressure or a decrease in a fluid's potential energy."

In fluid dynamics, Bernoulli's principle states that "an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure or a decrease in the fluid's potential energy" (Walker et al., 2014, p 553). Where the Bernoulli equation simply states that "total energy per unit mass of flowing fluid, at any point in the subsurface, is the sum of the kinetic, potential, and fluid-pressure energies and is equal to a constant value" (John & Raymond, 2004, p. 432).

Bernoulli's principle is based on various concepts in the Bernoulli principle, such as pressure and temperature fluctuations, difficulty identifying body variables and related variables, etc. Therefore, it does not come as a surprise that Physics and Engineering students have difficulty understanding or explaining questions about Bernoulli's principles (Chain & Glidding, 2014; Loverude et al., 2000).

This involves the connection of distinct concepts, the misinterpretation of physical factors, and the inability to recognise associated variables (such as pressure and temperature, as well as area and volume), all of which make understanding the fluid flow notion challenging (Besson & Viennot, 2004; Hartini & Sinensis, 2019).

Regarding this, the study shows that undergraduate students at New England University, according to Meredith, Young, Misaiko and Vesenka (2013), had different ideas about Bernoulli's principle and the kinetic theory.

Researchers discovered that students struggle to determine relationships between pressure, temperature, velocity, and cross-sectional area in fluid flow due to misconceptions about fluid mechanics (Absi, 2011). Similarly, Engineering students struggle to grasp the link between temperature and pressure (Besson & Viennot, 2004; Hartini & Sinensis, 2019). All of this research took place in various locations around the world.

5.10 CHAPTER SUMMARY

This chapter presented the results for the control and experimental groups before any interventions. In this chapter, the results and discussion of the students' difficulties in the conceptual understanding and the dominant category of the students' understanding of fluid mechanics were described in detail. Consequently, the statistical analysis of the answers to the first two research questions was presented.

The introduction to Chapter 5 was presented in Section 5.1. Both groups of students' understanding of the four concepts of fluid mechanics were identified in this chapter. The results were given and discussed in detail. The conceptual challenges of each of the fluid mechanics' concepts were recognised and summarised. The data from the first phase of this study were used to design and implement a teaching intervention to address these problems with the conceptual understanding of fluid mechanics concepts.

In Section 5.2, results and discussions of conceptual understanding difficulties in Archimedes' Principle (buoyant force) were described in detail. The statistical analysis revealed that, after adding the results from the M2 and M3 groups, it appears that the majority of undergraduate first-year Physics students do not fully understand Archimedes' principle. In addition, the student notes indicate that most undergraduate Physics students who took part in this study had an incomplete understanding of the concepts of fluid mechanics before any intervention. Furthermore, these students did not have valid and acceptable knowledge of the Archimedes principle, and sometimes they responded to the questions with answers that were completely unrelated to the questions, or they guessed the answers. Also noted were other alternative conceptions, such as the fact that most of the students struggled to distinguish between Archimedes' principle (buoyancy force) and pressure, and these were all discussed and integrated with findings from relevant literature.

In Section 5.3, the dominant category of the students' understanding of Archimedes' Principle (buoyancy force) is described in detail. The discussion of conceptual understanding difficulties of Pascal's principle (pressure measurement) is found in Section 5.4. Undergraduate students found basic concepts such as the link between pressure and height difficult to grasp. They assume that as the height of the fluid in the container lowers, the fluid pressure will rise. They also struggle to explain how density interacts with pressure. Furthermore, many college students have trouble memorising the pressure unit as well as using and comprehending density and weight formulae.

In Section 5.5, the dominant category of the students' understanding of Pascal's principle was described in detail. In Section 5.6, a discussion of the conceptual difficulties of understanding fluid flow was presented. In this part of the analysis, the results of the third concept of fluid mechanics, called fluid flow data, which was collected from OEQ and FMCI, were presented. This was discussed by comparing the experimental and control groups as classified in the three conception models, as well as with the related literature.

In Section 5.7, the dominant category of the students' understanding of fluid flow was described in detail. Section 5.8 discussed the conceptual understanding challenges of the Bernoulli Principle. The results of the fourth concept of fluid mechanics, called Bernoulli's principle, which were collected from OEQ and FMCI, were presented in this section. In Section 5.9, the dominant category of the students' understanding of the Bernoulli Principle was described in detail.

CHAPTER 6: RESULTS OF THE INSTRUCTIONAL INTERVENTION APPROACH

6.1 INTRODUCTION

The second phase of the research was aimed at designing and implementing an instructional intervention to address the conceptual understanding difficulties identified in the first phase. Thus, MRs-based instruction was designed and implemented as an educational intervention. This method of instruction was used for the first group of students. VTL was crucial in the planning and design of the MRs' educational intervention. MRs were used to teach fluid mechanics, and students were provided with conceptual activities to help them understand what they were learning (Fraser, 2013). In this chapter, the topics in fluid mechanics were presented in the experimental group using MRs-based intervention. Each student received MRs-based course materials and homework before attempting interactive learning on their own. In addition to keeping students engaged in the learning process, these exercises helped them gain a better understanding of fluid mechanics concepts.

In this chapter, the following research questions were answered.

- What are the effects of multiple representation approaches on students' understanding of fluid mechanics concepts?
- What are students' attitudes towards multiple representation approaches in fluid mechanics concepts?

When students are actively involved in MRs, it has been shown that they gain a better understanding of concepts. During the fluid mechanics teaching session, the researcher led the group. There were four major types of representations chosen to produce the MR-based instruction (see Section 6.3). For each of the four fluid mechanics topics, a representation was selected that made sense. It was found that students were able to better understand fluid mechanics concepts after viewing these representations.

Students were provided with different representations of a single fluid mechanics concept. The four topics of fluid mechanics were presented using four representational styles in Sections 6.2–6.4. In Chapter 5, the students' conceptual understanding of fluid mechanics was examined and categorised. This is what the VTL calls the students' "previous objects of learning" (Bussey et al., 2013, p.18), which could influence the current object of learning. This chapter covers the most important components of each of the four fluid mechanics topics. As part of the fluid mechanics' course, it is concerned with Archimedes' principle (buoyancy), Pascal's principle, fluid flow, and Bernoulli's principle.

6.1.1 The Object of Learning for Students

Prior conceptual understanding of fluid mechanics was taken into account when evaluating the impact of fluid mechanics on students' lived experiences. In VTL, conceptual knowledge and existing knowledge are closely linked.

Researchers used the OEQ and FMCI for fluid mechanics to gather information about students' "previous objects of learning." (See Section 4.4). To understand how a prior conceptual understanding of fluid mechanics may affect the lived (discerned) objects of learning, the researcher examined the students' prior conceptual understanding of fluid mechanics.

To illustrate the relationship between prior conceptual knowledge and the existing object of learning, a figure was included within the VTL (see Figure 3.1). The intended aim of learning is what students should understand about a particular learning item (Marton & Booth, 1997). In this section, the study's intended learning objectives were the important aspects of each of the four topics in fluid mechanics. The goal of a teacher is to decide how to address each of the four essential topics in fluid mechanics, as well as what students should learn.

6.1.2 The Instructional Strategy for Improving Fluid Mechanics Learning

Aristotle once said that "without imagination, thinking is impossible" (cited in Stokes, 2002). Furthermore, without critical thinking, a deeper understanding of a concept is impossible. Hence, the main reason for using MR was to display and present the concepts of fluid mechanics to students to enable them to discern more critical aspects and then develop their understanding and representations of fluid mechanics concepts. Multiple representations were used to facilitate students' understanding of fluid mechanics concepts. How using the MR facilitated the students' understanding of each of the four concepts via interactive learning activities is presented in Sections 6.2.1–6.2.5.

6.2 THE USE OF MULTIPLE REPRESENTATIONS IN ARCHIMEDES' PRINCIPLE

6.2.1 Lesson Plan Developed Using the MR Instructional Approach in Archimedes' Principle

Multiple Representations (MRs) are different forms of representations used for instructional purposes for each of the four concepts of fluid mechanics. Using the MRs approach, the researchers created a variety of learning environments in the classroom.

The students' conceptual difficulties associated with the understanding of fluid mechanics were identified and discussed in Sections 5.2 5.4, 5.6 and 5.8. The MR is an educational intervention designed to alleviate students' conceptual challenges in fluid mechanics. It was designed based on the findings of the investigation in Phase 1 and the categorisation of students' conceptual difficulties.

Various forms of representation were selected and used to address the students' conceptual difficulties and enhance their conceptual understanding of fluid mechanics. These were verbal, textual, symbolic, and numeric. Each topic of fluid mechanics was displayed and presented through MRs. In the lesson plan, the tasks that were completed in the classroom were described (see Table 6.1). The researcher created and facilitated the educational activities. While determining the appropriate forms of representation, the content and structure of fluid mechanics in Ethiopia's undergraduate Physics curriculum (see Section 1.2) were analysed and considered. These forms of representation, the interactive learning tutorial activities associated with them, and the use of each representation in facilitating students' conceptual understanding are presented in Table 6.1. The text picture diagram and equation referred to in the table are shown next to Table 6.1. Appendix J provides the teaching lesson plans for the remaining three concepts.

The teacher's role in this regard is to assist the students in understanding and using the learning objectives of the fluid mechanics' lesson. According to Bussey et al. (2013), the desired learning objects depend on the knowledge and experience of the teacher. Likewise, MR-based instruction was developed to meet the learning objectives. The researcher assisted students in understanding fluid mechanics topics by selecting, organising, and presenting various types of representations.

In the following table (see Table 6.1) the Archimedes' principle (buoyancy force) in fluids is explained using MR instruction. The learning goals were taken from the curriculum of the university.

Table 6.1: The Archimedes' principle (buoyancy force) in fluids is explained using MR instruction

<table>
<tr><td colspan="3">Lesson 1 lasts 1 hour.
Learning goals
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.</td></tr>
<tr><td>Duration in minutes</td><td>Phases</td><td>MR representations:</td></tr>
<tr><td></td><td></td><td>Use (text, pictures, diagrams, and symbolic or mathematical formulae) and textbook (Serway & Jewett, 2004), p. 395- 399.</td></tr>
<tr><td>5'</td><td>Introduction</td><td>Introduce:
• The Archimedes' principle
• Buoyancy
• The Interaction between molecules in pressure and Archimedes' principles</td></tr>
<tr><td>35'</td><td>Presentation</td><td>Present:
• The Statement of Archimedes' Principle;
• Describe the interaction between pressure and buoyancy;
• Demonstrate Archimedes' principle by using a block of wood immersed in a fluid. Therefore, showing them how the block and the fluid interact and the pressure difference between the block and the fluid (see Figure 6.1);
• Explain this in terms of Buoyancy force equals up trust pressure by using the picture;
• Evaluate the relationships and the ratio of their density and volume change by using mathematical equations and formulae.</td></tr>
<tr><td>5'</td><td>Summarisation</td><td>Summarise pressure and the relationship between pressure and Archimedes' principle.</td></tr>
<tr><td>15'</td><td>Evaluation</td><td>• 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 I read the spring balance?
• The students will now work in their workbooks to complete the activity in their workbooks individually.
• Picture 1 (Figure 6.1). This shows the relationship between pressure and Archimedes' principle.
• Picture 2 (Figure 6.1) 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 teacher will give them corrections for their responses so that they get the correct answer.</td></tr>
</table>

6.2.1.1. The use of textual in MR representations

The researcher used a verbal-text representation to describe Archimedes' principle of fluid mechanics. The lesson presented Archimedes' principle: the interaction between pressure and buoyancy. When the fluid mechanics' concepts were presented in text form, students were given the opportunity to understand the concept.

They used a verbal-linguistic form of representation to help them share various ways of conceptual understanding with one another via a verbal discussion of the questions given in the activity. This was aimed at helping students improve their conceptual grasp of fluid mechanics through critical thinking and discussion during the discussions.

6.2.1.2. The use of pictures in MR representations

Pictures were used to illustrate how objects are completely submerged in a fluid. In accordance with Archimedes' principle, buoyancy, pressure interaction, and buoyancy force equal trust pressure were illustrated. Students could then depict the transformation by sketching objects submerged in a fluid. The illustration in Figure 6.1 depicts the submerging of the object in a fluid and the pressure acting on an object (Archimedes' principle). This allowed students to predict and discuss Archimedes' concept of buoyancy.

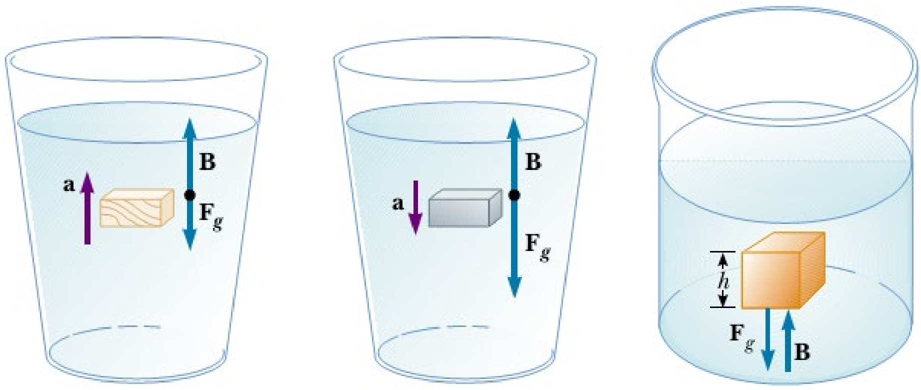

Figure 6.1: The submerging of the object in a fluid

Source: (Jewett & Serway, 2008, p. 397).

A diagram or pictures were used to demonstrate Archimedes' principle (buoyancy) as well as the interaction of pressure and buoyancy force. For example, the researcher used the diagram below, in which a piece of wood is suspended from a thread and subsequently submerged in water. The diagram presented here was displayed by a projector using PowerPoint, and the lecturer explained what was happening. Students were shown the picture in Figure 6.2 to discuss Archimedes' principle and to help them gain a better understanding of Archimedes' principle of fluid mechanics.

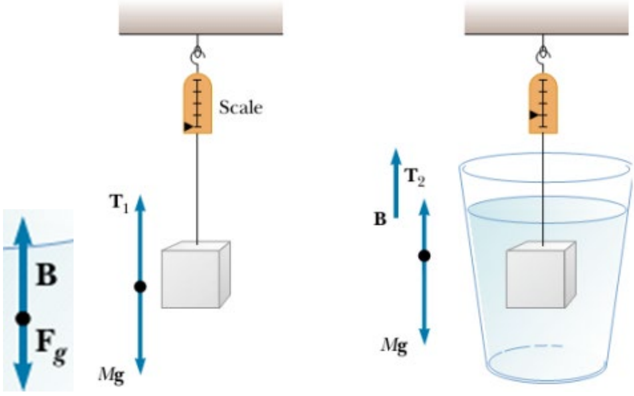

Figure 6.2: The interaction between buoyancy and pressure - the Archimedes' principle

Source: (Jewett & Serway, 2008, p. 397).

6.2.1.3 The use of mathematical equations in MR representations

Symbols and numeric representations were used to describe the ratio between density and volume in the Archimedes' principle. With equations, students can understand relationships and draw graphs. Examples include scientific equations to help them understand the relationship between the density and volume of fluid. Equation 6.1 was shown to students to help them understand relationships and ratios between physical quantities such as density and volume change.

$$\frac{\rho_o}{\rho_f} = \frac{V_f}{V_o} \qquad 6.1$$

6.2.1.4 The use of interactive simulations in MR representations

The process was set out as follows: set P constant, open the top T, and let V both decrease. Set V constant, push on the pump to add molecules, and P and T both increase. The researcher tried to simulate this by having a V constant, and the researcher added molecules to make the pressure about 2.3 and adjusted the temperature to 275. Then the researcher changed T from 275 to 300. The researcher made the pressure change very little, so the students would be led to decide that there had been a leak (30+14.7=45 (3 ATM)). The students then worked in their workbooks to complete the activity.

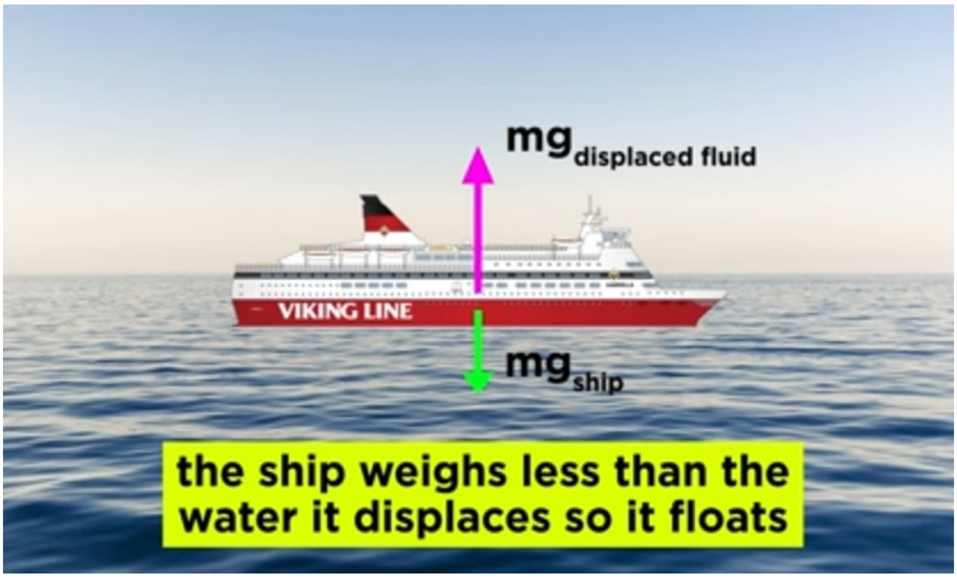

Figure 6.3: The interaction between pressure in buoyance force and weight

(Source: https://www.youtube.com/watch?v=16HDJNoXQII&t=138s)

6.3 THE USE OF THE TRADITIONAL LECTURE INSTRUCTIONAL APPROACH IN ARCHIMEDES' PRINCIPLE

6.3.1 Lesson Plan Using the Traditional Lecture Instructional Approach

The second group of students received traditional instruction. This time was allocated to two weeks based on the course plan stated in Table 6.2. These students received traditional instruction for two weeks at the same time as the first group. By its nature, the traditional instruction system minimises the benefits of an interactive learning environment where the educator guides the students as they apply concepts and where students also engage creatively in the subject. This method of teaching is commonly used in classrooms with large numbers of students. Chalk and talk are normally used for this method (Chen & Gladding, 2014).

Although it has been found that lecturing traditionally does not generally help students figure out fluid mechanics concepts and hinders their ability to solve problems (Chen & Gladding, 2014; Euler & Gregorcic, 2018), the traditional lecture method is still used by a majority of university instructors.

Table 6.2: The lesson plan for the traditional lecture approach on Archimedes' principle (buoyancy force) in fluids

Lesson 1: 1 hrs. Learning goals Students will be able to: • **Describe Archimedes' principle;** • **Explain Buoyancy force;** • **Describe the interaction between pressure, and Archimedes' principle (buoyancy force);** • **Know about physical quantities such as pressure P, volume V, and force F.**		
Duration in minutes	Phases	Traditional representation:
		Use text, pictures, diagrams, and symbolic or mathematical formulas and a textbook (Serway & Jewett, 2004, p. 420).
5'	Introduction	Introduce • Archimedes' principle; • Buoyancy; • Interaction between pressure, and Archimedes' principle.
35'	Presentation	Present: • Archimedes' principle; by talking and writing on the blackboard • Interaction between pressure, and Archimedes' principle.
5'	Summarisation	Summarise: • Pressure • Relationship between pressure and Archimedes' principle.
15'	Evaluation	Classwork was given and students reflected individually A piece of wood 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 on reading spring balance?

In this context, the teaching-learning process is centred on the students. They decide what to learn and how to select and organise content and materials; how to integrate fluid mechanics with other disciplines; how to manipulate computational aspects of the course; how to solve problems; conduct class activities, and manage activities to finally achieve the end with little intervention from the subject teacher. However, the method is less likely to solve more complex ideas and concepts that need demonstration, explanation, and guidance by the subject teacher (Shaheen, 2015).

Mohammad et al. (2012) suggest that the traditional method is a weak method for teaching fluid mechanics principles because it does not offer students many opportunities to put into practice what they are learning. Moreover, it does not give students an idea of how they are learning or how they can improve their performance. A traditional method is a top-down approach. As a result, students are not involved in the teaching-learning process.

The traditional method does not take into account some pertinent factors that have an impact on the process of teaching fluid mechanics. These include teaching materials, teaching methods, homework, timetable, classroom activities, students' intelligence, students' motivation, and teachers' perceptions of students' understanding and experience. Thus, to teach fluid mechanics efficiently, it is essential to use a teaching-learning approach that will facilitate students' active participation, responsiveness, innovation, creativity, and respect for the teacher.

However, the MR considers teaching materials, teaching methods, homework, timetable, classroom activities, students' intelligence, students' motivation, and teachers' perceptions of students' understanding and experience. Therefore, in using MR, the lecturer plays a major role in compiling and presenting the course as he is the manager of the learning process and developer of a combination of suitable materials.

6.4 THE EFFECTS OF MR INSTRUCTIONAL APPROACH ON ARCHIMEDES' PRINCIPLE

The students' conceptual difficulties associated with understanding fluid mechanics were identified and discussed in Section 5.2. The difficulty in conceptualising fluid mechanics was addressed through the selection of appropriate representations. It is composed of text, pictures, diagrams, and numerical and equation representations.

These forms of representation, the interactive learning tutorial activities associated with them, and the use of each representation in facilitating students' conceptual understanding are presented in Tables 6.1 and 6.2. After the intervention, students in both groups (experimental and control) were asked to complete the OEQ. The results of the post-intervention OEQ are presented in Table 6.3.

6.4.1 Results of OEQ After First Intervention on Archimedes' Principle

Table 6.3: Categories of students' responses on OEQ in buoyancy force

Name of the Category	Descriptions of the categories	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The Buoyancy force equals up trust pressure is the Pressure that implies internal forces; • The volume of an object is equal to the volume of displaced water.	20	62.50%	15	46.87%

Name of the Category	Descriptions of the categories	Experimental group		Control group	
		N=32	In %	N=32	In %
Alternative conception model (M2)	• Boundary pressure equals buoyancy force. • The buoyancy force is a natural force that exists within the body. • The buoyancy force is volume.	6	18.75%	8	25%
Null conception model (M3)	• The buoyancy force equals the volume of an object. • An object's buoyancy force is equal to its mass. • The buoyancy force of an object equals its weight.	6	18.75%	9	28.13%

As can be seen in Table 6.3, the OEQ was completed by 64 undergraduate students and their responses were analysed qualitatively by using the content data analysis method (see Section 4.8.2). Students' conceptual understanding was explored and categorised using qualitative data analysis procedures described in Section 4.8.1. As a result, students' conceptions were categorised into three basic categories – M1, M2, and M3.

Table 6.3 shows the comparison of the students' OEQ mean scores between the experimental and control groups in the three conception models after the intervention. In the experimental group, there was a 15.63% difference in students' correct answers (M1) compared to the control group. This result showed a difference from the result of the pre-test (see Section 5.2.1). Regarding the result of M2, the control group exceeds the experimental group by 6.87%. This result showed a difference from the result of the pre-test (see Section 5.2.1). Furthermore, the scores in M3, the control group, exceeded the experimental group by 9.38%, and there was a difference with the result of the pre-test (see Section 5.2.1).

The literature shows that the study discovered that many students were confused regarding pressure and Archimedes' concepts, as well as the critical function of displaced volume in determining the buoyant force. Even after instruction was made, undergraduate students had diverse notions of buoyant force, according to studies in the literature (Faour & Ayoubi, 2018; Raissi, Yazdani & Karniadakis, 2020).

6.4.2 Results of FMCI After the Intervention on the Archimedes' Principle

Having completed the experimental and control groups' post-tests using OEQ, the researcher conducted the FMCI post-test. As before, Archimedes' principle was discussed (buoyancy force). For the items of the Iteration, the researcher used the FMCI for Archimedes' principle.

Table 6.4a: Results of responses to each conception model in the experimental group and the control group.

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.60	0.48
Alternative conception model (M2)	0.22	0.30
Null conception model (M3)	0.18	0.21

Table 6.4a presents the difference in mean results between experimental and control groups regarding Archimedes' principle (buoyancy force) after the intervention. There was a difference of 12% in students' correct answers (M1) in the experimental group compared to the control group. Furthermore, there was a decrease in the experimental groups (M2 and M3) compared to the control group by 8% and 3%, respectively.

Table 6.4b: A comparison of the students' results based on the FMCI post-test results in Iteration I

		Paired differences				**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. error mean**	**95% confidence interval of the difference**				
				Lower	**Upper**			
Pair I	M1	.07813	.05434	-.03271	.18896	1.438	31	.161
Pair II	M2	-.09375	.05471	-.20532	.01782	-1.714	31	.097
Pair III	M3	.01563	.02735	-.04016	.07141	.571	31	.572

Table 6.4b shows the distributions of paired-sample t-test results for the responses in the experimental and control groups for the items of FMCI for Archimedes' principle (buoyancy force) in the post-test (Iteration I). Regarding the similarity of experimental and control group results in Table 6.4a, the paired-sample t-tests are shown in Table 6.4b between the experimental and control groups (M1, M2, and M3) are compared. Results indicated that M1 was statistically significantly different with t (31) = 1.43, p-value 0.161 at the 95% confidence interval of the difference. Thus, the result was not statistically significant.

After Intervention I, the MR approach failed to show an absolute difference between the experimental and control groups. However, there has been a change brought on by the groups' understanding of fluid mechanics concepts. Furthermore, the results for the M2 and M3 groups were not statistically significant. At the 95% confidence interval of the difference, the results were $p > 0.005$ (two-tailed); $t = 1.71$, p-value 0.097, which is $p > 0.005$ (two-tailed); and t value was -0.57, p-value 0.572, which is $p > 0.005$ (two-tailed). This result was similar to the result in Chapter 5 (see Section 5.2.2).

Moreover, regarding the effect size, the results of ANCOVA were given on Archimedes' Principle in the next Section (see Section 6.3.2).

6.4.3 Results of ANCOVA on FMCI in Iteration I on the Archimedes' Principle

The FMCI post-test scores were analysed using a one-way between-groups ANCOVA, with pre-test scores as a covariate to determine if there were any significant differences between the two groups (experimental and control). A study was conducted to determine whether the first intervention (with MR) changed students' alternative perceptions of Archimedes' principle (buoyancy force) in fluid mechanics. The FMCI scores from both groups (64 students) were analysed. In addition to the descriptive statistics and the measure of the reliability of the covariate, the researcher also applied Levene's test of equality of error variances to the results of the ANCOVA.

It is necessary to satisfy three conditions for ANCOVA to be used (descriptive statistics, measurement of the reliability of the covariate, and Levene's test of equality of error variances). The first condition for using ANCOVA is that the covariate is measured before the intervention or experimental manipulation (Pallant, 2007). This was done to minimise bias between the scores of the pre-test (the covariate) and the scores of the post-test (the dependent variable). Table 6.5 shows the distributions of mean percentages and standard deviations (descriptive statistics) of students' scores in the experimental and control groups for the items on the FMCI for the Archimedes' principle (buoyancy force) in Iteration I.

Table 6.5: Students' scores for the Archimedes' principle

Dependent variable: FMCI post-test in Ex and Co Group			
Group	**Mean**	**Std. deviation**	**N**
E	.5703	.14528	32
C	.4922	.23318	32
Total	.5312	.19670	64

In this study, the researcher used a quasi-experimental design to test the key assumptions for the use of one-way ANCOVA. ANCOVA can be used when measuring covariates before experimental manipulation or intervention (Pallant, 2007). The researcher did this to reduce the interaction effect between the covariate (pre-test score) and the dependent variable (post-test score).

As a second condition for using ANCOVA, the correlation between the covariates needs to be measured. Consequently, the FMCI pre-test was estimated using Kuder Richardson-21 (KR-21 = 0.854), which showed an acceptable result for both individual and group testing (see Section 4.5.4).

The third prerequisite for ANCOVA was checking to see if the error variances were equal (Pallant, 2007). This condition was checked, and the significance value of 0.992 was greater than 0.05, which indicated that the assumption of equal variances was not violated (see Table 6.6). Therefore, the homogeneity of error variances was not violated since the variability of scores was the same for each group.

Table 6.6: Distributions of the Levine's test of equality of error variances

Dependent variable: FMCI post-test in Ex and Co Group			
F	**df1**	**df2**	**Sig.**
.050	1	62	.824
a. Design: Intercept + pre + group			

As shown in Table 6.6: Distributions of the Levine's test of equality of error variances of students' scores in the experimental and control groups for the items of FMCI for Archimedes' principle (buoyancy force) in Iteration I.

The independent variable was the type of intervention (MR) and the dependent variable was the students' scores on the post-FMCI test. The student's scores on the pre-FMCI test were used as the covariate in this analysis.

Table 6.7: Distributions of ANCOVA results

Dependent variable: FMCI post-test in Ex and Co Group						
Source	**Type III sum of squares**	**df**	**Mean square**	**F**	**Sig.**	**Partial eta squared**
Corrected model	1929.388[a]	2	964.794	13.995	.000	.315
Intercept	2306.333	1	2306.333	33.359	.000	.354
Pre-test	1748.822	1	1748.822	25.371	.027	.294
Group	374.902	1	374.902	5.439	.023	.082

Error	4204.774	61	68.929			
Total	219347.125	64				
Corrected total	6134.062	63				
a. R squared =.315 (adjusted R squared =.292)						

Table 6.7 shows the distributions of the effect sizes of students' scores (see Section 4.6.3) in the experimental and control groups for the items of FMCI for the Archimedes' principle (buoyancy force) in the first intervention.

As shown by the ANCOVA, there was no significant difference between the intervention group (MR) and control group (TL) on the result, (1, 63) = 2.94, p = 0.027 (Table 6.7). Although the MR approach contributed somewhat to addressing students' alternative conceptions compared to the control group, i.e., there was a slight shift towards M1 away from M2 and M3, the effect size did not help to determine its effectiveness.

The literature shows that, before the MRs intervention, students had difficulty understanding Archimedes' principal concepts. To address these challenges, the MR instructional approach was implemented, and the results showed that students can overcome their conceptual misunderstanding by using a combination of representations such as text, pictures, and simulations (Koes, Muhardjito & Wijaya, 2018). Students find it difficult to meaningfully connect different representational forms in a given task or problem and to extract the intended conceptual understanding (Volkwyn et al., 2019). For that reason, it does not come as a surprise that studies show that an MR teaching approach helps students learn Physics more effectively (Brahmia et al., 2020; Saleh, 2014). It is thus important to use a diversity of tools, such as text, formulae, calculations, illustrations, and interactive learning techniques that can create a better understanding for students.

Similarly, a test conducted as part of an effort to design a diagnostic exam that can assess undergraduate students' fluid mechanics demonstrated that changing workshop activities has a favourable impact on student performance (Wagner, Cohen & Moyer, 2009).

Moreover, this difficulty in understanding Archimedes' principles was not only found at the undergraduate level but also the high school level. The results of undergraduate students' conception of Archimedes' principle (buoyancy force) after the first intervention were discussed in Section 6.2.

A study to test the effectiveness of the conceptual problem-solving (CPS) learning approach, which involved 35 11th-grade students in a school Science programme, concluded that the 5E learning cycle (i.e., engage, explore, explain, elaborate, and evaluate) can assist students in understanding the Archimedes' principle (Diyana, Sutopo & Haryoto, 2020). A sample of 153 thirteen-year-old students from Serbia was also used in a study to investigate the effects of standard teaching and an active learning approach on students' notions of floating and sinking. It was evident that significantly higher achievement levels were obtained when using a modern constructivist approach to teaching (Radovanovi, 2019).

6.5 THE EFFECTS OF MR INSTRUCTIONAL APPROACH ON PASCAL'S PRINCIPLE

Undergraduate Physics students were surveyed regarding their understanding of Pascal's principle (pressure measurement), part of fluid mechanics in OEQ and FMCI. These results are summarised in Table 6.8. A lesson on each of the topics was conducted with an experimental group MR using four different representations (see Lesson 1 in the main part of the thesis (Section 6.3); Lessons 2, 3, and 4 are provided in Appendix J). After the lessons on each of the topics, both groups were asked to complete the OEQ and FMCI assessments to demonstrate their understanding.

In the control group, the course was conducted using the traditional method of lecturing. The results are presented in Tables 6.8, 6.9a, 6.9b, and 6.9c.

6.5.1 Results of OEQ After First Intervention on Pascal's Principle

Table 6.8 Distributions of the comparison results of students' responses of OEQ post-test in Pascal's principle

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The pressure in a liquid increases with depth. • The atmospheric pressure decreases with increasing altitude. • The pressure is the same at all points having the same depth, independent of the shape of the container. • The density of a substance is mass per unit volume.	17	53.12%	15	46.87%

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
	• Densities of substances depend on temperature.				
Alternative conception model (M2)	• Water pressure decreases with depth. • The atmospheric pressure is independent of the altitude. • Sometimes the pressure P at a depth h below a point in the liquid is greater by a certain amount of ρgh.	7	21.87%	10	31.25%
Null conception model (M3)	• At 0° C the densities of gases are equal to the densities of solids and liquids. • Atmospheric pressure is dependent on density.	8	25%	7	21.75%

As can be seen in Table 6.8, which shows the distribution of the comparison results of the students' responses to the OEQ post-test in Pascal's principle, there was a difference of 6.25% in students' correct answers (M1) in the experimental group compared to the control group. This shows there was an increase in both groups in M1 compared to the pre-test (see Section 5.4.1).

Regarding the alternative conception model (M2) result, the control group result exceeds the experimental group by 8.38%. Furthermore, in the Null conception model (M3), the result of the students' control group experiment exceeds the experimental group by 3.25%. There was a decrease in both groups in M2 and M3 compared to the pre-test (see Section 5.4.1).

6.5.2 Results of FMCI After First Intervention on Pascal's Principle

Table 6.9a: Distributions of the results for the post-test items on the FMCI for Pascal's principle

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.59	0.48
Alternative conception model (M2)	0.23	0.32
Null conception model (M3)	0.18	0.20

Table 6.9a presents the distribution of the results for M1, M2, and M3 for the items in the FMCI on Pascal's principle in Iteration I. When comparing the results in M1 of the experimental and control groups, the difference was 11%. In the M2 group, the difference was 09% in the experimental and control groups, respectively. In the M3, the difference was only 02%.

Table 6.9b: FMCI post-test paired-samples t-test results on Pascal's principle

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair I	M1	.11188	.19729	.03488	-.13080	.03705	-1.139	31	.263
Pair II	M2	-.09229	.15761	.02786	-.14912	-.03547	-3.212	31	.002
Pair III	M3	-.01906	.18814	.03326	-.08689	.04877	-.573	31	.571

In addition, Table 6.9b shows the distributions of paired-sample t-test results for the responses in the experimental and control groups for the items of FMCI for Pascal's principles in the post-test (Iteration I). The results indicated that M1 was not statistically significantly different with t (31) = 1.13, p-value 0.263 at the 95% confidence interval of the difference. Thus, the result was not statistically significant. After intervention I, the MR approach failed to show an absolute difference between the experimental and control groups. However, there has been a change brought on by the groups' understanding of fluid mechanics concepts. Furthermore, the results for the M2 groups were statistically significant. Results were $p > 0.005$ (two-tailed); t = -3.21, p-value 0.02, which is $p > 0.005$ (two-tailed). Besides, the M3 groups were not statistically significant. t value was -0.57, p-value 0.571, which is $p > 0.005$ (two-tailed) at a 95% confidence interval of the difference. This result was similar to the result in Chapter 5 (see Section 5.2.2).

Table 6.9c: FMCI ANCOVA results on Pascal principle

Dependent Variable: P POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.255a	2	.128	4.790	.013	.133
Intercept	3.075	1	3.075	112.932	.000	.649
PPREFMCI	.055	1	.055	2.025	.160	.032
GROUP	.183	1	.183	6.703	.012	.099
Error	1.661	61	.027			
Total	20.149	64				
Corrected Total	1.916	63				
a. R Squared =.133 (Adjusted R Squared =.105)						

Regarding the effect size, the results of ANCOVA were given on Pascal's Principle in Table 6.9c. As shown by the ANCOVA, there was no significant difference between the intervention group (MR) and control group (TL) on the result, (1, 63) = 0.032, p = 0.160 (Table 6.9c). Although the MR approach contributed somewhat to addressing students' alternative conceptions compared to the control group, i.e., there was a slight shift towards M1 away from M2 and M3, the effect size did not help to determine its effectiveness.

Studies show that it is important for undergraduates to be taught in a variety of ways (Kohl & Finkelstein, 2006; Volkwyn et al., 2020), as it can improve their comprehension skills (Bakó-Biró et al., 2012). Therefore, since students prefer a variety of representations, researchers in the field of fluid mechanics agree that teaching using MR methods could make a difference (Minichiello, et al., 2020; Hartini, et al., 2020). In addition, studies in the field have shown that Physics students are more successful in problem-solving when using MR principles (Gestson et al., 2018), as their ways of understanding may differ because of the different ways they might approach a problem (Bako, 2012; de Cock, 2012; Fredlund et al., 2015). Therefore, it is a good idea to use all kinds of representations to engage students. In addition, this allows students to be more successful in understanding basic Physics using MRs (Abdurrahman, et al., 2019). Another advantage of using MRs is that students can easily understand a variety of designs, such as formulae, calculations, diagrams, and abstract concepts (Lin, 2014).

6.6 THE EFFECTS OF MR INSTRUCTIONAL APPROACH ON FLUID FLOW

6.6.1 Results of FMCI After First Intervention on Fluid Flow

Table 6.10: Distributions of the results on fluid flow in Iteration I

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The equation of continuity for fluids states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid. • The product Av, which has the dimensions of volume per unit time, is called either the volume flux or the flow rate. • In steady flow, every fluid particle arriving at a given point in space has the same velocity. • The condition Av constant is equivalent to the statement that the volume of fluid that		52%		42%

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
	enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval if no leaks are present.				
Alternative conception model (M2)	• According to the equation of continuity for fluids, the product of area and volume is always constant. • The product Av, is area times velocity; • In steady flow, the area and velocity are constant; • The condition Av constant is equivalent to the statement that the area and volume of fluid that enters one end of a tube in a given time interval equal the volume leaving the other end of the tube in the same time interval.		30%		37%
Null conception model (M3)	• According to the equation of continuity for fluids, the product of pressure and temperature is always constant. • The product Av, is fluid static; • In steady flow, the tube is similar; • The condition Av constant is fluid always passes in a tube.		18%		21%

When comparing the post-intervention results of the OEQ in the experimental and control groups, the difference was 10%. This is not a noteworthy difference. In the M2 group, the difference in OEQ was 17% in the experimental and control groups respectively. In the M3 group, the difference was 02%.

6.6.2 Results of FMCI After First Intervention on Fluid Flow

Table 6.11a: FMCI post-test results on fluid flow

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.65	0.48
Alternative conception model (M2)	0.17	0.26
Null conception model (M3)	0.18	0.26

Table 6.11a presents the distribution of the post-test results for M1, M2 and M3 for Pascal's principle in Iteration I. When comparing the results in M1 of the experimental and control groups, the experimental group exceeded the control group by 17%. In the M2, the control group lagged behind the experimental group by 09%. Whereas in the M3, the experimental group lagged the control group by 08%.

Table 6.11b: FMCI post-test-I paired-samples t-test results on fluid flow

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.10937	.22911	.04050	.02677	.19198	2.701	31	.011
Pair II	M2	-.08750	.18622	.03292	-.15464	-.02036	-2.658	31	.012
Pair III	M3	-.02188	.13616	.02407	-.07096	.02721	-.909	31	.370

In addition, Table 6.11b shows the distributions of paired-sample t-test results for the responses in the experimental and control groups for the items of FMCI for Pascal's principles in the post-test.

Results indicated that M1 was not statistically significantly different with t (31) = 2.70, p-value 0.011 at the 95% confidence interval of the difference. Thus, the result was not statistically significant. After intervention, the MR approach failed to show an absolute difference between the experimental and control groups. However, there has been a change brought about in the groups' understanding of fluid flow concepts. Furthermore, the results for the M2 groups were statistically significant. Results were $p > 0.005$ (two-tailed); t = -2.65, p-value 0.012, which is $p > 0.005$ (two-tailed). Besides, the M3 groups were not statistically significant. At a 95% confidence interval of the difference, the t value was -0.57 and the p-value was -0.909, indicating that $p > 0.370$ (two-tailed). This result was similar to the result in Chapter 5 (see Section 5.3.2).

Table 6.11c: FMCI ANCOVA results on fluid flow

Dependent Variable: F POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.647a	2	.324	18.801	.000	.381
Intercept	1.600	1	1.600	92.943	.000	.604
FPREFMCI	.007	1	.007	.426	.516	.007
GROUP	.600	1	.600	34.927	.000	.363
Error	1.050	61	.017			
Total	18.920	64				
Corrected Total	1.698	63				
a. R Squared =.381 (Adjusted R Squared =.361)						

Moreover, regarding the effect size, the results of ANCOVA were given on the fluid flow in Table 6.11c. As shown by the ANCOVA, there was a significant difference between the intervention group (MR) and control group (TL) on the result, (1, 63) = 0.363, p = 0.000 (Table 6.11c). Although the MR approach contributed somewhat to addressing students' alternative conceptions compared to the control group, i.e., there was a moderate shift towards M1 away from M2 and M3, the effect size did not help to determine its effectiveness.

Representing difficulties in several ways helps students to increase their chances of solving equations by combining quality and numerical expressions that give students a deeper understanding of pressure and frequency (Barton & Heidema, 2002; de Cock, 2012). It can produce better results by teaching Physics better in many representations (Barton & Heidema, 2002; Linder, 2013). Using a variety of representations could assist the student in developing an understanding by choosing different representations of the same concept (Gooding, 2004; Kohl & Finkelstein, 2005a; Kozma & Russell, 2005). Algebraic representations are difficult to analyse and find it challenging to solve real problems (Duffen et al., 2007; Martnez & Rebello, 2012; Kohl & Finkelstein, 2005a; Christensen & Thompson, 2012). A study examining the effectiveness of students' use of different types of representations shows that this improves their ability to easily solve complex Physics questions (Franke et al., 2019).

However, using MRs is difficult and expensive, while having a variety of representations to explain one concept is time-consuming and needs technological advancements to be implemented in a class (Dufer et al., 2007; Martnez & Rebello, 2012). Therefore, it may not be effective for all subjects. Furthermore, it requires money, time, energy and Technology (Bakó-Biró et al., 2012). Another obstacle to using this method is that students do not understand MRs in advance. In addition, students have ambiguities while using MRs simultaneously (Kohl & Finkelstein, 2006).

6.7 THE EFFECTS OF MR INSTRUCTIONAL APPROACH ON BERNOULLI'S PRINCIPLE

6.7.1 Results of OEQ's First Intervention on Bernoulli Principle

Table 6.12: Distributions of the comparison results of students' responses of OEQ pre-test in the Bernoulli principle

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The relationship between fluid speed, pressure, and elevation is the Bernoulli principle. • Bernoulli's equation shows that the pressure of a fluid decreases as the speed of the fluid increases. • The pressure decreases as the elevation increases. • The general behaviour of pressure with speed is true even for gases: as the speed increases, the pressure decreases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases.		62%		48%
Alternative conception model (M2)	• As a fluid moves through a region where its speed or elevation above the Earth's surface changes, the pressure in the fluid is constant. • Bernoulli's equation shows that the pressure of a fluid increases as the speed of the fluid increases. • The pressure increases as the elevation increases. • According to the Bernoulli Effect, this higher-speed air exerts high pressure on a car than the slower-moving air on the other side of your car.		23%		30%
Null conception model (M3)	• Bernoulli's equation shows that as pressure increases the speed of the fluid increases • The pressure did not depend on the elevation • No answer • Silence		15%		22%

In the M1 in the OEQ, the experimental group exceeded the control group by 14%. In M2 when comparing the post-intervention results of the OEQ in the experimental and control groups, the difference was 07%. This is not a noteworthy difference. In the M3 group, the difference between the experimental and control groups, the difference was 07%.

6.7.2 Results of FMCI After First Intervention on Bernoulli's Principle

Table 6.13a: Distributions of the results of Bernoulli's principle in Iteration I

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)

Correct conception model (M1)	0.61	0.49
Alternative conception model (M2)	0.21	0.30
Null conception model (M3)	0.18	0.21

As can be seen in Table 6.13a, when comparing the results of the FMCI in experimental and control groups, the experimental group exceeded the control group by 12% regarding the M1 category. In the M2 category, the control group exceeds the experimental group by 09%. Whereas in the M3 category, the control group exceeds the experimental group by 03%.

Table 6.13b: FMCI post-test-I paired-samples t-test result on Bernoulli's principle

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.12010	.22321	.03946	.03963	.20058	3.044	31	.006
Pair II	M2	-.08365	.18315	.03238	-.14968	-.01761	-2.584	31	.015
Pair III	M3	-.03687	.22585	.03993	-.11830	.04455	-.924	31	.363

As can be seen in Table 6.13b, the similarity of the post-test result on Bernoulli's principle concept of the groups was determined by using a paired-sample t-test. Results indicated that M1 was not statistically significantly different with t (31) = 3.04, p-value 0.006 at the 95% confidence interval of the difference. Thus, the result was not statistically significant. After Intervention I, the MR approach failed to show an absolute difference between the experimental and control groups. However, there has been a change brought about by the groups' understanding of Bernoulli's principle concepts. Furthermore, the results for the M2 groups are not statistically significant. Results were p > 0.005 (two-tailed); t = -2.54, p-value 0.015, which is p > 0.005 (two-tailed). Besides, the M3 groups were not statistically significant. t value was -9.92, p-value 0.363, which is p > 0.005 (two-tailed) at a 95% confidence interval of the difference. This result was similar to the result in Chapter 5 (see Section 5.4.2).

Table 6.13c: FMCI ANCOVA results on Bernoulli's principle

Dependent Variable: B POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.326a	2	.163	7.392	.001	.195

Intercept	3.053	1	3.053	138.284	.000	.694
BPREFMCI	.096	1	.096	4.330	.042	.066
GROUP	.196	1	.196	8.858	.004	.127
Error	1.347	61	.022			
Total	21.015	64				
Corrected Total	1.673	63				
a. R Squared =.195 (Adjusted R Squared =.169)						

Table 6.13c presents the FMCI ANCOVA results on the Bernoulli principle, moreover, regarding the effect size, the results of ANCOVA were given on Pascal's Principle in Table 6.14c. As shown in Table 6.13c, in the ANCOVA, there was no significant difference between the intervention group (MR) and control group (TL) on the result, (1, 63) = 0.127, p = 0.004 (Table 6.14c). Although the MR approach contributed somewhat to addressing students' alternative conceptions compared to the control group, i.e., there was no big shift towards M1 away from M2 and M3.

Developing concepts by using different representations improves students' understanding (Meltzer, 2008), as it assists students to organise their knowledge (Kohl & Finkelstein, 2005; 2006). It also helps the student develop a dynamic understanding of the concept (Martnez & Rebelo, 2012; Distrik, Supardi & Jatmiko, 2021). The MR approach is suitable for teaching Physics and covers topics ranging from geoPhysics to medicine (Wiyarsi et al., 2018). Moreover, findings from a material Science training study show teachers need to use a variety of examples in their teaching practices, such as drawings, descriptions, compositions, and numeracy, to improve students' problem-solving skills (Rice, Lowenthal & Woodley, 2020).

Researchers have indicated that combining numerical and written expressions using multiple representations enriches the experience and makes learning easier. For example, you can easily describe the concept of melting graphically, using a video or using mathematical equations (Frederick et al., 2015). In this way, students can analyse and understand concepts derived from Algebra and algebraic representations to help them answer various Physics questions efficiently. In many cultures, using MRs seems to be successful when solving Physics problems (West et al., 2013). Therefore, to learn, interpret, and build different physical and scientific knowledge structures, there must be a variety of representations in the Physics class. Building knowledge through MRs develops students' comprehension skills (Kohl, Rosengrant & Finkelstein, 2007).

6.8 STUDENTS' ATTITUDES TOWARDS MULTIPLE REPRESENTATIONS

Students were given the Students' Attitude towards Multiple Representation Questionnaire (SAMRQ) about their experience with the MR teaching approach that was used in the experimental group. This is the first iteration's outcome (see Table 6.14).

In this section the following research question was answered:

- What are students' attitudes toward multiple representation approaches in fluid mechanics concepts?

Table 6.14 shows the results of item analysis performed using SPSS for the multi-item scale of SAMRQ. According to the results of the first intervention, item mean, item variance correlations for the five items on the scale, and students have a positive view of the MR approach.

6.8.1 Students' Feelings Towards the MR Approach

Table 6.14: Distributions of the results of the statements of SAMRQ for the experimental group in the first intervention

No	Statements on feelings of MR approach	N	Mean	SD
1	Using multiple representations will help me to better understand	32	3.30	0.575
2	Using multiple representations requires a lot of mental effort	32	3.63	0.635
3	Using multiple representations will improve my problem-solving skills	32	3.76	0.675
4	Multiple representations encourage me to learn a fluid mechanics topic to the best of my ability	32	3.87	0.635
5	The MR approach will be difficult for me to master	32	3.98	0.671
	Grand Mean			

According to Table 6.14, Item 1, 'Using multiple representations will help me to better understand, had a mean score of 3.30 (SD = 0.575).

Students' opinions on Item 2, 'Using multiple representations does not require much mental effort', had a mean score of 3.63 and SD = 0.635.

As for Item 3, 'I believe that MR will improve my problem-solving skills, the mean score was 3.76, while the SD was 0.675. This shows that they believed that using MRs would not improve their problem-solving abilities.

Responses to Item 4, 'Multiple representations encourage me to learn a fluid mechanics topic to the best of my ability, had a mean score of 3.87 and a standard deviation of 0.635. These findings indicate that they believed that MRs would not be sufficient to motivate them to master a fluid mechanics topic'.

For Item 5, 'The MR approach will be difficult for me to master', the mean score was 3.98 and the standard deviation was 0.67. Their scores suggest they believed they would have trouble mastering the MR approach.

According to Table 6.14, the maximum mean score for the statements on students' feelings on the MR approach was Item 5, which is about 'The MR approach will be difficult for me to master'. The mean score was 3.98 and the standard deviation was 0.67, whereas the minimum result was Item 1, about 'Using multiple representations will help me to better understand', with a mean score of 3.30 (SD = 0.575). Thus, the grand mean is 3.899. The Likert scale results are 3.98, which is the closest to the 4-point scale. This implies that the respondents almost agreed to having good feelings towards the MR approach (Likert, 2009).

6.8.2 Motivation for Using Multiple Representations

For each section of the scale, Table 6.15 provides a summary statistic for the correlation between item mean and item variances. Using an MR approach in the first iteration was beneficial to students in the experimental group, according to the findings.

Table 6.15: Distributions of the results on the advantages of the MR strategy

	Advantages of a Multi-Representation Strategy	**N**	**Mean**	**SD**	**mean error**
1	Finding a solution is easier with multiple representations.	32	3.35	.966	.306
2	Multiple representations can increase my interaction with my environment.	32	3.30	.316	.100
3	Learning with MRs will provide me with better learning opportunities than traditional methods.	32	3.22	.830	.291
4	A lot of mental effort is required to use MRs on the computer system.	32	3.23	.471	.149
5	There are many challenges associated with using MR technologies.	32	3.60	.738	.233
6	I will be more efficient with the help of MR.	32	3.76	.422	.133
7	MR will allow me to accomplish more work than otherwise possible.	32	3.09	0.63	0.202

According to Table 6.15, Item 1, 'Finding a solution is easier with multiple representations', had a mean score of 3.35 and an SD of 0.966. As a result, students generally agreed with the statement. Multiple representations are a unique learning approach conducive to all students.

Concerning item 1, research indicates that MR approaches are multifaceted approaches in which students excel at using words, images, and Maths while another excels at only one (Sewell, 2002). According to Bakri and Mulyati (2018), MR is an appropriate teaching method through which students' instruction can be utilised on the design and teaching of basic Physics. This includes concept maps, videos, figures, data tables, charts of data tables, verbal explanations, equations, problems, and solution examples and exercises.

According to Table 6.15, Item 2, 'Multiple representations can increase my interaction with my environment, had a mean score of 3.30 and an SD of 0.316. Students generally agreed with the statement.

Table 6.15, Item 3, 'Learning with MRs will provide me with better learning opportunities than traditional methods, had a mean score of 3.22 and an SD of 0.830. Students generally agreed with the statement.

Item 4, 'A lot of mental effort is required to use MRs on the computer system', scored on average 3.23 out of a possible 5 points. The students agreed with the statement.

On Item 5, 'There are many challenges associated with using MR technologies', the mean was 3.60 and the SD was 0.738. In other words, students agreed with the statement.

For Item 6, 'I will be more efficient with the help of MR', the mean score was 3.76 and the standard deviation was 0.422, showing that students agreed with the statement.

Item 7, 'MR will allow me to achieve more work than would otherwise be possible', had a mean score of 3.09 and an SD of 0.47, indicating that students agreed with the statement.

6.8.3 Perceptions in Learning Through a Multiple Representation Approach

The results on the items for multi-representational learning as a desire to learn are presented in Table 6.16.

Table 6.16: Distributions of the results on multi-representational learning as a desire to learn

No.	Multi-representational learning as a desire to learn	N	Mean	SD	Mean error
1	Interacting with a variety of techniques, such as video, virtual labs, computer simulations, and so on, is often interesting.	32	2.40	.966	.306

2	Multiple representations are more engaging than traditional lecture methods.	32	3.10	.316	.100
3	I enjoy working with multiple representations.	32	3.20	.789	.291
4	Multiple representations are my favourite way to learn.	32	3.00	.556	.149
5	Multiple representations stimulate my interest in learning.	32	3.10	.738	.233
6	I am inspired to do my best in class by the MR approach.	32	3.20	.422	.133

Item 1, ‘Interacting with a variety of techniques, such as video, virtual labs, computer simulations, and so on, is often interesting’, had a mean score of 3.10 and an SD of 0.316, indicating that students generally agreed with the statement.

Item 2, ‘Multiple representations are more engaging than traditional lecture methods’, had an average score of 3.20 and an SD of 0.789’, indicating that students mostly agreed with the statement.

Item 3, ‘I enjoy working with multiple representations’, had a mean score of 3.20 with an SD of 0.789’, indicating that students mostly agreed with the statement.

Item 4, ‘Multiple representations are my favourite way to learn’; had a mean score of 3.00 and an SD of 0.556, indicating that students mostly agreed with the statement.

The mean score for Item 5, ‘Multiple representations stimulate my interest in learning’, was 3.10, and the standard deviation was 0.738. According to the results, students mainly agreed with the statement.

For Item 6, ‘I am inspired to do my best in class by the MR approach’, the mean score was 3.20 and the SD was 0.422, indicating that students generally agreed with the statement.

Before the first intervention, both groups (experimental and control) were at the same level (Section 5.2 to 5.5). This first intervention (using an MR approach in the experimental group, which included text, pictures, diagrams, and mathematical equations) was a teaching approach to enhance students’ understanding (Einsworth, 2006; Kohl & Finkelstein, 2005b, 2006; Tytler & Prain, 2013). There was a difference between the control and experimental groups after the intervention. The researcher found that using MR assisted students in moving from M2 to M1, and from M3 to M2 (Section 6.2 to 6.5). This shows that if we add some representation and use of MR, it can enhance undergraduate students’ understanding of fluid mechanics.

When these results are compared with the control group, the results indicate that even though the students moved from M2 to M1, some of them still had difficulties in understanding the concepts. According to a study by Martnez (2012), many first-year Physics students were unable to explain the buoyancy force that equals trust pressure and Archimedes’ principle. Similar results were found by Raissi et al. (2020).

Despite some minor differences between the experimental and control groups, these differences are not statistically significant.

Therefore, it is necessary to find an alternative to see if there is a significant difference between the experimental and control groups. Accordingly, a further review of the literature found that the use of reconstructed MR (e.g., text, diagrams, illustrations, graphs, maths equations, and simulations) could simplify the study of fluid mechanics (Hwang & Hu, 2013; Distrik, Supardi & Jatmiko, 2021; Moseley & Brenner, 1997; Uslima, Ertikanto & Rosidin, 2018). Therefore, it was decided to repeat the entire process but add another 4 MR (namely: video, animation, virtual lab, and simulations).

6.9 CHAPTER SUMMARY

In the second phase of the study, a MRs-based approach was planned and designed to enhance the students’ conceptual understanding. This instructional intervention was developed and designed using information received from the outcomes of Phase 1. The VTL was used to develop the MR intervention as a potential source of information. During the pre-intervention, data were collected using an Open-Ended Questionnaire to investigate students' prior understanding of each of the four fluid mechanics topics being discussed. Four tables show the results acquired post-intervention. The second group of students (N = 32) was taught by using the traditional lecture approach in the second phase. The students were taught by MR, which includes four representations to illustrate each of the four concepts of fluid mechanics that were discussed. In addition, the study worked on the activities that were prepared based on MRs in small groups. These MRs-based interactive learning activities were given to the students to work on in groups or as homework. The results of the data collected from students regarding each of the four components of fluid mechanics were presented and discussed. The study compared traditional teaching of fluid mechanics with MR teaching. In addition, the study adds that MRs include materials, teaching methods, timetable, classroom activities, and students’ attitudes, motivations, and perceptions. Then, to teach fluid mechanics efficiently, it is essential to use a teaching-learning approach that will facilitate students’ active participation, responsiveness, innovation, creativity, and respect for the teacher.

CHAPTER 7: EFFECTIVENESS OF THE INTERVENTION

7.1 INTRODUCTION

A third phase was designed to examine whether the second intervention addressed the conceptual difficulties more effectively than the first intervention. The instructional intervention used in this phase on the first group of students was MRs-based instruction, which includes eight representations with interactive fluid mechanics learning tutorials. The data were collected using the OEQ, FMCI and SAMRQ instruments with students (N = 32) who had been exposed to the MR intervention. This data was analysed both qualitatively and quantitatively (see Sections 4.8.2 and 4.8.3).

In this chapter, the following research question was answered.

- Is there any significant difference between Iteration 1 and Iteration 2 in the experimental group in terms of Student understanding of multiple representation approaches in fluid mechanics concepts?

The effectiveness of the second intervention was explored in which way the intervention addressed the students' conceptual difficulties with each of the four fluid mechanics concepts. The findings were confirmed based on whether the number of students who correctly identified the critical aspect of each of the four fluid mechanics concepts increased from pre-to post-intervention in Iteration II. A second question was how many M2 and M3 students moved into category M1. A third question was whether the number of students who were satisfied with using MR in the post-intervention of Iteration II increased compared to the post-intervention of Iteration 1.

If these conditions were met, then the second intervention of Iteration II could be said to be more effective than the first intervention of Iteration 1 in enhancing students' conceptual understanding of fluid mechanics. These three points are used in the discussion of the results.

If these conditions were met, then the second intervention of Iteration II could be said to be more effective than the first intervention of Iteration 1 in enhancing students' conceptual understanding of fluid mechanics. These three points are used in the discussion of the results.

7.2 CATEGORISATION OF STUDENTS' CONCEPTUAL UNDERSTANDING OF ARCHIMEDES PRINCIPLE IN PRE-INTERVENTION II

7.2.1 Results of OEQ in the Pre-Test of Iteration II

The four steps of the qualitative analysis process were used to analyse the students' conceptual understanding of each of the four concepts of fluid mechanics (see Section 4.7.2). In addition, the VTL was utilised by students to identify the critical features (see Section 3.2). Data were collected from a new group of 64 students, 32 for the experimental group and 32 for the control group. A similar process was followed as in Iteration I. Table 7.1 provides the data of the M1, M2, and M3 categories after they wrote the pre-test in Iteration II, which was the same as the pre-test in Iteration I.

Table 7.1: The percentage of responses for M1, M2, and M3 for Iteration II items

Name of the Category	**Descriptions of the Categories**	**Experimental group**		**Control group**	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The buoyancy force equals up trust pressures, which indicate internal forces. • The volume of an object is equal to the volume of displaced water.	12	37.50%	12	37.50%
Alternative conception model (M2)	• Boundary pressure equals buoyancy force. • The buoyancy force is a natural force that exists within the body. • The buoyancy force is volume.	13	40.62%	14	43.75%
Null conception model (M3)	• The buoyancy force equals the volume of an object. • An object's buoyancy force is equal to its mass. • The buoyancy force of an object equals its weight.	7	21.87%	6	18.75%

As can be seen, Table 7.1 presents the comparison of students' OEQ mean results between the experimental and control groups in the three conception models before the second intervention. There was no difference in M1 in the experimental group compared to the control group. Furthermore, the experimental group exceeds the control group by 3.13%. Whereas in M3, the experimental group exceeds the control group by 3.13%. When comparing the students in the experimental group with those in the control group in pre-test II with those in pre-test I, the result was almost similar to the three conception models (see Section 5.2.1).

7.2.2 Results of FMCI in the Pre-test II of Iteration II

Data were collected from a new group of 64 students from two groups. Therefore, 32 were for experimental and 32 were for control. The process was repeated for Iteration 1. Table 7.2 provides data on the experimental and control groups' categories after they wrote the pre-test II.

Table 7.2a: The percentage of responses in each conception model for the items of Iteration II of the FMCI pre-test for internal force in the experimental and control groups

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.39	0.34
Alternative conception model (M2)	0.43	0.40
Null conception model (M3)	0.18	0.26

As can be seen in Table 7.2a, the difference in M1 students' grades was 5%. In the same way, when comparing the M2 and M1 students, it was found to be almost similar; there was a difference of 3%. When comparing the M3 students in the experimental and control groups, there was a difference of 8%. When comparing the students in the experimental group with those in the control group, the result was almost similar to the pre-test of Iteration I (see Section 5.2.2).

Table 7.2b: Distributions of paired-sample t-test results for the response in the M1, M2 and M3 experimental and control groups for FMCI items for the Archimedes' principle (buoyancy force) in the pre-test for Iteration II

		Paired differences				t	df	Sig. (2-tailed)
		Mean	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Pair I	M1	-.00781	.02629	-.06143	.04580	-.297	31	.768
Pair II	M2	.23422	.05913	-.08935	.15185	.528	31	.601
Pair III	M3	-.07813	.03627	-.15209	-.00416	-2.154	31	.039

Table 7.2b shows the similarity of the results for M1 students in both groups in the pre-test of Iteration II were t (31) = - 0.297, p-value 0.768, which is $p > .0005$ (two-tailed). The mean difference for M2 at t (31) = 0.528, p-value 0.601, which is $p > .0005$ (two-tailed), the mean difference for M3 students at t (31) =-2.154, p-value 0.039, which is $p > .0005$ (two-tailed) in the pre-test of Iteration II. There was no statistically significant mean difference in either case. Moreover, the results in the pre-test for Iteration II were similar to those in the Iteration I pre-test I. And in both cases, there was no statistically significant mean difference (see Section 5.2.2).

By considering Archimedes' principle, the buoyancy force can be explained. Studies show that undergraduate students find it difficult to explain and analyse Archimedes' principle (Chen &

Gladding, 2014), and students find it difficult to calculate and explain the sinking and floating behaviour of simple objects (Loverude et al., 2003). They are confused when they have to explain the difference between the weight and density of the material inserted into a fluid. In addition, undergraduate students failed to distinguish between density and volume (Hewitt, 2009).

Furthermore, most undergraduate students have difficulty distinguishing between internal force and pressure (Wagner, Cohen & Moyer, 2009). In the same manner, undergraduates are confused when they have to identify the difference between the mass and volume of the material immersed into a fluid (Loverude, Heron & Kautz, 2010).

Students find it difficult to accurately evaluate and provide mathematical calculations when a substance is partially or submerged completely in a fluid (Heron & Christian, 2003; Loverude et al., 2003). It is difficult to understand the difference in calculations when an object is completely immersed, partially immersed, or floated in a fluid, and students often use the same formula when describing all three cases. They find it difficult to describe two or more related physical terms, and this results in their inability to solve and calculate problems about internal force. Furthermore, they find it difficult to analyse the results of the problems and what they conclude after solving them.

7.3 CATEGORISATION OF STUDENTS' CONCEPTUAL UNDERSTANDING OF PASCAL'S PRINCIPLE IN PRE-INTERVENTION II

Table 7.3 shows distributions of the comparison results for the response in each conception model in the experimental and control groups for the items of OEQ for Pascal's principle (pressure measurement) in the pre-test II of Iteration II.

Table 7.3: Distributions of the comparison results of students' responses of OEQ pre-test II in Pascal's principle

Name of the Category	**Descriptions of the responses**	**Experimental group**		**Control group**	
		N=32	**In %**	**N=32**	**In %**
Correct conception model (M1)	• The pressure in a liquid increases with depth. • The atmospheric pressure decreases with increasing altitude. • Independent of the shape of the container, the pressure is the same at all points with the same depth.	10	31.25%	12	37.50%

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
	• The density of a substance is its mass per unit volume.				
Alternative conception model (M2)	• Water pressure decreases with depth. • The atmospheric pressure is independent of the altitude. • Sometimes the pressure P at a depth h below a point in the liquid is greater by a certain amount of pgh.	14	4375%	13	40.62%
Null conception model (M3)	• At 0° C the densities of gases are equal to the densities of solids and liquids. • Atmospheric pressure is dependent on density.	8	25%	7	21.87%

As can be seen in Table 7.3, when comparing the students in the M1 experimental group with those in the control group, the difference between the groups was 6.25%. In the same way, when comparing the M2 students, the difference between the groups was 3.13%. With the M3 students, the difference between the groups was 6.87%. It was found that the results were almost similar within pre-test I of Iteration II (see Section 5.4.1).

Table 7.4a: Undergraduate first-year Physics students' understanding of Pascal's principle

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.34	0.35
Alternative conception model (M2)	0.40	0.42
Null conception model (M3)	0.26	0.23

Table 7.4a shows that some first-year Physics students struggle with the pressure measurement component of fluid mechanics before learning. When comparing the results of FMCI, who were classified in M1 between pre-test Iteration II, there was a difference of 1%. When comparing the results in the M2 category, the difference was 02%. Furthermore, concerning the M3, the difference was 03%. This result was similar to the one observed in Chapter 5 (see Section 5.4.2).

Table 7.4b: Pre-intervention-II paired-samples t-test results on pressure measurement

Paired-Samples Test							
	Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			

					Lower	Upper			
Pair I	M1	-.04688	.22394	.03959	-.12762	.03387	-1.184	31	.245
Pair II	M2	-.01563	.14110	.02494	-.06650	.03525	-.626	31	.536
Pair III	M3	.06250	.20080	.03550	-.00990	.13490	1.761	31	.088

As can be seen in Table 7.4b, the similarity between the experimental and control group score results was determined using a paired-sample t-test. Results indicated that M1 was not statistically significantly different with t (31) =-1.184 p-value 0.245 at the 95% confidence interval of the difference. Furthermore, the results for the M2 groups were not statistically significant. Results were $p > 0.005$ (two-tailed); $t = -.626$, p-value 0.536, which is $p > 0.005$ (two-tailed). Besides, the M3 groups were not statistically significant. $t = 1.761$, p-value 0.088, which is $p > 0.005$ (two-tailed) at a 95% confidence interval of the difference. Thus, the result was not statistically significant. Before the intervention, there was no absolute difference between the experimental and control groups in all three categories. This result was similar to the Iteration I pre-test result (see Section 5.4.2).

Tire pressure, water pressure, and gas stations all use pressure measurement (Walker et al., 2014). Therefore, from elementary to high school, the pressure concept is dealt with in general Science, and later it forms part of the Physics course in fluid mechanics. Introducing it at an early age could help students learn and understand the fundamental concepts of pressure. At the undergraduate level, students are expected to provide some analysis and explanation of pressure measurement. However, undergraduate students are confused about pressure differences at different heights and are more likely confused about pressure variations at different temperatures. Similarly, there is confusion among students about pressure and volume (Aksit, 2011; Minichiello, et al., 2020). However, this problem is not only seen in students but also teachers (Taylor & Lucas, 2000).

Undergraduate students have difficulty explaining the difference between weight and pressure (Raissi et al., 2020). Students also find it difficult to distinguish between pressure and temperature (Loverude et al., 2003). Studies also show that there is difficulty with pressure and volume detection (de Berg, 1995; Psillos, 1999), as well as the difference between pressure and force (Misaiko & Vesenka, 2014). The concept of compressed air for undergraduate students has been explored, and it was established that students do not understand size and pressure (de Berg, 1995).

For undergraduate students (Goszewski et al., 2013), the relationship between pressure and height is difficult to analyse. Increasing the height between two points of reference increases the pressure change while decreasing the height between the two points decreases the pressure change (Serway, Moses & Moyer, 2004). Not understanding proportional reasoning could be challenging too. Sometimes undergraduate students find it difficult to understand elementary concepts such as the relationship between pressure and height. They indicate that when height decreases, the pressure of the fluid increases. They also find it difficult to explain how pressure interacts with density. Furthermore, many undergraduate students have difficulty remembering the pressure unit and have problems using and understanding formulae to describe density and weight (Akis, 2011).

7.4 CATEGORISATION OF STUDENTS' CONCEPTUAL UNDERSTANDING OF FLUID FLOW IN PRE-TEST II

Table 7.5 shows the distributions of the comparison results for the response in each conception model in the experimental and control groups for the items of OEQ for fluid flow in the pre-test II in the experimental and control groups.

Table 7.5: Distributions of the comparison results of students' responses of OEQ pre-test in fluid flow

Name of the Category		Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The equation of continuity for fluids states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid. • The product AV, which has the dimensions of volume per unit time, is called either the volume flux or the flow rate. • In steady flow, every fluid particle arriving at a given point in space has the same velocity. • The condition Av constant is equivalent to the statement that the volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval if no leaks are present.	10	31.25	12	37.50%
Alternative conception model (M2)	• According to the equation of continuity for fluids, the product of area and volume is always constant. • The product Av, is area times velocity; • In steady flow, the area and velocity are constant; • The condition Av constant is equivalent to the statement that the area and volume of fluid that enters one end of a tube in a given time interval equal the volume leaving the other end of the tube in the same time interval.	15	46.87%	11	34.37%

Null conception model (M3)	• According to the equation of continuity for fluids, the product of pressure and temperature is always constant. • The product Av, is fluid statics; • In steady flow, the tube is similar; • The condition Av constant is fluid always passing in a tube.	7	21.87%	9	28.13%

As can be seen in Table 7.5 in the M1 of OEQ, the experimental groups compared to the students in the control group, and the difference between the groups was 6.25%.

In the same way, when comparing the M2 students, the difference between the groups was 12.50%. Whereas M3 was 6.26% in the pre-test II of Iteration II.

Moreover, when comparing students, in both groups in all three categories it was found that the results were almost similar in the pre-test I of Iteration I (see Section 5.6.1).

Table 7.6a: The undergraduate first-year Physics students' understanding of the fluid flow part of fluid mechanics in FMCI in Intervention II

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.32	0.36
Alternative conception model (M2)	0.48	0.42
Null conception model (M3)	0.20	0.22

As can be seen in Table 7.6a, in the M1 of FMCI, the experimental groups compared to the students in the control group, the difference between the groups was 04%.

In the same way, when comparing the M2 students, the difference between the groups was 06%. Whereas M3 was 02% in the pre-test II of Iteration II.

Moreover, when comparing students, in both groups in all three categories it seems almost similar in the pre-test I of Iteration I (see Section 5.6.2). To check this, A paired-sample t-test was used to determine the similarity between the two groups and the results are provided in the next section.

Table 7.6b: Pre-intervention-II paired-samples t-test result on fluid flow

Paired-Samples Test								
	Paired Differences					**t**	**df**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			

Pair I	M1	-.07813	.19508	.03448	-.14846	-.00779	-2.265	31	.031
Pair II	M2	.14063	.21001	.03712	.06491	.21634	3.288	31	.006
Pair III	M3	-.06250	.23760	.04200	-.14816	.02316	-1.488	31	.147

As can be seen in Table 7.4b, the similarity between the experimental and control group score results was determined using a paired-sample t-test. Results indicated that M1 was not statistically significantly different with $t\ (31) = -\ 2.265$ p-value 0.031 at the 95% confidence interval of the difference. Furthermore, the results for the M2 groups were not statistically significant. Results were $p > 0.005$ (two-tailed); $t = 3.288$, p-value 0.006, which is $p > 0.005$ (two-tailed). Besides, the M3 groups were not statistically significant. $t = 1.488$, p-value 0.147, which is $p > 0.005$ (two-tailed) at a 95% confidence interval of the difference. Thus, the result was not statistically significant. Before the intervention, there was no absolute difference between the experimental and control groups in all three categories. This result was similar to the Iteration I pre-test result (see Section 5.6.2).

Fluid flow involves the motion of a fluid subjected to unbalanced forces. This motion continues as long as unbalanced forces are applied (Jewett & Serway, 2008). Therefore, fluid flow is a function of the rate at which fluids flow in a tube, such as speed and volume. Everyday examples include drinking juice from a straw and having a garden hose connected to a tap that can be opened and closed.

Students find it difficult to understand constant velocity and volume while learning fluid mechanics (Raissi et al., 2020). Studies show that alternative conceptions of fluid flow exist at the undergraduate level. This includes the linking of different concepts, confusion of physical variables, and difficulty identifying related variables (such as pressure and temperature as well as area and volume), which makes it difficult to understand the fluid flow concept (Besson & Viennot, 2004; Hartini & Sinensis, 2019).

7.5 CATEGORISATION OF STUDENTS' CONCEPTUAL UNDERSTANDING OF BERNOULLI'S PRINCIPLE IN PRE-TEST II

The undergraduate first-year Physics students' understanding of Bernoulli's principle as part of fluid mechanics in OEQ was determined for Intervention II (Table 7.7).

Table 7.7: Distributions of the comparison results of students' responses of OEQ pre-test in the Bernoulli principle

	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The relationship between fluid speed, pressure, and elevation is the Bernoulli principle. • Bernoulli's equation shows that the pressure of a fluid decreases as the speed of the fluid increases. • The pressure decreases as the elevation increases. • The general behaviour of pressure with speed is true even for gases: as the speed increases, the pressure decreases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases.	10	31.25%	11	34.37%
Alternative conception model (M2)	• As a fluid moves through a region where its speed or elevation above the Earth's surface changes, the pressure in the fluid is constant. • Bernoulli's equation shows that the pressure of a fluid increases as the speed of the fluid increases. • The pressure increases as the elevation increases. • According to the Bernoulli Effect, this higher-speed air exerts high pressure on the car than the slower-moving air on the other side of the car.	14	43.75%	14	43.75%
Null conception model (M3)	• Bernoulli's equation shows that as pressure increases, the speed of the fluid increases • The pressure does not depend on elevation • No answer • Silence	8	25%	7	21.87%

As can be seen in Table 7.6a, in the M1 in the OEQ, the control group's students had a difference of 3.12% from the experimental group. In the M2 category, the results were the same. Moreover, in the M3 category, the results were 03.13%. Accordingly, in all three categories, the difference was similar to the results in Iteration I (see Section 5.6.2).

Table 7.8: Distributions of the comparison results for the response in each conception model in the experimental and control groups for the items of FMCI for Bernoulli's principle in the pre-test of Iteration II

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.31	0.31
Alternative conception model (M2)	0.42	0.44
Null conception model (M3)	0.27	0.25

The result was similar in the M1 category. When comparing the results in the M2 category in pre-test II, the difference was 02%. The result of M3 was a difference of 3%. These results were similar to the results found in test I of Iteration I (see Section 5.8.2).

Moreover, the similarity of the groups was made by employing a paired-sample t-test between the two groups which is presented in next section.

Table 7.9: Pre-intervention-II paired-samples t-test result on Bernoulli's principle

		Paired differences				t	df	Sig. (2-tailed)
		Mean	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Pair I	M1	-.04688	.04115	-.13080	.03705	-1.139	31	.263
Pair II	M2	.03906	.04217	-.04693	.12506	.926	31	.361
Pair III	M3	.00781	.03966	-.07308	.08871	.197	31	.845

As can be seen in Table 7.9, the similarity between the experimental and control group score results was determined using a paired-sample t-test. Results indicated that M1 was not statistically significantly different with t (31) = - 1.139 p-value 0.263 at the 95% confidence interval of the difference. Furthermore, the results for the M2 groups were not statistically significant. Results were $p > 0.005$ (two-tailed); $t = 0.926$, p-value 0.361, which is $p > 0.005$ (two-tailed). Besides, the M3 groups were not statistically significant. $t = 0.197$, p-value 0.845, which is $p > 0.005$ (two-tailed) at a 95% confidence interval of the difference. Thus, the result was not statistically significant. Before the intervention, there was no absolute difference between the experimental and control groups in all three categories. This result was similar to the Iteration I pre-test result (see Section 5.8.2).

Bernoulli's principle is a very important concept in our lives. This includes the use of Bernoulli principles, such as air travel, wing design, ballooning, parachute fighter jets, bombers, and so on.

Bernoulli's principle states that "an increase in a fluid's speed occurs simultaneously with a decrease in its static pressure or potential energy" (Walker et al., 2014, p. 553). At any point in time in the subsurface, the total energy per unit mass of flowing fluid is equal to a constant value. Thus, kinetic, potential, and fluid-pressure energies are all included (Jewett & Serway, 2008, p. 432). It should not come as a surprise that Physics and Engineering students have difficulty understanding or explaining questions about Bernoulli's principles (Chen & Gladding, 2014; Loverude et al., 2000).

7.6 SECOND INTERVENTION FOR ITERATION II

In Iteration II, the lessons were re-designed by adding another four representations, for a total of eight representations (text, picture, diagram, symbolic or mathematical formula, video, animation, virtual lab, and simulation) offered in the class (see Table 7.7). The lesson plan is presented with the required content as well as teaching activities on the sub-topic of Archimedes' principle. The other three sub-topics of fluid mechanics are provided in Appendix R.

Table 7.10: A teaching lesson plan for Intervention II (Iteration II) regarding the Archimedes' principle (buoyancy)

Time	Phases	MR representations: Iteration II
		Use (Text, pictures, diagram, and symbolic or mathematical formula) and textbook (Serway et al., 2004 pp: 420).
5'	Introduction	Introduce today's lesson
35'	Presentation	Present the lesson about: • Archimedes' principle; • Buoyancy; • Relationship between pressure and Archimedes' principle. Then demonstrate Archimedes' principle, of buoyancy, the relationship between pressure and Archimedes' principle (buoyancy force) by using the picture.
		Picture 7.1 Shows a picture taken from a video of balancing the ring block of gold before sinking in a fluid • Define Archimedes' principle. • Discuss Archimedes' principle concerning buoyancy by using the picture. • Discuss what would happen when the block is suspended on the fluid concerning buoyancy. • Show the pressure that the fluids exert on the woodblocks. • Describe the relationship between pressure and Archimedes' principle (buoyancy force) by using the diagram. • Explain the relationship between the ratio of density and volume change of the water by using the mathematical formula. • Describe Archimedes' principle concerning buoyancy by using the mathematical formula.

Time	Phases	MR representations: Iteration II
		Picture 7.2 Shows a picture taken from a video that the block of gold sinks more than the ring. Picture 7.3 Shows an animation picture of the relationship between his weight and the weight of the water he was displacing • Explain the relationships of density and volume change of the water. • Describe Archimedes' principle concerning buoyancy. Picture 7.4 Shows an animation picture of the fake crown spilling more water than the one made of pure gold • Explain the relationship between the ratio of density and volume change of the water. Picture 7.5 shows the apparent weight loss due to buoyancy in Archimedes' principle • Describe Archimedes' principle concerning buoyancy. • Explain the pressure that the fluids exert on the woodblocks. The students will now work in their workbooks to complete the activity.
5'	Summary	Summarise the lesson about: • Pressure • Relationship between pressure and Archimedes' principle.
5'	Evaluation	Classwork: A piece of wood 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 on reading spring balance? The students will now work in their workbooks to complete the activity in their workbooks individually. Describe the relationship between pressure and Archimedes' principle (buoyancy force) in Picture 7.3. Finally, provide correct answers for their response so that students will record the correct answer.

7.6.1 The Use of a Virtual Lab

Present the lesson about Archimedes' principle: Buoyancy; Relationship between pressure and Archimedes' principle. Then demonstrate Archimedes' principle of buoyancy, the interaction between pressure and Archimedes' principle (buoyancy force), by using the picture and virtual experiment.

Discuss what would happen when the block is suspended in the fluid, with regard to buoyancy. Describe the relationship between pressure and Archimedes' principle (buoyancy force). Show the pressure that the fluids exert on the woodblocks. Describe the relationship between pressure and Archimedes' principle (buoyancy force).

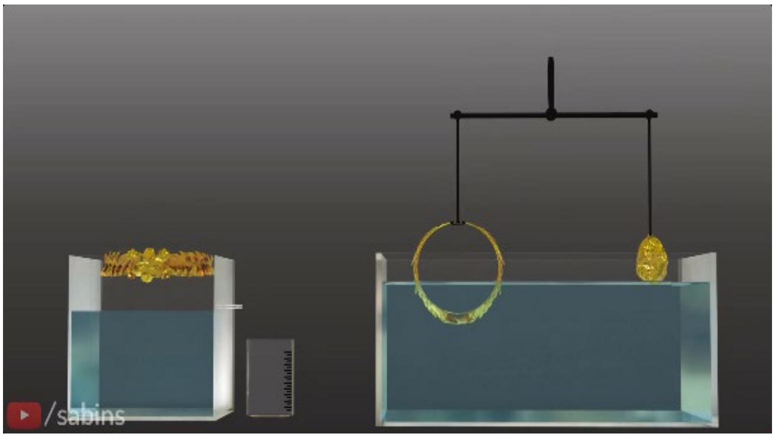

Figure 7.1: Picture taken from a video showing balancing the ring block of gold before sinking in a fluid

(Source: https://www.youtube.com/watch?v=XfkJ7wBT-PA&t=181s)

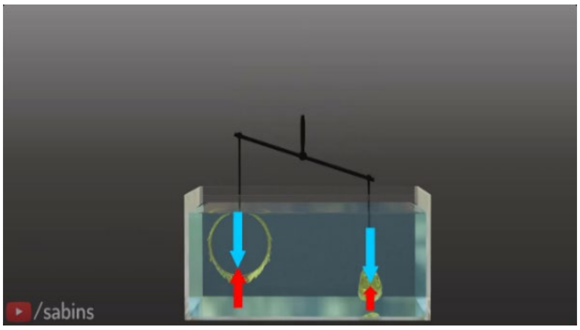

Figure 7.2: Picture taken from a video showing that the block of gold sinks more than the ring

(Source: https://www.youtube.com/watch?v=XfkJ7wBT-PA&t=181s)

7.6.2 The Use of Animation Video

In the classroom, undergraduate students are constantly exposed to visual popular culture (e.g., movies, TV shows, graphic novels, etc.). Since many students find pop culture references in the classroom engaging, Science and Engineering instructors have used graphics from visual pop culture to teach scientific and Engineering concepts. An investigation of the efficacy of using pop culture for instruction found that high school students who learned from graphic novels had a deeper understanding of the subject and were more engaged with the content than students who learned from traditional textbooks. Moreover, students who did not self-identify as “Science people” were even more engaged with the instructional comics. Therefore, it is possible to describe Archimedes’ principle concerning buoyancy. Explain the relationship between the ratio of density and the volume change of the water.

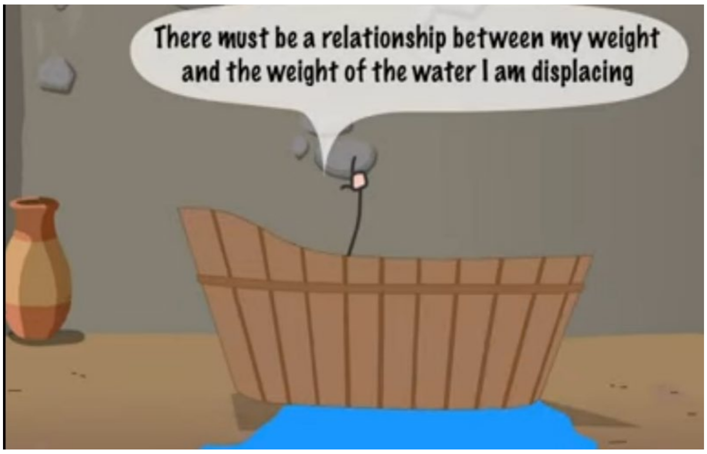

Figure 7.3 Animation picture for the relationship between his weight and the weight of the water he was displacing (Source: https://www.youtube.com/watch?v=wChr0hCga5g&t=302s)

Figure 7.4: Animation picture for the fake crown spilling more water than the one made of pure gold

(Source: https://www.youtube.com/watch?v=wChr0hCga5g&t=302s)

7.6.3 The Use of the Video

It is possible to understand technical concepts explained decades ago by way of videos (Kelves, 1992; Ford, 1993). The use of educational films is a long-standing trend across grade-school levels and colleges, even if they require clumsy projection equipment. Visual learning tools are seamlessly integrated into modern computer-based multimedia learning aids. A study by

Hmelo, Lunken, Gramoll and Yusuf (1996) found that multimedia is particularly useful in Engineering education. Using multimedia software, Montgomery (Montgomery, 1995) found that visual learners benefited more from its use than verbal learners, but that the latter were more likely to build their visual contexts using it. Dwyer (1972) proved that multicoloured line drawings convey scientific concepts better than monochrome ones. Picture 7.5 shows the apparent weight loss due to buoyancy in Archimedes' principle.

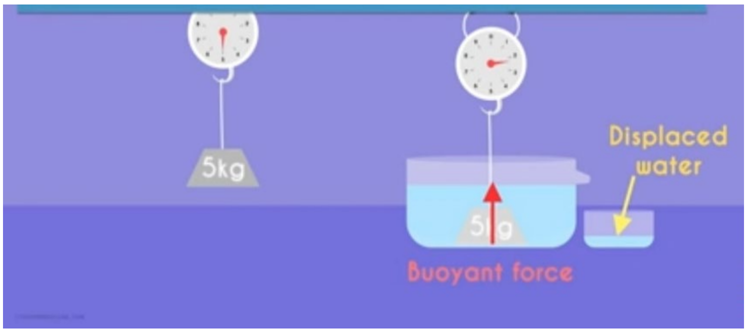

Figure 7.5: The apparent weight loss due to buoyancy in Archimedes' principle

(Source: https://www.youtube.com/watch?v=05WkCPORlj4)

7.7 DIFFERENCE BETWEEN ITERATION I AND ITERATION II IN ARCHIMEDES' PRINCIPLE

For the three concepts of Archimedes' principle, pressure measurement, fluid flow, and Bernoulli's principle, a theoretical model of the OEQ and FMCI, were presented to the experimental and control groups.

Here is a summary of the basic results of the preliminary diagnosis of students' understanding of fluid mechanics concepts (OEQ and FMCI) (see Section 5.2.2). The concept of Archimedes' principle (buoyancy force) has been discussed in Sections 7.2.1 and 7.2.2.

In each conception model, the percentage of the result obtained in one assessment (OEQ) was similar to the percentage obtained in the other assessment (FMCI) (see Section 7.2.1 and 7.2.2). Moreover, for the quantitative data, when looking at the mean difference between the two groups in the distribution, it can be seen that there was no statistically significant difference in mean between the experimental and control groups (see Sections 5.2.2).

Furthermore, the proportion of M2 and M3 students in both groups was greater than 50% before the intervention (see Section 5.4). This indicates that many undergraduate Physics students struggled to understand fluid mechanics in its four components before Intervention II. The experimental and control groups showed similar results (see Sections 7.2.1 and 7.2.2).

7.7.1 Results of OEQ Difference Between Iteration I and Iteration II in Archimedes' Principle

Data were collected from 64 students, 32 in the experimental group and 32 in the control group. The process was repeated for the Iteration I described in Chapter 6. Table 7.11 provides data on the experimental and control groups' categories after they wrote the second post-test. Again, only Archimedes' principle (buoyancy) of OEQ was used as an example. The other concepts are included in Appendix P and Q.

After Iteration II, the difference in students' OEQ mean results were analysed (see Table 7.11).

Table 7.11: Responses to the buoyancy force questions in OEQ

Name of the Category	**Descriptions of the Categories**	**Experimental group**		**Control group**	
		N=32	**In %**	**N=32**	**In %**
Correct conception model (M1)	• The Buoyancy force equals up trust pressure is the Pressure that implies internal forces; • The volume of an object is equal to the volume of displaced water.	22	68.75%	16	50%
Alternative conception model (M2)	• Boundary pressure equals buoyancy force. • The buoyancy force is a natural force that exists within the body. • The buoyancy force is volume.	7	21.87%	12	37.50%
Null conception model (M3)	• The buoyancy force equals the volume of an object. • An object's buoyancy force is equal to its mass. • The buoyancy force of an object equals its weight.	3	09%	4	12.50%

There was an 18.75% greater student response in the M1 experimental group than in the control group. Besides, in Iteration II, the M2 in the experimental group was 15.63% fewer than in the control group. Moreover, in M3, the experimental group was 3.50% fewer than the control group. This result had a greater difference than in Iteration I (See Section 6.4.1).

7.7.2 Results of FMCI Difference Between Iteration I and Iteration II in Archimedes' Principle

The results for the FMCI are presented in Table 7.12 a, b and c.

Table 7.12a: The distributions of FMCI post-test rest for Archimedes' principle

Categories of students' conception model	Experimental Group	Control Group

	(EG)	(CG)
Correct conception model (M1)	0.70	0.46
Alternative conception model (M2)	0.15	0.32
Null conception model (M3)	0.13	0.22

When these were compared in the experimental and control groups, the distributions were not exactly similar in the correct conception category (M1). There was less than a 2% difference in the groups. Regarding the M2 students, 42% of them were from the experimental group and 40% from the control group. Of the students who used the Null conception model, 25% of them from the experimental group and 25% from the control, were classified as M3. There was no difference between the two groups. Moreover, the similarity of the two groups for all three categories was established using a paired-sample t-test (see Section 5.2.2).

Table 7.12b: Results of paired-sample t-tests on the Archimedes' principle (buoyancy force) for experimental and control groups in Iteration II for FMCI items for each conception model

		Paired differences				t	df	Sig. (2-tailed)
		Mean	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Pair I	M1	.23438	.02957	.17407	.29468	7.927	31	.000
Pair II	M2	-.14844	.03525	-.22032	-.07655	-4.211	31	.000
Pair III	M3	-.18750	.04047	-.27005	-.10495	-4.733	31	.000

Table 7.12c: Distributions of the effect size of students' scores in the experimental and control groups for the items of FMCI for the Archimedes' principle (buoyancy force) in Iteration II

Dependent variable: FMCI post-test in Ex and Co Group						
Source	**Type III sum of squares**	**df**	**Mean square**	**F**	**Sig.**	**Partial eta squared**
Corrected model	.890[a]	2	.445	24.901	.000	.448
Intercept	2.120	1	2.120	118.147	.000	.659
Pre-test of Ex and Co	.011	1	.011	.615	.436	.010
Group	.884	1	.884	49.269	.000	.447
Error	1.094	61	.018			
Total	23.275	64				
Corrected total	1.984	63				
a. R squared =.448 (adjusted R squared =.430)						

Table 7.9a shows the mean difference in the three FMCI conception models of Archimedes' principle (buoyancy force) after Intervention II. There was a difference of 24% in M1 students in the experimental group compared to the control group in Iteration II. There was a 12% difference in the M2 and M3 groups in Iteration 1 compared to the control group. Furthermore, the M2 and M3 groups decreased by 17% and 9% in Iteration II compared to the control group, whereas this difference was 8% and 3% in Iteration I (see Section 7.7 for discussion).

Therefore, after the second intervention (reconstructed MR) in the experimental group, more students moved from M2 and M3 to M1. However, more than 50% of students in the control group still did not comprehend the concept of Archimedes' principle (buoyancy force) even after learning had occurred. According to this study, numerous undergraduate first-year Physics students have a poor understanding of Archimedes' principle (buoyancy force) after learning by conventional lecture methods.

Therefore, after Intervention II (the reconstructed MR) in the experimental group, more students moved from M2 and M3 to M1. Despite this, more than 50% of control group students still had a limited understanding of Archimedes' Principle (buoyancy force). The result indicates that a significant number of undergraduate first-year Physics students participating in this study have an impaired understanding of the concept of Archimedes' principle (buoyancy force) after learning traditional lecture methods.

Before the intervention started, most of the undergraduate students were not using M1, but about 2/3 of them were using M2 and M3. When looking at the results of both assessments in each conception model, the results obtained in one assessment (OEQ) were repeated in the other assessment (FMCI). This indicates that the results obtained by one were confirmed by the other. Thus, more than 65% of the students used M2 and M3.

When looking at the difference between the two groups, in Iteration II, it can be seen that there was a statistically significant difference between the experimental and control group, and the distribution was not similar in both groups. However, when looking at the difference between the two groups, in Iteration I, it can be seen that there was no statistically significant difference between the experimental and control group, and the distribution was similar in both groups (see Section 6.2.2).

The similarity between the two groups was established using a paired-sample t-test. Iteration II found a statistically significant mean difference in M1 at $t(31) = 7.927$, p 0.0005 (two-tailed), which is 0.000. In Iteration I, however, there was no statistically significant difference in the mean value of M1 at t (31) = 1.438, p-value 0.161, which is p> 0.0005 (two-tailed). Furthermore, in Iteration II, the results were statistically significant when compared to the M2 and M3. Experimental and control groups showed p> 0.0005 (two-tailed); -4.101, p-value 0.000, which is p 0.005 (two-tailed); and t value is -4.73, p-value 0.000, which is p 0.005 (two-tailed). As a result, there was a statistically significant mean difference between the two groups. The results of Iteration I did not show any statistical significance in comparison to M2 and M3. These results indicated that the experimental and control groups were p> 0.005 (two-tailed); t = -1.714, p-value 0.097; and t = -0.571, p-value 0.572, respectively, which indicates p> 0.005.

In the same way, ANCOVA (one-way analysis of covariance) was used to compare the scores of the two groups (experimental and control) after Intervention I. The experimental and control groups were compared using a one-way between-group analysis of variance with pre-intervention scores as covariates to determine if any significant differences existed between their performances. Sixty-four students from both groups submitted their pre-and post-scores to FMCI.

As in Section 6.4.3, before using ANCOVA analysis, the three conditions (descriptive statistics, measuring the reliability of the covariate, and Levine's test of equality of error variances) were fulfilled (see Appendix X).

Based on an ANCOVA analysis, Table 7.14 summarises the confirmation of the effectiveness of reconstructed MR. After Iteration II, there was a significant difference between the two groups' FMCI scores, (1, 63) = 0.447, p = 0.000 (partially squared eta squared value for the effect size of 0.447 (see Table 7.14)). According to the partial eta squared value for the effect size for the second intervention, Iteration II had a greater effect size. In Iteration, I, the FMCI score was (1, 63) = 0.294, p = 0.000 (Partial eta squared value for the effect size of 0.294 (see Table 7.14).

The study increased the number of MRs from 4 to 8. The study proved that using eight representations in teaching fluid mechanics was more effective in addressing students' alternative conceptions. While the MR approach contributed somewhat to students' alternative conceptions compared to the control group, i.e., some students shifted from M2 and M3; the effect size was not substantial enough to confidently claim the approach's efficacy in the experimental group.

However, in Iteration II, the results indicated that the reconstructed MR approach contributed to addressing students' alternative conceptions. Therefore, in shifting students from the category of M3 and M2 to the category of M1, Iteration II (reconstructed MR) was more effective than Iteration I (MR).

In general, in enhancing the alternative conceptions of the students, the experimental group (reconstructed MR) class was more effective than the control group (TL) class.

Before the intervention commenced, most of the undergraduate students used M1, but about 2/3 of them used M2 and M3. When looking at the results of both assessments in each conception model, the results obtained in one assessment (OEQ) were repeated in the other assessment (FMCI). This indicates that the results obtained by one were confirmed by the other. Thus, the M2 and M3 students comprised more than 65% of the 64 students.

Furthermore, when looking at the difference between the two groups, there was no statistically significant difference between the experimental and control groups, and the distribution was the same for both groups (Section 7.2.2).

Multiple representations are a unique learning approach conducive to all students. These approaches are multifaceted, for example, with one student excelling at using words, images, and Maths, while another excels at only one (Sewell, 2002). According to Bakri and Mulyati (2018), MRs are appropriate teaching methods that have been applied to the design and teaching of basic Physics. This includes concept maps, videos, figures, data tables, charts of data tables, verbal explanations, equations, problems, and solution examples and exercises. The representations of contextual learning can be categorised into stages as follows: relating, experiencing, applying, transferring, and cooperating. Physics education as part of natural Science indeed deals with the study of matter. It is also concerned with the study of interconnections between the elements within it. Hence, MRs play an integral role in learning Physics. They offer the opportunity to manage fluid mechanics questions. In addition, they can provide students with the opportunity to learn more about Physics concepts, including text and animated images, diagrams, tables and graphs, Algebra notation, as well as tables and mathematical equations (Bakri & Mulyati, 2018). In most cases, the process of learning Physics is successful when teachers are interested in using the MR approach. Moreover, using MRs helps students to improve their problem-solving skills, develop their creative thinking, and understand how to build their knowledge through experience and context rather than being taught. Therefore, the use of multiple representations in teaching Physics is an effective method to develop students' ability to learn cooperatively, respond to other learners in class, and communicate with them (Bakri & Mulyati, 2018). Hartini and Sinensis (2019) argue that MRs are important teaching-learning techniques that enable classroom teachers to improve the students' learning outcomes, which are consolidated through the provision of different ideas and technical equipment that enhance the students' learning in Physics.

This indicates that many first-year Physics students have difficulty understanding fluid mechanics. Most undergraduate Physics students had no idea about fluid mechanics before starting the course, therefore they had conceptual difficulties. Thus, when students were asked to explain internal forces, most of them had difficulty answering the question. Instead, they answered by guessing. It also showed that these students did not have valid and acceptable knowledge of the topic. Other research in the field supports the results of this study. Studies have shown, for example, that students lack adequate knowledge and understanding of fluid mechanics before learning occurs (Loverude et al., 2003; Raissi et al., 2020). Another study found that when first-year Physics students were asked to explain the buoyancy force equals up trust pressure and Archimedes' principle, they encountered difficulties (Muriset al., 2003). Another study found that most undergraduate first-year students had learning difficulties when trying to understand fluid mechanics. Because topics such as the Physics of ideal fluids (non-viscous and incompressible) are covered in introductory Physics and Engineering university courses, as well as those related to medicine and life Sciences, an in-depth understanding of the specific concepts of fluids such as current pipelines, pressure, and conservation of different physical quantities, is crucial to understanding classical mechanics (statics, kinematics, and dynamics) (Suarez, Kahan, Zavala & Marti, 2017).

In addition to confusion in communication, students found it difficult to know how the volume of the block and the volume of displaced fluid were related to each other when a block was completely submerged in fluid (Aksit, 2011; Benson, Wittrock & Baur, 1993). In addition, pre-service secondary Science teachers had alternative concepts of fluid mechanics such as tidal phenomena (Oh, 2014). As a result of these difficulties, students developed negative attitudes towards Physics (Faour & Ayoubi, 2018).

The study showed the effects of traditional teaching and a model of application of active learning to eliminate students' alternative conceptions of floating and sinking. Significant differences were found between the control and experimental groups. As a result, a constructivist view of learning must be implemented in the teaching process (Radovanovi, Sliko & Ili, 2019).

In traditional instruction methods, students move from a group learning environment to an individual learning environment. Thus, it minimises the results of an interactive learning environment where the educator guides the students in applying the concepts and the students also engage creatively with the subject. The traditional lecture is a method of teaching many students in a classroom at the same time. Normally, this method uses chalk and talk (Chen & Gladding, 2014). A traditional lecture method is an approach, and it is said to be less effective than the modern approach (Geyer & Kuske-Janßen, 2019; Faleye & Mogari, 2010). Similarly, the study shows that using a traditional lecture approach was not fruitful in enhancing students' understanding of fluid mechanics and hindered their ability to solve problems (Chen & Gladding, 2014; Euler & Gregorcic, 2018).

Most Engineering instructors employ a lecture-based pedagogical model. Among these reasons is the persistence of this model, which requires a lesser number of resources and time than traditional fluid mechanics courses. However, the method can be used if it is supplemented with visual graphics of the relevant materials (Wayan & Kartini, 2020). Here, students are predicted to be at the centre of the teaching-learning process. They decide what to learn and how to select and organise content and materials. In addition, they learn how to integrate fluid mechanics with other disciplines. Furthermore, how to manipulate computational aspects of the course, how to solve problems, conduct class activities, and manage activities to finally achieve the end with little intervention from the subject teacher. However, the method is less likely to solve more complex ideas and concepts that need demonstration, explanation, and guidance as expected from the subject teacher (Shaheen, 2015).

A study by Mohammad et al. (2012) found that the traditional method of teaching fluid courses is not an effective method of teaching. This is due to the fact that it leaves students with fewer opportunities to combine what they learn, how they learn, and how to improve their school performance. This is because students have no role in the teaching-learning process. As a result, the teacher plays a vital role; he/she is the manager when the learning process relies heavily on enforcing the rules. In a broader sense, the traditional method affords a chance to promote a top-to-bottom approach. The Ministry of Education becomes the principal producer of academic course materials, without much concern being given to the role of other stakeholders. The traditional method does not take into account some important factors that have an impact on the process of teaching fluid mechanisms. Many factors influence whether a child performs well in school. This includes family background, materials, teaching methods, homework, class schedule, classroom activities, students' intelligence and motivation, a teacher's level of knowledge and experience, educational facilities, and the number of students in a class. Therefore, it is essential to use an efficient teaching-learning approach when teaching fluid mechanics courses. This helps students to be active, reactive, responsive, innovative, creative, and respectful to the teacher, who is the organiser of the procedure for teaching fluid mechanics concepts.

7.8 DIFFERENCE BETWEEN ITERATION I AND ITERATION II IN PASCAL'S PRINCIPLE

The understanding of Archimedes' principle (buoyancy force) in fluid mechanics was examined in the OEQ, FMCI and S for undergraduate first-year Physics students. Table 7.15 summarises the results.

The lessons were conducted with an experimental group MR using four different representations for each topic (see Lessons 1, 2, 3, and 4 in Appendix J). After discussing each topic, students were required to complete an OEQ and FMCI assessment to determine their comprehension. In the control group, no teaching methods were used apart from traditional lectures. Tables 7.13, 7.14, 7.15, and 7.16 present the results. Also, in the similarity analysis, the paired-sample results are shown in Appendix S and T.

7.8.1 Results of OEQ Difference Between Iteration I and Iteration II in Pascal's Principle

Table 7.13: Distributions of the comparison results of students' responses of OEQ pre-test in Pascal's principle

Name of the Category	Descriptions of the responses	Experimental group		Control group	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The pressure in a liquid increases with depth; • The atmospheric pressure decreases with increasing altitude; • The pressure is the same at all points having the same depth, independent of the shape of the container; • The density of a substance is mass per unit volume; • Densities of substances depend on temperature;		69%		51%

Alternative conception model (M2)	• Water pressure decreases with depth. • The atmospheric pressure is independent of altitude. • The pressure P at a depth h below a point in the liquid is sometimes greater by an amount of pgh.		22%		36%
Null conception model (M3)	• At 0°C the densities of gases are equal to the densities of solids and liquids. • Atmospheric pressure is dependent on density.		09%		13%

7.8.2 Results of FMCI Difference Between Iteration I and Iteration II in Pascal's Principle

Table 7.14: Summary of the basic results of the preliminary diagnosis of students' understanding of Pascal's principle of fluid mechanics concepts

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.70	0.49
Alternative conception model (M2)	0.21	0.33
Null conception model (M3)	0.09	0.18

When comparing the results in the M1 of the FMCI in experimental and control groups, the difference was 21% in Iteration II, whereas these results were 11% in Iteration I. In Iteration II, M2 and M3 students differed by 12% in the experimental and control groups, respectively. These differences were 09% in Iteration I, whereas M3 students showed a difference of 04% and 9% in Iteration II, whereas these results were 02% in Iteration I (see Section 5.6.5.2).

Weight and pressure are difficult to separate for undergraduate students (Raissi et al., 2020). It is also difficult for students to distinguish between pressure and temperature (Loverude et al., 2003). There is also a difficulty in detecting pressure and volume (de Berg, 1995; Psillos, 1999), as well as the distinction between pressure and force (Misaiko & Vesenka, 2014). Undergraduate students were tested on their understanding of compressed air, and it was observed that they did not understand the notions of volume and pressure (de Berg, 1995).

Table 7.15: FMCI post-test-II paired-samples t-test results on pressure measurement

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.20906	.20255	.03581	.13603	.28209	5.839	31	.000

Pair II	M2	-.11281	.16514	.02919	-.17235	-.05327	-3.864	31	.001
Pair III	M3	-.09344	.11807	.02087	-.13600	-.05087	-4.777	31	.000

Table 7.16: FMCI ANCOVA results of pressure measurement

Dependent Variable: POST-FMCI						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	.707a	2	.354	10.173	.000	.250
Intercept	2.942	1	2.942	84.734	.000	.581
Pre-test	.008	1	.008	.230	.633	.004
Group	.702	1	.702	20.181	.000	.249
Error	2.121	61	.035			
Total	25.355	64				
Corrected Total	2.828	63				
a. R Squared =.250 (Adjusted R Squared =.226)						

7.9 DIFFERENCE BETWEEN ITERATION I AND ITERATION II IN FLUID FLOW

The undergraduate first-year Physics students' understanding of the fluid flow part of fluid mechanics in OEQ and FMCI was evaluated. A summary of the results is presented in Table 7.17.

Table 7.17: Distributions of the comparison results of students' responses of OEQ pre-test in fluid flow

Name of the Category	**Descriptions of the responses**	**Experimental group**		**Control group**	
		N=32	**In %**	**N=32**	**In %**
Correct conception model (M1)	• The Equation of continuity for fluids states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid. • The product AV, which has the dimensions of volume per unit time, is called either the volume flux or the flow rate. • In steady flow, every fluid particle arriving at a given point in space has the same velocity. • The condition AV constant is equivalent to the statement that the volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval if no leaks are present.		69%		50%

Alternative conception model (M2)	• According to the equation of continuity for fluids, the product of area and volume is always constant. • The product Av, is area times velocity; • In steady flow, the area and velocity are constant; • The condition Av constant is equivalent to the statement that the area and volume of fluid that enters one end of a tube in a given time interval equals the volume leaving the other end of the tube in the same time interval.		21%		31%
Null conception model (M3)	• According to the equation of continuity for fluids, the product of pressure and temperature is always constant. • The product Av, is fluid statics; • In steady flow, the tube is similar; • The condition Av constant is fluid always passes in a tube.		10%		19%

Table 7.18: Distributions of the comparison results for the responses in each conception model in the experimental and control groups for the items of OEQ and FMCI for fluid flow in Iteration II

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.73	0.52
Alternative conception model (M2)	0.20	0.30
Null conception model (M3)	0.07	0.18

When comparing the results in the M1 category in the FMCI in the experimental and control groups, the difference was 21% in Iteration II. In Iteration, I, these results were 20%. In the M2 group, the difference in FMCI was 10% in the experimental and control groups in Iteration II, respectively, whereas these results were 16% in Iteration I. M3 students showed a difference of 11% in Iteration II, whereas these results were 4% in Iteration I (see Section 5.6.5.3).

Table 7.19: FMCI post-test-II paired-samples t-test results on fluid flow

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.20938	.22340	.03949	.12883	.28992	5.302	31	.000
Pair II	M2	-.10937	.17663	.03122	-.17306	-.04569	-3.503	31	.002
Pair III	M3	-.10937	.11461	.02026	-.15070	-.06805	-5.399	31	.000

Table 7.20: FMCI ANCOVA results of fluid flow

Dependent Variable: POST-FMCI						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected model	.736a	2	.368	14.704	.000	.321
Intercept	1.960	1	1.960	76.718	.000	.557
Pre-test	.035	1	.035	1.359	.248	.022
Group	.736	1	.736	28.802	.000	.321
Error	1.559	61	.026			
Total	27.170	64				
Corrected total	2.295	63				
a. R Squared =.321 (Adjusted R Squared =.299)						

7.10 RESULTS ON BERNOULLI'S PRINCIPLE

The understanding of fluid flow by first-year Physics students was assessed in terms of both OEQ and FMCI.

Table 7.21: Distributions of the comparison results of students' responses of OEQ pre-test in Bernoulli's principle

Name of the Category	**Descriptions of the responses**	**Experimental group**		**Control group**	
		N=32	In %	N=32	In %
Correct conception model (M1)	• The relationship between fluid speed, pressure, and elevation is the Bernoulli principle. • Bernoulli's equation shows that the pressure of a fluid decreases as the speed of the fluid increases. • The pressure decreases as the elevation increases. • The general behaviour of pressure with speed is true even for gases: as the speed increases, the pressure decreases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases. • Bernoulli's equation shows how the pressure of an ideal fluid decreases as its speed increases.	10	68%	9	52%
Alternative conception model (M2)	• As a fluid moves through a region where its speed or elevation above the Earth's surface changes, the pressure in the fluid is constant. • Bernoulli's equation shows that the pressure of a fluid increases as the speed of the fluid increases. • The pressure increases as the elevation increases.	14	20%	13	30%

	• According to the Bernoulli Effect, this higher-speed air exerts high pressure on a car than the slower-moving air on the other side of your car.				
Null conception model (M3)	• Bernoulli's equation shows that as pressure increases, the speed of the fluid increases • The pressure does not depend on elevation • No answer • Silence	8	12%	10	18%

In the M1 in the OEQ, the control group's students had a difference of 6% from the experimental group.

Table 7.22: Summary of the basic results of the preliminary diagnosis of students' understanding of the Archimedes' principle of fluid mechanics concepts

Categories of students' conception model	Experimental Group (EG)	Control Group (CG)
Correct conception model (M1)	0.66	0.50
Alternative conception model (M2)	0.25	0.28
Null conception model (M3)	0.09	0.22

Table 7.23: FMCI post-test-II paired-samples t-test results on Bernoulli's principle

		Paired Differences					**T**	**df**	**Sig. (2-tailed)**
		Mean	**Std. deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
					Lower	**Upper**			
Pair I	M1	.16219	.18295	.03234	.09623	.22815	5.015	31	.000
Pair II	M2	-.12969	.18750	.03315	-.19729	-.06208	-3.913	31	.000
Pair III	M3	-.06781	.16174	.02859	-.12613	-.00950	-2.372	31	.024

Table 7.24: FMCI ANCOVA results of Bernoulli's principle

Dependent Variable: B POST-FMCI						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected model	.591a	2	.296	13.036	.000	.299
Intercept	2.466	1	2.466	108.708	.000	.641
Pre-test	.171	1	.171	7.518	.008	.110
Group	.411	1	.411	18.136	.000	.229
Error	1.384	61	.023			
Total	23.586	64				
Corrected total	1.975	63				
R Squared =.299 (Adjusted R Squared =.276)						

In Iteration II, when comparing the results for M1 students in the OEQ vs. FMCI in the experimental and control groups, the difference between the groups was 16% and 16%, whereas, in Iteration I, these results were 16% and 12%. In Iteration II in the M2 category, the difference in OEQ vs FMCI was 10% and 3% in the experimental and control groups, respectively, whereas these results were 12% and 8% in Iteration I.

In Iteration II in the M3 category, the difference between OEQ and FMCI was 6% and 13%, whereas these results were 4% and 3% in Iteration I (see Section 5.8.2).

The experimental and control groups were at the same level before the first intervention (see Section 5.2). This first intervention (in the experimental group, employing a MRs approach that included text, pictures, diagrams, and Maths equations) is a teaching approach that may help students develop alternate conceptions (Einsworth, 2006; Kohl & Finkelstein, 2005b, 2006; Tytler & Prain, 2013). There was a difference between the control group and the experimental group after the intervention. According to the findings (see Sections 5.8), the use of MR aided the students in shifting from M2 to M1, M3 to M2, and even M3 to M1. This indicates that, compared to traditional lecture approaches, the use of MR can enhance undergraduate students' understanding. The paired-sample results are provided in Appendices S-3 and T-3.

These findings indicate that although students progress from M2 to M3 to M1 in their understanding, some of them still struggle to grasp concepts following training. This is supported by a study that found that when first-year Physics students were asked to explain the buoyancy force equals up trust pressure and Archimedes' principle while learning, the majority of students had difficulties (Martnez, 2012). Similar results were reported by Raissi et al. (2020). Furthermore, the groups had different scores on both assessments (OEQ and FMCI) (see Sections 7.2.2, 7.4.2, 7.6.2, and 7.8.2). However, when using a paired-sample t-test, the differences between the groups were not statistically significant (see Sections 5.2.2, 5.4.2, 5.6.2, and 5.8.2).

On the other hand, Lusiyana (2019) indicates that teaching Physics is a very challenging academic task because learning Physics concepts needs detailed mathematical equation-solving skills and knowledge. Thus, students require the use of various methods in understanding and translating different words, tables, graphs, equations, and diagrams. For this purpose, students are expected to solve mathematical equations, which are a vital prerequisite skill in understanding Physics; otherwise, learning Physics can be an unthinkable attempt without having adequate mathematical skills. In this regard, studies reveal that students are required to know basic concepts of Physics and Mathematics because there is a close relationship between the two academic disciplines. Therefore, teaching students about the concepts of Physics by using their mathematical abilities is an important approach. It seems to be very difficult to learn Physics without having mathematical problem-solving knowledge because the two fields of study parallel each other i.e., students who learn Mathematics may be better able to solve Physics problems. According to Prahani et al. (2021), students are interested in learning Physics because it provides people with skills and knowledge that can be used to solve complex life-related problems. According to the authors, the MRs approach is a poor teaching method for satisfying the interests of all students. It is said that the method is suitable for teaching students who have active learning skills. This means the method needs the use of multiple learning domains such as cognitive and psychomotor, so that Physics learning is more meaningful. Here, Physics teachers need to modify their approaches depending on the information on the students' social, cultural, academic, and language backgrounds to improve their learning abilities. On the one hand, this creates an additional work burden for them. On the other hand, in learning Physics, students need to know the laws, principles, and theories. Students who lack such knowledge are less likely to learn Physics through the application of the MRs approach (Destini, 2020).

7.11 RESULTS OF STUDENTS' ATTITUDES' RELATED TEST

The students' attitudes in the Likert scale questionnaire were analysed (see Table 7.25). A summary of the item statistics is presented below.

7.11.1 Attitude Towards Multiple Representation Approach

Table 7.25: Distributions of the results of the item statistics to measure students' attitudes towards the Multiple Representation Approach in the experimental group for Iteration II

No.	Item Statement on Attitude Towards Multiple Representation Approach	N	Mean	SD
1	Using multiple representations will help me to better understand.	32	4.17	.732
2	Using multiple representations requires a lot of mental effort.	32	4.30	.796
3	Using multiple representations will improve my problem-solving skills.	32	4.73	.719
4	Multiple representations encourage me to learn a fluid mechanics topic to the best of my ability.	32	4.74	.744
5	The MR approach will be difficult for me to master.	32	4.38	.768

Table 7.25 shows the item analysis output from SPSS for the multi-item scale of students' attitudes towards the MR approach. A description of the sections and the means for the five items comprising the scale shows students had a good attitude towards the MR approach in the experimental group for Iteration II. The results in Table 7.25 show the results of the analysis performed using SPSS for the multi-item scale of ART. According to the results of the first intervention, students have a positive view of the MR approach.

As shown in Table 7.25, Item 1, 'Using multiple representations will help me to better understand', had a mean score of 4.17 and an SD of 0.732. This indicates that students believed that MRs would enhance their understanding of fluid mechanics concepts.

Similarly, Item 2, 'Using a Multiple Representation Approach requires a lot of mental effort', indicated a mean score of 4.30 and an SD of 0.796, which shows that students generally agreed that using multiple representations does not require much mental effort.

Item 3, 'using a Multiple Representation Approach will improve my problem-solving skills, had a mean score of 4.73 and SD = 0.719. This result shows that students typically agreed with the statement.

Regarding Item 4, 'the MR approach encourages me to learn a fluid mechanics topic to the best of my ability' had a mean score of 3.31 and SD of 0.54. This result shows that students mostly agreed with the statement.

Item 5, 'The MR approach will be difficult for me to master', had a mean score of 4.38 and an SD of 0.768. This result shows that students mainly agreed with the statement.

Higher education institutions (HEI) all over the world have been hard-pressed to reconsider how they provide courses, accommodate growing student populations, and address increasing student diversity as a result of the internet's quick-changing technologies. Additionally, there has been and still is a demand for high-quality instruction at HEIs. HEIs ought to replace teacher-centred tactics with more student-centred ones, according to Livingstone (2015). Blended learning is one method that many HEIs are employing to encourage a more student-centred approach.

Blended learning, as defined by Graham (2006), combines traditional face-to-face instruction with online instruction. This educational strategy mixes face-to-face interactions with lecturers and students during class with online (synchronous or asynchronous) interactions (Graham, Woodfield & Harrison, 2013). Additionally, it can aid students in acquiring crucial 21st-century skills such as teamwork, creativity, and information literacy, as well as the capacity to employ digital Technology for a variety of objectives (Zurita, Hasbun, Baloian & Jerez, 2015). Even though these are crucial talents, students' capacity to study in a blended learning setting will determine their ability to gain these skills.

7.11.2 Advantages of Using Multiple Representations

Table 7.26: Distributions of the results of the item statistics to measure students' benefits from the MR approach in the experimental group for Iteration II

	Advantages of a Multi-Representation Strategy	N	Mean	SD
1	Finding a solution is easier with multiple representations.	32	4.20	.966
2	Multiple representations can increase my interaction with my environment.	32	4.15	.826
3	Learning with multiple representations will provide me with better learning opportunities than traditional methods.	32	4.26	.919
4	A lot of mental effort is required to use MRs on the computer system.	32	4.00	.771
5	There are many challenges associated with using MR technologies.	32	4.12	.738
6	I will be more efficient with the help of MR.	32	4.16	.722
7	MR will allow me to accomplish more work than otherwise possible.	32	4.09	0.738

Table 7.26 shows the description of the items and the summary statistics for the seven items comprising the scale, and shows that students benefited from the MR approach in the experimental group for Iteration II. For each section of the scale, Table 7.26 provides summary statistics for the correlation between item mean and item variances. Using multiple representational approaches in the first iteration was beneficial to students in the experimental group, according to the analysis.

Item 1 has a mean score of 4.20 and SD = 0.966, meaning that students generally believed that multiple representations do not make it easier to find a solution.

Item 2 had a mean score of 4.15 and an SD of 0.826. This means that students largely believed that multiple representations could improve their interaction with the environment.

Item 3 had a mean score of 4.26 and SD = 0.919, meaning that students mostly believed that they would have a better chance of learning with multiple representations than with traditional methods.

Item 4 had a mean score of 4.00 and an SD of 0.771, meaning that students typically believed that the computer system requires a lot of mental effort to use.

Item 5 had a mean score of 4.12 and an SD of 0.738, meaning that students mostly believed that MR technologies had many challenges associated with them.

Item 6 had a mean score of 4.16 and SD =.722, meaning that students mainly believed that they would become more efficient when using MRs.

Item 7 had a mean score of 4.09 and an SD of 0.738, meaning that students typically believed that MRs would allow them to complete more work than they would otherwise be able to.

In other words, after taking an introductory Physics course, students' attitudes toward MR Physics were more positive. The same pattern was noticed by Zeilik and Morris, (2003) at the beginning of astronomy classes. They concluded that there was "minimal change throughout each semester in students' modestly positive entering attitudes about astronomy and Science" using data from more than 400 students at the University of New Mexico enrolled in Introductory Astronomy courses. Despite the inclusion of cutting-edge evaluation methods such as concept mapping, small group work, and the detection of student misconceptions11, this attitude shift nonetheless took place. In other words, changing the structure of a class to prioritize active learning and implementing cutting-edge assessment strategies did not seem to have an impact on students' attitudes.

Recently, Adams et al., (2006) created a new tool called the Colorado Learning Attitudes about Science Survey to measure student attitudes and beliefs in basic Physics courses across a variety of areas such as personal engagement, real-world connections, and sense-making (CLASS). However, why should there be concerns about students' attitudes? Education research has repeatedly demonstrated over the past few decades that learning is inextricably associated with student attitudes and expectations.

In other words, we need to pay attention to students’ attitudes if we care about learning. This research sought to determine whether it is possible to influence student attitudes in an introductory Physics course in a constructive manner.

7.11.3 Interest in Learning Through a Multiple Representation Approach

Table 7.27: Distributions of the results of the item statistics to measure students' interest in learning through the Multiple Representation Approach in the experimental group for Iteration II

No.	Multi-representational learning as a desire to learn	N	Mean	SD
1	Interacting with a variety of techniques, such as video, virtual labs, computer simulations, and so on, is often interesting.	32	4.22	.738
2	Multiple representations are more engaging than traditional lecture methods.	32	4.34	.716
3	I enjoy working with multiple representations.	32	4.70	.632
4	Multiple representations are my favourite way to learn.	32	4.23	.966
5	Multiple representations stimulate my interest in learning.	32	4.77	.738
6	I am inspired to do my best in class by the MR approach.	32	4.30	.676

Table 7.27 shows the list of items and the summary statistics for each item to show whether students were interested in learning through the MR approach.

Item 1, respondents' opinions on interacting with a variety of approaches such as video, virtual labs, and computer simulations, are interesting with a mean score of 4.22 and an SD of 0.738, meaning that students generally believed that the use of a variety of tools, such as video, virtual labs, computer simulations, and so on, is interesting.

Item 2 shows that multiple representations are more engaging than traditional lecture methods, with a mean score of 4.34 and SD = 0.716 regarding the students' responses.

Item 3 had a mean score of 4.70 and an SD of 0.632. The results suggest that students believe that MRs have a greater potential for engagement than traditional teaching techniques.

Item 4 had a mean score of 4.23 and an SD of 0.966, meaning that students typically agreed that their favourite learning method was to use multiple representations.

Item 5 had a mean score of 4.77 and a SD of 0.738. This means that the respondents mostly enjoyed learning with multiple representations. This stimulates their interest in learning.

Item 6 had a mean score of 4.30 and an SD of 0.676, meaning that students generally felt that the MR approach inspired them to do their best in class.

Bandura's (1977) social cognitive theory, the idea of self-efficacy, and the Technology Acceptance Model were all theoretical foundations for this study (Davis, 1989). Self-efficacy is the belief in one's ability to carry out a particular job (Bandura, 1977). Strong self-efficacy encourages "intrinsic interest" and "deep engrossment in activities," as it enables people to approach challenging tasks as trials to be mastered rather than as threats to be avoided (Bandura, 1994, p. 1). High self-efficacy is characterised by people's increased likelihood to attempt tasks and activities they believe are capable of completing, and vice versa (Teo & Ling Koh, 2010).

The findings of the study show that undergraduate Physics students found understanding fluid mechanics difficult before the intervention. This claim is made as similar results were found in both the experimental and control groups before the two interventions. The lack of students' understanding of fluid mechanics can be because these students possibly do not have the requisite background knowledge in fluid mechanics. This finding is supported by previous researchers who indicated that undergraduate Physics students failed to apply what they had learned in previous Physics classes and what they developed through experience (Absi et al., 2011; Moseley & Brenner, 1997).

Researchers found that students had difficulty understanding the concepts even after an intervention (Hwang & Hu, 2013). However, it was decided to develop an intervention. Based on the literature (see Section 2.5), it was decided to use the MR as it can enhance students' alternative conceptions (Rosengrant et al., 2009; Tytler & Prain, 2013).

Lessons were designed by including four representations (text, picture, diagram, and mathematical symbol). Findings indicated that adding four representations produced change. However, the change was not significant or effective (see Sections 6.4).

The effectiveness of the planned and implemented teaching approach was evaluated by comparing the pre-and post-test results of OEQ and FMCI, while students' attitudes towards MR were determined by using SAMRQ (see Section 6.8).

A control group (using the traditional approach) was established at another institution, and during both interventions, the results were compared.

After Iteration I, the high number of M2 and M3 students declined, and they shifted from M2 and M3 into M1 after the intervention in the experimental group (see Section 7.4) compared to the control group. The difference in the experimental group was determined to be the result of the use of the MR. However, the observed difference was not statistically significant (see Section 5.4).

Furthermore, it is difficult to conclude that the use of MR is better than the traditional lecture method. Therefore, the researcher further experimented by developing another intervention with a new group of students the following year. The MR instructional approach included a total of eight representations, namely, text, pictures, diagrams, mathematical equations, simulations, animations, videos, and virtual labs. The effectiveness of the reconstructed approach was evaluated using the FMCI test. The same test was used after the first and second interventions as a pre-test and post-test. Finally, the results were compared to determine whether the students' understanding was enhanced. Findings indicated that adding eight representations produced significant change, which shows the effectiveness of the MRs approach (see Sections 7.5).

A one-way between-groups ANCOVA on the OEQ and FMCI post-test scores, with pre-test scores as a covariate, was used to determine if there was any significant difference between the results of the two groups (experimental and control group) and if there was a significant difference between the experimental group and the control group on the post-test scores of the FMCI test.

A small p-value (typically > 0.05) indicates strong evidence. The intervention using the experimental group enhanced the students' alternative conceptions and changed them to the correct conception, as the experimental group (MR) was more effective than the control groups (TL) (see Appendix M).

The results of Iteration II satisfied the differences between the two groups, and it was observed that they were statistically significant. Finally, when looking at the differences between the two groups, it can be seen that the MR approach gave better results. This difference was also confirmed by the t-test, and the difference in OEQ and FMCI in all three conception models was significant. Therefore, it is safe to conclude that the MR approach could have a better influence on students' understanding of fluid mechanics than the traditional lecture approach. Moreover, the researcher conducted a post-lesson Likert scale survey with the experimental group about how they felt about the teaching approach and its effectiveness. The students agreed that an MR approach was interesting and helpful (see Appendix O & W).

According to this study, the use of MRs was effective in teaching fluid concepts in introductory Physics courses, based on the results from undergraduate students. The use of MRs, such as animation and digital video projects, was effective in teaching fluid concepts in introductory Physics courses (Jaeger et al., 2009). At the same time, using video projects and using virtual laboratories helped students develop their creative and problem-solving skills. Hence, this method turns ideas into reality and facilitates peer learning. This was supported by the results found by Faour and Ayoubi (2018). Moreover, the use of MRs helps to relate graph and mathematical relations as well as text and pictures, which can help make visual imagination that can enhance student learning. Regarding these, the study found that visual imagery led to success in learning (Martnez & Rebello, 2012) when students used graphical logic to generate graphs (Fredlund et al., 2015).

To improve learning and comprehension of fluid mechanics topics. In this regard, the study found that the use of interactive simulations can help in visualising physical phenomena by providing a better understanding of fluid mechanics concepts. In relation to these results, the studies from the literature also showed that interactive simulation learning strategies were effective (Romero & Martnez, 2013; Smetana & Bell, 2012). In addition, the study found that by using simulations, it is possible to help students recall their previous understandings and expand them in new ways. The previous study also supported this idea (Fraser, 2013).

Furthermore, simulations helped students understand abstract concepts such as Bernoulli's principle and Archimedes' principle in-depth. These results were supported by previous studies (Heron & Christian, 2003).

In addition, the study also used computer-assisted animation and observed that it was effective in enhancing students' understanding. These animated videos can be effective in terms of coasting and saving time in the classroom when teaching. These results were supported by the results found by Faley (2011).

Moreover, the use of simulation methods in fluid mechanics increases students' understanding due to its rich expression in many ways. The study by Parlinduan, Andi and Liliasari (2014) concurs with this idea.

Generally, the use of the MRs approach is good for developing students' understanding. It also encourages students to grasp clues in the text, video, picture graph simulation, and animation, and these can help them to understand the concept of fluid mechanics. Therefore, the use of MR teaching methods is effective in fluid mechanics and Physics teaching.

7.12 CHAPTER SUMMARY

This chapter examined the effectiveness of the intervention, as the third phase was designed to examine whether the second intervention addressed the conceptual difficulties more effectively than the first. There was sufficient data and analysis in light of the task and it were described in great depth with empirical data shown in Tables in Sections 7.2–7.6. The qualitative analysis method was utilised to analyse the data obtained before, after, and two weeks after the first and second interventions. The VTL was used as a framework to identify the three categories of description, namely M1, M2, and M3. The overall findings in Chapter 7 show that MR-based approach learning sessions assist in improving students' conceptual understanding.

CHAPTER 8: CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This chapter discusses key findings from the research and links them to the literature. This study examined the use of the MR approach to develop fluid mechanics learning in undergraduate Physics classes in Ethiopia. By integrating a variety of research instruments, qualitative and quantitative approaches were both utilised. The study provided insight into the following sub-questions:

The study endeavoured to answer the following research questions:

- What are the categories of a students' understanding of fluid mechanics concepts?
- Which category of a students' understanding is dominant in fluid mechanics concepts?
- What are the effects of multiple representation approaches on students' understanding of fluid mechanics concepts?
- What are students' attitudes towards multiple representation approaches in fluid mechanics concepts?
- Is there any significant difference between Iteration 1 and Iteration 2 in the experimental group in terms of the students' understanding of multiple representation approaches in fluid mechanics concepts?

In the preceding chapter, the results of the data collection were presented. Within this chapter, research questions are answered, and how the theoretical framework influenced the interpretation of the findings. Lastly, the potential contributions of this study and the recommendations for future research are presented.

8.2 SUMMARY OF RESULTS

Fluid mechanics is a fundamental topic that is usually taught at the undergraduate level in Physics and Engineering classes. Basic concepts in fluid mechanics are applied in many fields of Science and Technology and are applicable in everyday life. However, there is a lack of student understanding of fluid mechanics. This study was conducted at two universities in Ethiopia to respond to a lack of student understanding of fluid mechanics, but more specifically on four concepts: Archimedes' principle (buoyant force), Pascal's principle (pressure measurement), fluid flow, and the Bernoulli principle. The concepts of the Archimedes' principle and buoyant force were used interchangeably, as were Pascal's principle and pressure measurement.

These two universities were conveniently selected, and two groups of undergraduate students (experimental N = 32 students and control N = 32 students) were selected for the first intervention. The study was based on a combination of three theories: variation theory, multiple intelligence theory, and cognitive learning theory. Both case study research design and experimental research design were used in different phases of the study, depending on the objective.

The research instruments used to collect data were the OEQ (see Section 4.4.1), the FMCI (see Section 4.4.2), and the SAMRQ (see Section 4.4.3).

The research was conducted in three phases. In the first phase, students' pre-understanding was analysed and classified. The data collected were analysed using model analysis, content analysis, and scale analysis, and it was divided into three categories: the correct conception model (M1), the common alternative conception model (M2), and the Null conception model (M3) (see Section 4.9). According to the analysis of the data, students do not have a complete understanding of fluid mechanics. This was found in both experimental groups and control groups before the interventions (see Section 4.9).

In the second stage, the first intervention was developed and used as an intervention in the experimental group (see Section 6.2). The control group was taught using normal teaching approaches. The developed teaching intervention used an MR instructional approach. The use of MRs has been shown in the literature to be effective (Fredlund et al., 2015). The first MR approach included four (4) representations (text, picture, diagram, and mathematical equations).

In the third stage, the first intervention was evaluated to find Iteration I (see Section 5.4), which needed to be altered to address students' understanding as the findings were not statistically significant. In addition, findings from the SAMRQ indicated that students had a strong positive attitude towards the MR approach.

In the fourth stage, the intervention was re-developed by adding another four (4) representations, making a total of eight (8) representations. The second intervention was implemented (see Section 7.6).

In the fifth stage, the re-developed intervention was evaluated for its effectiveness after Iteration II (see Section 7.6). Findings indicated that this re-developed intervention was statistically significant. Findings from the SAMRQ indicated that students had a strong positive attitude towards the MR approach.

8.2.1 Addressing the First Research Question

- Research Question 1: What are the categories of students' understanding in fluid mechanics concepts?

To answer the first research question, data were collected and analysed in the first phase during pre-intervention. Pre-intervention description categories refer to the different ways in which students were classified before any intervention. Following the developmental model analysis procedure, 64 (composed of 32 sets of students from each group) categories of description were produced in these three categories for each of the four concepts (see Tables 5.1–5.7). These depicted the various ways in which students comprehended and portrayed each of the four concepts (Archimedes' principle (buoyant force), Pascal's principle (pressure measurement), fluid flow, and the Bernoulli principle) disclosed in the three categories. One of the theories that were used in this research was the cognitive learning theory, which states that students' pre-perceptions (pre-conceptions) can hinder their new learning (Tennyson & Rasch, 1998). Moreover, Ausubel (1968) maintain that meaningful learning occurs when new knowledge is actively connected with a student's existing concepts or preconceived notions.

Therefore, the study began by examining students' preconceptions and then categorising them into three conception models (M1, M2, and M3) before any intervention. This was done to understand the students' prior knowledge (pre-conception). According to the findings, prior to the intervention, the majority of undergraduate Physics students were classified as M2 and M3, rather than M1. Students classified as M2 and M3 made up more than 65% of both the experimental and control groups (see Sections 5.2, 5.4, and 5.6). This indicated that most undergraduate Physics students had difficulty understanding fluid mechanics concepts before taking the course and that they did not have valid and acceptable prior knowledge of the topic. A statistically significant difference between the experimental and control groups in OEQ and FMCI assessments (see Sections 5.2–5.8) could not be established. The results of this study were supported by previous studies in the field (Loverude et al., 2003; Raissi et al., 2020), which indicated that students had a limited understanding and unsatisfactory knowledge of fluid mechanics prior to learning.

8.2.2 Addressing the Second Research Question

- Research Question 2: Which category of the students' understanding is dominant in fluid mechanics concepts?

Sections 5.2.1 and 5.2.2, which show the qualitative description of each idea in the Archimedes' principle, revealed the dominant category of students' understanding of the Archimedes' principle. These categories are presented in a hierarchy in which students understand and depict Archimedes' principle concepts. From this, it can be observed that when students were asked to state Archimedes' principle, the results indicated that most of the undergraduate Physics students fell into the alternative conceptions model category (M2). This shows that, on average, more than 40% of undergraduate Physics students had an alternative conception regarding Archimedes' principle. Furthermore, the results of Archimedes' principle concept analysis, which were collected using FMCI and Open Ended Questionnaire research instruments in both experimental and control groups, are presented in Sections 5.2.1 and 5.2.2.

Tire pressure, water flowing from the top of the mountain to the city, and petrol stations all use the Pascal principle (Halliday & Resnick, 2004). As a result, the pressure idea is covered in general Science from elementary through high school, and it eventually becomes part of the undergraduate Physics course in fluid mechanics. Accordingly, in this part of the analysis, the results of the data collected from OEQ and FMCI regarding the dominant category of students' understanding of Pascal's principle, as shown in Tables 5.4 and 5.5a, were presented. In conclusion, the dominant category of the students' understanding of Pascal's principle was in the M2 category, with an average of 44.60%. The next section provides a discussion of the literature on the alternative conceptions of Pascal's principle. "The motion of a fluid subjected to unbalanced forces is referred to as fluid flow." As long as unbalanced forces are applied, this motion will persist (Serway et al., 2004, p. 428). As a result, fluid flow is determined by the rate at which fluids flow through a tube, as well as other factors such as speed and volume. A garden hose attached to a tap that may be opened and closed is a practical example. Similarly, when studying fluid mechanics, students have difficulty grasping constant velocity and volume (Raissi et al., 2020). Alternative conceptions of fluid flow exist. In the M2 category, in the OEQ, the mean score was 40.62% (40.62 + 40.62). In the FMCI, there was an average of 39.50% (39% + 40%). As a result, in the experimental and control groups, the data collected by the research instruments (OEQ and FMCI) showed that an average of 40.06% of students were in the M2 category.

The Bernoulli principle is a fundamental idea in our daily lives. These applications include air transport, wing design, ballooning, parachute fighter jets, bombers, and other applications of Bernoulli principles. According to Bernoulli's law in fluid dynamics (Halliday & Resnick, 2004, p. 553), "an increase in speed is concurrent with a decrease in static pressure or a decrease in a fluid's potential energy." The results are discussed by comparing the experimental and control groups as described in the three conception models offered (see Table 5.9), as well as with the related literature. In conclusion, the dominant category of students' understanding of Bernoulli's principle was in the M2 category; an average of 39.5% of students were in the M2 category.

8.2.3 Addressing the Third Research Question

- Research Question 3: What are the effects of multiple representation approaches on students' understanding of fluid mechanics concepts?

Based on the findings from the first phase, MRs-based teaching was recommended in order to enhance the existing alternative conceptions of fluid mechanics. As MR is successful in various subjects, it was decided to use the variation theory in designing teaching activities to enhance learning in fluid mechanics. Teachers should be able to build learning approaches and activities for students to strengthen their learning of the concept to be learned (Cheng, 2016). They ought to encourage students to create similarities and differences among the concepts. Therefore, it is important to consider teaching holistically (Gardner, 1983).

As a result, MRs-based teaching was designed and built to address this question. This means the MRs-based teaching was created and constructed using the VTL as a lens, depending on the critical features (IAs) determined in the first phase (pre-intervention). The VTL was used as a lens to identify and organise the necessary learning circumstances for the concepts (Marton & Pang, 2006; Marton, 2014; Wright & Osman, 2018). Moreover, researchers in Science and Technology education agree that designing an instructional approach based on VLT can successfully improve teaching (Fredlund et al., 2015). This has been found in Science (Fraser et al., 2006), Engineering (Romero & Martnez, 2012; Bernhard, 2010; Ingerman et al., 2009), Chemistry (Lo, 2012), Mathematics (Runesson, 2005), Languages (Marton et al., 2010) and Economics (Pang et al., 2006) as well as in students with diverse backgrounds. The learning activities were designed and built with various types of representations, including verbal and written explanations; equations; graphs; diagrams; simulations; videos; animations; and virtual labs (see Sections 6.2 & 7.5). The VTL asserts that different learners comprehend the same learning item in various ways (Marton & Booth, 1997; Marton & Tsui, 2004). Some researchers refer to these as semiotic resources (Volkwyn et al., 2020; Wright & Osman, 2018).

In addition to these, Gardner's theory of multiple intelligence states that everyone has natural inclinations and talents, and they choose to learn accordingly. Using their natural inclinations will help them better understand and develop problem-solving skills (Gardner, 1983). According to Gardner, it is effective to teach students with a variety of representations so that, based on their talents, they can learn according to their inclinations and talents as this motivates them. Similarly, the study states that individuals can understand the same concept (phenomenon) from different perspectives and, thus, come to understand the phenomenon that is expressed in different ways (Bussey, Orgill & Crippen, 2013; Orgill, 2012). It is for this reason that it is important to focus our attention on using the instructional approach, which includes a variety of representations, to make sure that students understand the concept.

Therefore, how the lessons were developed for the four different concepts are captured in Sections 6.2 and 7.5 and Appendices J and R.

8.2.5 Addressing the Fourth Research Question

- Research Question 4: What are students' attitudes towards multiple representation approaches in fluid mechanics concepts?

The third phase begun by exposing students in the control group to traditional instruction, and the experimental group was exposed to the MR approach.

To investigate the third study question, the pre-intervention findings were used as a baseline and compared to the post-intervention outcomes to determine the intervention's efficacy. The goal was to see if MRs-based education, which was used as an intervention, was effective. The students were exposed to the MRs teaching method for two weeks (see Table 5.1 and Section 5.2). The success of this teaching technique was determined using some criteria described in Section 6.1, which were chosen by the researcher, as well as Tables 6.1–6.6.

After the intervention, there were fewer M3 students, while a larger number of students had moved into the M1 category (see Table 6.1–6.6). Moreover, the study showed that the use of the MR interventions (which include the text, diagrams, illustrations, graphs, mathematic equations, and simulations) approach is a good strategic plan that can enhance students' alternative conceptions of fluid mechanics in an undergraduate Physics class. This was also supported by the results found in previous studies (Distrik, Supardi & Jatmiko, 2021; Einsworth, 2006; Hwang & Hu, 2013; Moseley & Brenner, 1997; Rosengrant et al., 2009; and Tytler & Prain, 2013).

Moreover, it was also recommended that further investigation should be done to evaluate teaching sequences. The MR-based teaching intervention was effective in developing students' ability to infer meaning and interpret information. Students actively engaged in understanding the text's unstated implications and assumptions as a result of its rich depth (Fredlund et al., 2015). For students, attempting to discern this significance, provide a great opportunity to discuss their interpretations based on the evidence provided in the text. In addition, the effectiveness of stimulation can be observed in improving students' critical thinking skills, which is one of the important skills in dealing with the demands and challenges of the 21st century. This idea was supported by Saputri, Rinanto and Prasetyanti (2019). In the case of class work, students will become more confident in expressing their thoughts (see Section 7.6).

Moreover, the conceptual model of student responses in both groups was not consistent after the intervention. Similarly, simulations have proven that students can recall their previous understanding and expand this in new ways. Studies have shown that the interaction of physical phenomena with computer simulations that visualise physical phenomena provides a better understanding of the concept of fluid mechanics theory (Fredlund et al., 2015; Romero & Martnez, 2013; Fraser, 2013).

On the other hand, using simulations allows students to understand Bernoulli's principle and Archimedes' principle in the classroom, making it easier for them to understand the concepts. Regarding these, the study by Heron and Christian (2003) concurs with the obtained result. In addition, simulation and the use of computer-assisted animation are effective in saving time in teaching. Moreover, the research also states that because the simulation method is rich in understanding the levels of interpretation in many ways, the MRs approach is good for developing students' skills and increasing their understanding. Romero and Martnez (2013) and Faley (2011) also support this idea.

It also encourages students to grasp the ambiguity of the text and helps them understand the meaning of the text. Similarly, the use of visual imagery and using mathematical equations to generate graphs of pressure vs. temperature was a great success in learning fluid mechanics. These ideas are supported by Martnez and Rebello (2012); Faley (2011); Fredlund et al., (2015); and Parlinduan et al., (2014).

Therefore, for undergraduate students, the use of MR, such as animation and digital video projects, was effective in teaching fluid concepts in introductory Physics courses. The study by Jaeger et al. (2009) also supports this idea. Therefore, based on this finding, the use of the MRs teaching method is effective in fluid mechanics Physics teaching.

8.2.5 Addressing the Fifth Research Question

- Research Question 5: Is there any significant difference between Iteration 1 and Iteration 2 in the experimental group in terms of students' understanding of multiple representation approaches in fluid mechanics concepts?

The understanding of Archimedes' principle (buoyancy force) in fluid mechanics was examined in the OEQ and FMCI for undergraduate first-year Physics students. Prior to the intervention, the majority of undergraduate students used M1, but about two-thirds of them used M2 and M3. When looking at the results of both assessments in each conception model, the results obtained in one assessment (OEQ) were repeated in the other assessment (FMCI). This indicates that the results obtained by one were confirmed by the other. Thus, the M2 and M3 students comprised more than 65% of the 64 students.

The study increased the number of MRs from 4 to 8. The study proved that using eight representations in teaching fluid mechanics was more effective in addressing students' alternative conceptions. In the same way, ANCOVA (one-way analysis of covariance) was used to compare the scores of the two groups (experimental and control) after Intervention I. The experimental and control groups were compared using a one-way between-group analysis of variance with pre-intervention scores as a covariate to determine if any significant differences existed between their performances. Sixty-four students from both groups submitted their pre- and post-scores to FMCI. Based on an ANCOVA analysis, Table 7.14 summarises the confirmation of the effectiveness of the reconstructed MR. There was a significant difference in FMCI scores between the two groups after Iteration II: (1, 63) = 0.447, $p = 0.000$ (partially squared eta squared value for the effect size of 0.447 (see Table 7.14).

According to the partial eta squared value for the effect size of the second intervention, Iteration II had a greater effect size. In Iteration I, the FMCI score was (1, 63) = 0.294, $p = 0.000$ (a partial eta squared value for an effect size of 0.294 as shown in Table 7.14).

While the MR approach contributed somewhat to students' alternative conceptions compared to the control group, i.e., some students shifted away from M2 and M3, the effect size was not substantial enough to confidently claim the approach's efficacy in the experimental group. However, in Iteration II, the results indicated that the reconstructed MR approach contributed to addressing students' alternative conceptions. Therefore, in shifting students from the category of M3 and M2 to the category of M1, Iteration II (reconstructed MR) was more effective than Iteration I (MR).

Furthermore, when looking at the difference between the two groups, there was no statistically significant difference between the experimental and control groups, and the distribution was the same for both groups (Section 7.2.2).

These findings indicate that although students' progress from M2 to M3 to M1 in their understanding, some of them still struggle to grasp concepts following training. According to a study, when first-year Physics students were asked to explain the buoyancy force equals trust pressure and Archimedes' principle while learning, the majority of students struggled (Martnez, 2012). Similar results were reported by Raissi et al. (2020). Furthermore, the groups had different scores on both assessments (OEQ and FMCI) (see Sections 7.3.1, 7.3.3, 7.3.7.2, 7.3.7.3, and 7.3.7.4). However, when using a paired-sample t-test, the differences between the groups were not statistically significant (see Sections 5.3.2, 5.3.5, and Appendices H and I). The difference between the experimental and control groups is, therefore, not statistically significant, even if it does exist.

Multiple representations are a unique learning approach conducive to all students. These approaches are multifaceted, for example, with one student excelling at using words, images, and Maths while another excels at only one (Sewell, 2002). According to Bakri and Mulyati (2018), MRs are appropriate teaching methods that have been applied to the design and teaching of basic Physics.

In general, in enhancing the alternative conceptions of the students, the experimental group (reconstructed MR) class was more effective than the control group (TL) class.

8.3 CONCLUSIONS

MRs can be used to support contextual learning in basic Physics. In a basic Physics course, students can be given multiple representations of a concept to help them understand it better.

The MRs approach, with eight different representations, namely text, pictures, diagrams, mathematical equations, simulations, animations, videos, and virtual labs, can simplify students' understanding of fluid mechanics. Thus, this is better than using the same approach with four representations (text, picture, diagram, and mathematical equations). Based on their performance in the instruments, after using the MR approach with eight different representations (text, pictures, diagrams, mathematical equations, simulations, animations, videos, and virtual labs), students' conceptual understanding improved. There are multiple representations presented in the form of contextual learning, including relating, experiencing, applying, cooperating, and transferring (Dimas et al., 2018). Learning Physics with a multi-exposure representation of Science is expected to make students better at resolving Physics problems (Munfaridah, Avraamidou & Goedhart, 2021).

8.4 CONTRIBUTION OF THE STUDY TO THE BODY OF KNOWLEDGE

This study differs from previous studies in the following ways:

Firstly, student understanding was established by categorising their answers into three different models (correct, alternative, and Null model). Although previous researchers such as Fredlund et al. (2015) found that students had difficulties with concepts in fluid mechanics, they did not categorise student answers into the three models. Categorising a student's alternative conceptions is a powerful learning mechanism (Peikos et al., 2020). The current study supports previous findings that student understanding was more inclined towards the alternative and Null conception models. In other words, they did not readily understand concepts in fluid mechanics.

The second contributing factor that distinguishes this study from others is that it combines three theories (namely, cognitive learning theory, Variation Learning Theory, and multiple intelligence theory) and develops methods based on the student's different learning needs to enhance their understanding. In past studies, researchers only used one or two theories (Roschelle, 2021). Therefore, this study is more inclusive as compared to previous studies.

Thirdly, the MR approach with eight representations was tried out in a developing country environment on the topic of fluid mechanics. According to the researcher's knowledge, this has never been done in any previous study. For example, Faour and Ayoubi (2018) used only three representations and did not try to improve them or add other representations at a later time.

8.5 RECOMMENDATIONS

Teaching fluid mechanics is needed for students' competence in the manipulation of problems, such as calculation of stating Bernoulli's principle mathematical equations and applying the concept in their daily life.

Policymakers and curriculum designers:

It is recommended that policymakers and curriculum designers ought to use the MR approach to establish effective instructional approaches for teaching fluid mechanics. This enables practitioners to provide students with the opportunity to improve their understanding of fluid mechanics.

University academic managers and teachers are expected to:

Every lesson using MR approaches is described (see Section 6.2) and can assist other researchers and higher education academics to use these lessons or change them according to their context. By providing examples of lessons, academics would not have to start from the beginning. Moreover, it is recommended that using the eight representations is better than four. When using the MR approach, eight or more different representations need to be added as they need to address students' different bits of intelligence (e.g., visual, words). Other topics and levels (primary, high school, or university) need to be explored using the MR approach.

The lessons must be flexible, and the activities must be adjustable according to the ability of the student. Research needs to be conducted to establish the effectiveness of any teaching sequence. If the teaching sequence is not effective, changes to the approach need to be made until conceptual understanding is facilitated.

It is recommended that students' prior understanding before developing a focused teaching approach ought to be established. Categorising students' understanding of fluid mechanics can provide other teachers and researchers with insight into research topics and come up with sound findings useful to support students' understanding of fluid mechanics.

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APPENDICES

APPENDIX A: ETHICAL CLEARANCE

UNISA | college of science, engineering and technology

Dear Mr Ashenafi, L. S. (5579947)

Date: 2014-09-09

Application number: 2014_CGS/ISTE_009

REQUEST FOR ETHICAL CLEARANCE: (Solving thermodynamics problems using a multiple representations approach: A case of an Ethiopian University.)

The College of Science, Engineering and Technology's (CSET) Research and Ethics Committee has considered the relevant parts of the studies relating to the abovementioned research project and research methodology and is pleased to inform you that ethical clearance is granted for your research study as set out in your proposal and application for ethical clearance.

Therefore, involved parties may also consider ethics approval as granted. However, the permission granted must not be misconstrued as constituting an instruction from the CSET Executive or the CSET CRIC that sampled interviewees (if applicable) are compelled to take part in the research project. All interviewees retain their individual right to decide whether to participate or not.

We trust that the research will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate, as stipulated in the UNISA Research Ethics policy. The policy can be found at the following URL:
http://cm.unisa.ac.za/contents/departments/res_policies/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf

Please note that the ethical clearance is granted for the duration of this project and if you subsequently do a follow-up study that requires the use of a different research instrument, you will have to submit an addendum to this application, explaining the purpose of the follow-up study and attach the new instrument along with a comprehensive information document and consent form.

Yours sincerely

Prof Ernest Mnkandla
Chair: College of Science, Engineering and Technology Ethics Sub-Committee

Prof IOG Moche
Executive Dean: College of Science, Engineering and Technology

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ISTE-SUB RESEARCH ETHICS REVIEW COMMITTEE

Date: 09/12/2014

Ref #: 2014_CGS/ISTE_009
Name of applicant (student/researcher): **Mr. ASHENAFI LEGESE SEGNI**
Student #:**55759947**
Staff #:

Dear **Mr. ASHENAFI LEGESE SEGNI,**

Decision: Ethics Approval

Name: Mr. ASHENAFI LEGESE SEGNI, Mizan-Tepi University, 55759947@mylife.unisa.ac.za +251912453238

Proposal: Solving Thermodynamics Problems using a Multiple Representations approach: a Case of an Ethiopian University

Qualification: Postgraduate degree research

Thank you for the application for research ethics clearance by the *ISTE SUB* Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the study

The application documents were reviewed in compliance with the Unisa Policy on Research Ethics by the Committee/Chairperson of ISTE SUB RERC on 09 September, 2014. The decision will be tabled at the next RERC meeting for ratification.

The proposed research may now commence with the proviso that:

1) *The researcher will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics, which can be found at the following website: http://www.unisa.ac.za/cmsys/staff/contents/departments/res_policies/docs/Policy_Research%20Ethics_rev%20app%20Council_22.06.2012.pdf. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the ISTE Sub Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*

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2) The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the IST Sub RERC.

Kind regards,

Signature
Dr CE Ochonogor
Title & Name of the chairperson

Signature
Title & Name of the Executive dean

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Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
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APPENDIX B: LETTER OF COOPERATION

Mizan-Tepi University
ሚዛን-ቴፒ ዩኒቨርሲቲ
College of Natural & Computational Science
የተፈጥሮና ኮምፒዩቴሽናል ሳይንስ ኮሌጅ
Dean's Office
ዲን ጽ/ቤት

ቁጥር No MTU/CNCS -319/11-4/07
ቀን Date 05/03/07

To Whom It May Concern:

Subject: Letter of Cooperation for Data Collection

Mr. Ashenafi Legesse Segni has requested permission to collect research data from students through a project entitled **Solving Thermodynamics Problems using a Multiple Representations approach: a Case Study in Mizan-Tepi University, Ethiopia.** I have been informed of the purposes of the study and the nature of the research procedures. I have also been given an opportunity to ask questions of the researcher.

Mizan-Tepi University has policies in conjunction with College and the Department regarding the following ethical requirement:

- The right of students to inspect, upon request a study created by a third party before the study is administered or distributed by a school to students.
- Arrangements to protect student privacy in the event of the administration of a study to students, including the right of participants to inspect, upon request.
- The right of participants to inspect, upon request, any instructional materials used as part of the educational curriculum for students.
- The administration of physical examinations or screenings that the school may administer to students.

As a representative of college of Natural and computational science, I am authorized to grant permission to have the researcher use research participants from our college Mr. Ashenafi Legesse Segni is also permitted to collect research data during school hour.

With Best regards

ደምሴ ታረቀኝ ገረመው
Demissie Tarekegn Geremew
የተፈጥሮ እና ኮምፒዩቴሽናል ሳይንስ ኮሌጅ ዲን

+251-47-556-2015
+251-47-556-1249
Please, Quote Our Reference No for reply
Fax - +251-047-556-1837
P. O. Box 121 -ቴፒ

Mizan Tepi University
College of Natural & computational science
Department of Physics

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የተፈጥሮና ቀመር ሳይንስ ኮሌጅ
የፊዚክስ ትምህርት ክፍል

ቁጥር/Ref. No.: PHD/116/14

ቀን/date Nov 14, 2014

To Whom IT may concerned

Subject : Letter of cooperation for data collection

I am writing to express my support for Mr. Ashenafi Legese Segni research study, "Solving Thermodynamics Problems using a Multiple Representations approach: a Case Study in Mizan-Tepi University, Ethiopia," to be conducted by our staff member in Mizan-Tepi University.

I have also been given an opportunity to ask questions of the researcher will explain regarding the following ethical requirement:

- The purposes, contents and procedures of the research;
- How they could potentially benefits from the research;
- No pain, physical problems etc will be suffered.
- The pre and post tests will not count for the students' final grade.

To that end, we are permeating and write our willingness to collect data regarding his study, because we strongly believe that these studies can help us to achieve our educational goal. Conducting his studies and research within our University would improve and increase our student's knowledge and practical experience towards their mission. We look forward to learning the results of his study. Thank you for your attention and considering our letter.

With regards,

Temesgen Kassaw

Head, Department of Physics

Cc:

- Department of Physics

☎ +251-47556 1496 Please quote our reference No for reply. Fax: 251 -47556 1837
✉ 121 Tepi, Ethiopia

APPENDIX C: STUDENT RESEARCH CONSENT FORM

Research Topic: The use of Multiple Representation Approach in enhancing the learning of fluid mechanics in undergraduate Physics classes in Ethiopia.

Purpose of the Research: The purpose of this study is to explore students' conceptual understanding in selected areas of undergraduate fluid mechanics Physics and then use a variation theory approach to design an instructional approach to alleviate their alternative conceptions; as one part of my PhD study at UNISA.

Researcher's Name: Ashenafi Legese Segni (SEGNI, A L)

Address: Mizan-Tepi University, P.O. Box 121, Tepi, Ethiopia

Telephone: +251912453238 (Mobile), E-mail: ashenafilegesse@mtu.edu.et

Research Site: An Ethiopian University.

Participant's Name: ________________________Position:______________

Address: ________________________________ Telephone: ___________

Participant Rights And Assurances

I have received a copy of the consent letter for the aforementioned research study. Having read the application, I am familiar with the purpose, methods, scope, and intent of the research study.

Please Check One Of The Following: ("Yes" For Willing Or "No" For Not Willing)

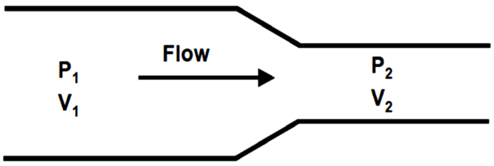
I am willing ______ I am not willing_______ to participate in the research study. I understand that during this research my responses will be kept strictly confidential and that none of the data released in this study will identify me by name or any other identifiable data, descriptions, or characterisations. In addition, I understand that I may discontinue/terminate /my participation in this study at any time or refuse to respond to any questions to which I choose not to respond. I am a voluntary participant and have no liability or responsibility for the implementation, methodology, claims, substance, or outcomes resulting in any adverse consequences or disparate treatment I fully understand that this research is being conducted for constructive and upgrading educational purposes and that my signature gives my consent to voluntarily participate in this study.

Participant's signature ________________ Date_____________________

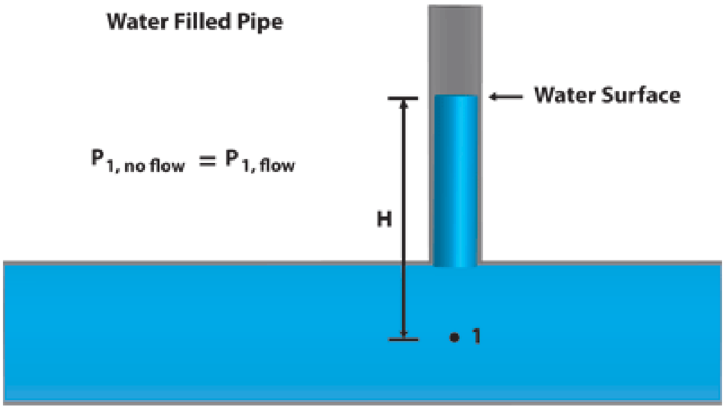
APPENDIX D: OPEN-ENDED QUESTIONNAIRES ON FLUID MECHANICS

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

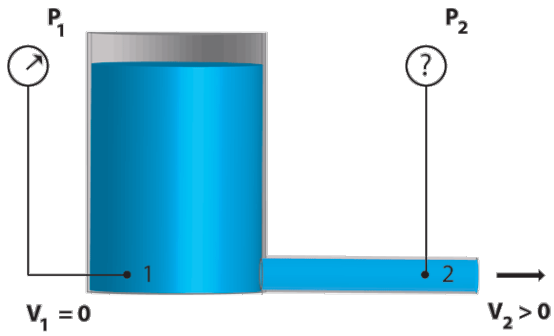
1. Water flows through a pipe and enters a section where the cross-sectional area is smaller. Viscosity, friction, and gravitational effects are negligible. What did you say about the change in pressure p and average velocity V? Why?



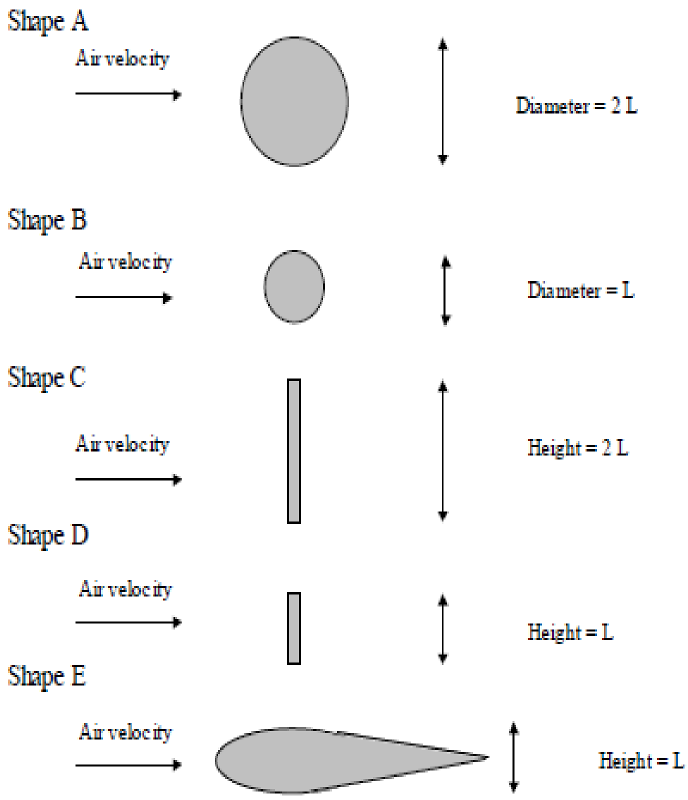
2. A pipe is filled with water under pressure as shown below and a small diameter tube open to the atmosphere is connected to the top of the straight pipe. When the water is not flowing, the pressure at point 1 causes water to rise at a distance of H from the pipe centreline. When water flows steadily through the pipe from left to right, how will the height in the vertical tube change if the static pressure at point 1 does not change (P1, no flow = P1, flow)? Why?



3. Water flows from a tank through a pipe section as shown below. Points 1 and 2 are located at the same vertical height and the pressure gauges are mounted at the same vertical position. If the water velocity at point 1 is negligible, frictional losses are essentially zero, and there are no entrance/exit effects in the tank and pipe, how is the pressure at points 1 and 2 related? Why?



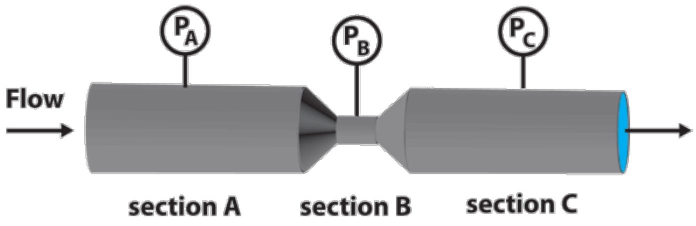
4. Problems 4 and 5: Air flows over the various shapes shown in the cross-section below. The air velocity is the same for each of the shapes and the relative dimensions are as given in the sketch.



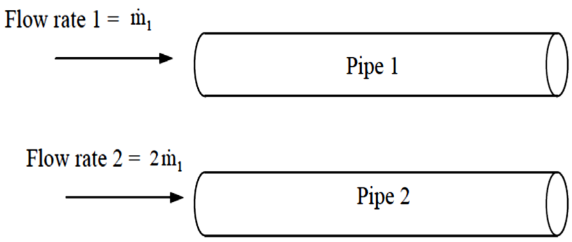
5. Which shape has formed the highest drag force (force due to pressure differences)? Why?

   Which shape has the highest skin friction drag force (force due to viscous friction)? Why?

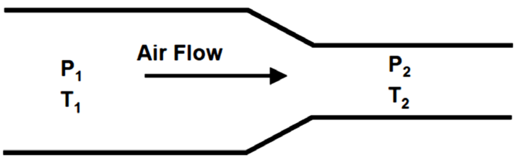
6. For the piping system shown below, water is flowing from left to right at a steady-state and constant temperature. You may assume the flow is frictionless. The pipe diameter is larger in Section A than in Section B. The diameters of Sections A and C are the same. If gravitation and frictional effects are negligible, what did you say about the relationships of the static pressure in Sections A and B? Why?



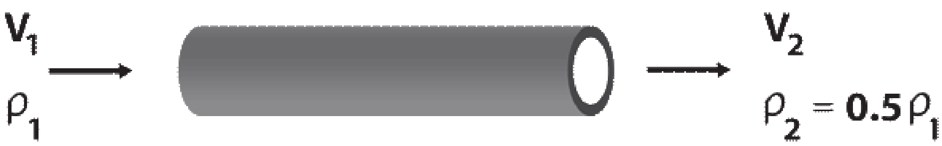
7. Water flows through two smooth pipes with the same diameter and length as shown below. The flow rate through the second pipe is twice that through the first pipe. Both flows are laminar and fully developed. What do you say about the pressure drop (pressure difference over the pipe length)? Why?



8. Air flows through a well-insulated pipe and enters a section where the cross-sectional area is smaller. Viscosity, friction, and gravitational effects are negligible. What do you say regarding the pressures of the airflow? Why?

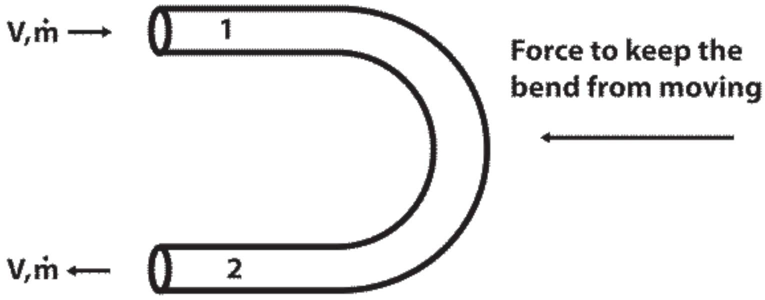


9. A fluid flows steadily through a circular pipe of the uniform cross-sectional area as shown below. If the outlet density of the fluid decreases to half of its inlet value, what happens to the average fluid velocity? Why?

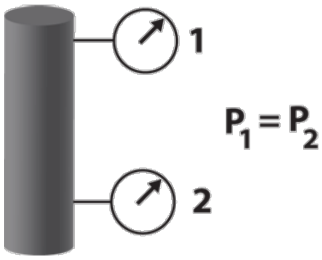


10. A horizontal bend of constant cross-sectional area (A) pipe is shown below (you are looking down on the bend from above). Water flows through the bend at steady flow conditions and the pressure is the same at points 1 and 2 (P1 = P2 = P). The mass flow rate (m) and velocity

(V) in the pipe are also constant. What is the magnitude of the force required to keep the bend from moving? Why?



11. A long vertical pipe filled with water is equipped with pressure gauges at each end as shown below. A Physics student observing the pipe notices that each pressure gauge reads the same value. Is the water flowing in the pipe? If so, in what direction is the water flowing? If not why?



12. A diver moves horizontally from the underside of a bridge structure (position 1) to open water (position 2). Ignoring effects like currents in the water, what pressure change will the diver sense between positions? Why?

APPENDIX E: DIAGNOSTIC EXAM ON FLUID MECHANICS CONCEPT INVENTORY (FMCI)

Purpose: The purpose of the inventory is to evaluate whether students understand the concepts in a course. The results of inventories will eventually use to improve instruction in fluid mechanics and related courses. To improve the way courses are taught. Concept Inventories have been and are being developed for many topics in Physics. There are 26 multiple choices and we would like you to try to answer each question based on your knowledge. Please do not use text to help answer the question.

Student code number _______________

Gender

a. Male b. Female

What University do you attend? ___________________________.

The instruction I: Student please try to answer each question based on your knowledge. Please do not use text to help answer the question.

1. A fluid flows steadily through a pipe with a uniform cross-section area. The density ρ of the fluid decreases to half its initial value as it flows through the pipe. Circle the letter of the correct statement about the average velocity V.

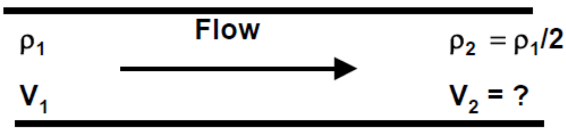
A. V2 equals 2 V1

B. V2 equals V1/2

C. V2 equals V1

D. V2 equals V1/4

E. V2 equals 4 V1



2. Water flows through a pipe and enters a section where the cross-sectional area is smaller. Viscosity, friction, and gravitational effects are negligible. Circle the letter of the correct statement about the change in pressure p and average velocity V.

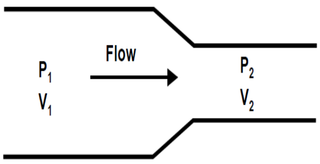
A. P2 is less than P1 and V2 is less than V1

B. P2 is less than P1 and V2 is greater than V1

C. P2 is greater than P1 and V2 is less than V1

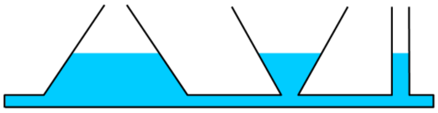
D. P2 is greater than P1 and V2 is greater than V1

E. P1 is equal to P2 and V1 is equal to V2

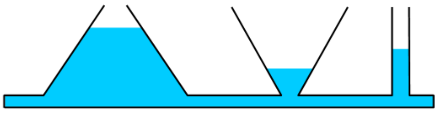


3. Three containers connected at the base are filled with fluid. The top of each container is open to the atmosphere and surface tension is negligible. The container shapes are all different. Circle the letter for the figure that shows the correct fluid levels in the containers at equilibrium conditions.

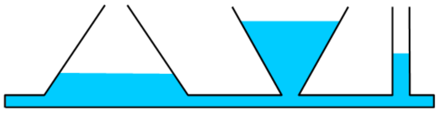
A.



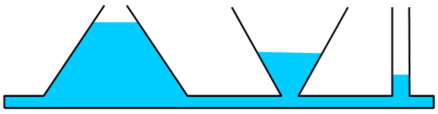
B.



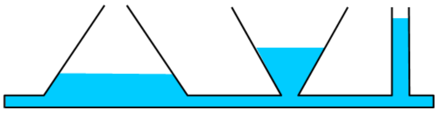
C.



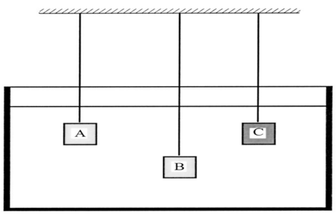
D.



E.



4. Three cubical blocks of equal volume are suspended from the string. Blocks A and B have the same mass and block C has less mass. Each block is lowered into a fish tank to the depth shown in the figure below.



In which one of the blocks is the tension the highest?

Ok, why did you say that?

Which one of the blocks the tension string is the smallest?

Ok, how do you explain your reasoning?

5. Air flows through a well-insulated pipe and enters a section where the cross-sectional area is smaller. Viscosity, friction, and gravitational effects are negligible. Circle the letter of the correct statement regarding the temperatures and pressures of the airflow.

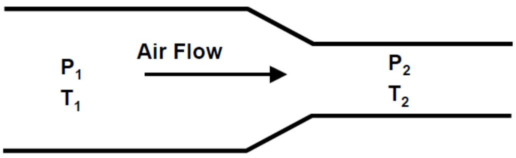
A. The pressure P2 equals P1 and the temperature T2 equals T1

B. The pressure P2 is greater than P1 and the temperature T2 is greater than T1

C. The pressure P2 is greater than P1 and the temperature T2 is less than T1

D. The pressure P2 is less than P1 and the temperature T2 is greater than T1

E. The pressure P2 is less than P1 and the temperature T2 is less than T1



6. A layer of water is between a stationary surface and a moving plate as shown in the two figures below. The plate velocities in each figure are the same. The water in the second figure is twice as deep as the water layer in the first figure. The water layer is laminar. Circle the letter of the correct statement about the forces.

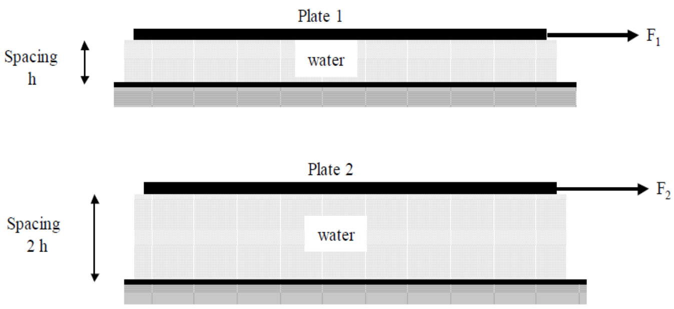
A. F1 equals 2 F2

B. F1 equals 4 F2

C. F1 equals F2/2

D. F1 equals F2/4

E. F1 equals F2



7. A two-dimensional gate is submerged in water. Circle the letter of the figure that best represents the pressure distribution of the water on the left-hand (water) side of the gate.

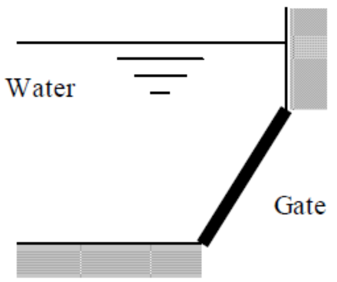
A. Figure A

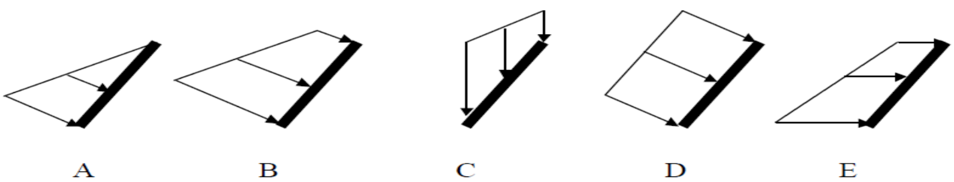
B. Figure B

C. Figure C

D. Figure D

E. Figure E



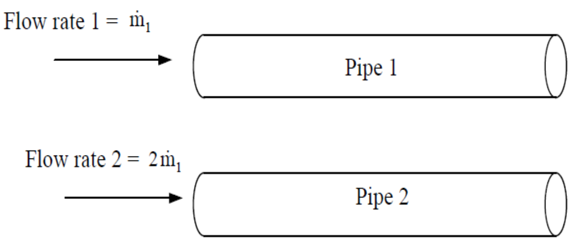


8. Water flows through two smooth pipes with the same diameter and length as shown below. The flow rate through the second pipe is twice that through the first pipe. Both flows are laminar and fully developed. Circle the letter of the statement that is correct about the pressure drop (pressure difference over the pipe length).

A. Pipe 1 has the higher pressure drop

B. Pipe 2 has the higher pressure drop

C. Pipes 1 and 2 have the same pressure drop



9. Pitot tubes are placed in two ducts in which air flows as shown below. The density and temperature of the flows are equal. The dynamic (velocity) pressure and the static pressure taps are connected to two manometers. The pressure difference for Duct A is 2” of water and that for Duct B is 4” of water. Circle the correct answer for the velocity VA in Duct A relative to the velocity VB in Duct B.

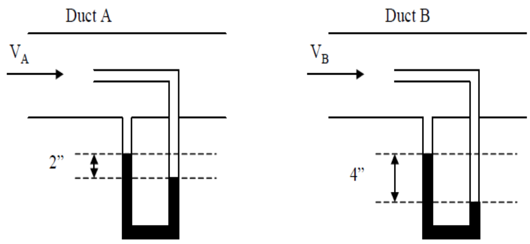
A. VB equals 2 VA

B. VB equals VA

C. VB equals VA

D. VB equals VA /

E. VB equals VA /2



10. Three cubical blocks of equal volume are suspended from the string. Blocks A and B have the same mass and block C has less mass. Each block is lowered into a fish tank to the depth shown in the figure below which of the block has the highest tension?

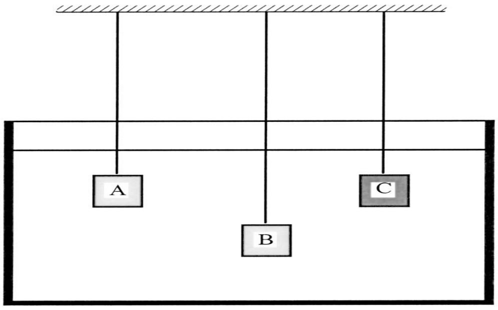
A. Block A

B. Block B

C. Block C

D. Block A and B

E. Block A and C



11. In the above question which one of the blocks the tensions string is the smallest.

A. Block A

B. Block B

C. Block C

D. Block A and B

E. Block A and C

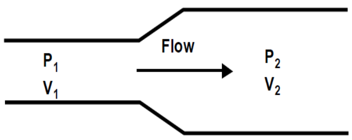
12. Water flows through a pipe and enters a section where the cross-sectional area is larger. Viscosity, friction, and gravitational effects are negligible. Circle the letter of the correct statement about the change in pressure p and average velocity V.

A. P2 is less than P1 and V2 is less than V1

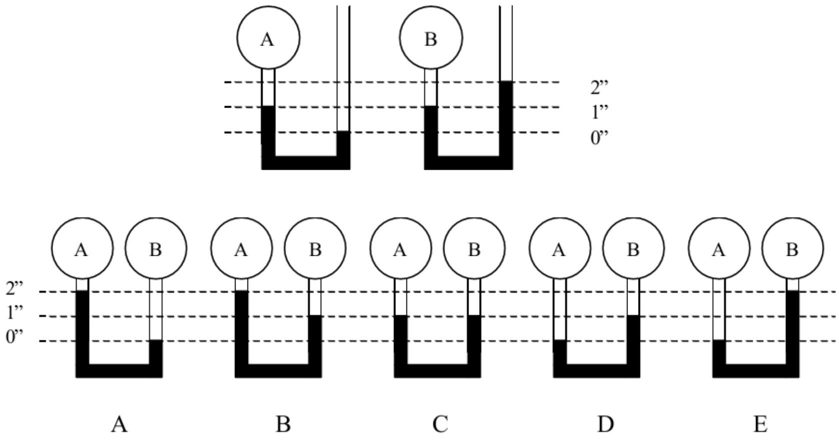
B. P2 is less than P1 and V2 is greater than V1

C. P2 is greater than P1 and V2 is less than V1

D. P2 is greater than P1 and V2 is greater than V1



13. Two tanks filled with air are shown below. Water-filled manometers that are open to the atmosphere are connected, and the water levels are as shown. Circle the letter of the correct answer for the water levels when a single manometer joins the two tanks.



A. Figure A

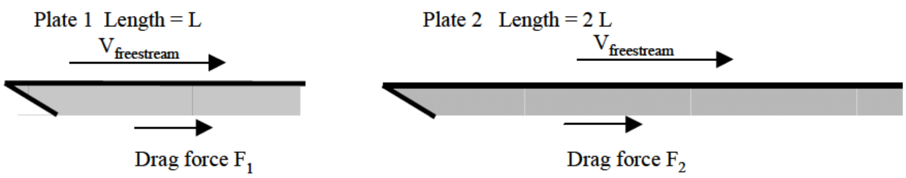
B. Figure B

C. Figure C

D. Figure D

E. Figure E

14. Water flows over two flat plates as shown below. The free stream velocity is the same for both plates and the flow is laminar. The second plate is twice as long as the first plate, but both plates have the same width. Circle the letter of the correct statement.



A. The drag force F2 is greater than 2 times the drag force F1

B. The drag force F2 equals 2 times the drag force F1

C. The drag force F2 is less than 2 times the drag force F1

D. The drag force F2 equals the drag force F1

E. The drag force F2 is less than the drag force F1

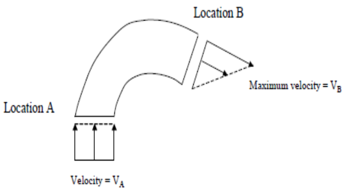
15. Water at room temperature and pressure flows steadily through the bend in the constant area channel shown below. As a result of the bend, the velocity profile changes from the uniform profile shown at location A to a profile at location B that is linear with a maximum velocity of VB. Circle the correct statement.

A. The velocity VA at location A equals VB/2

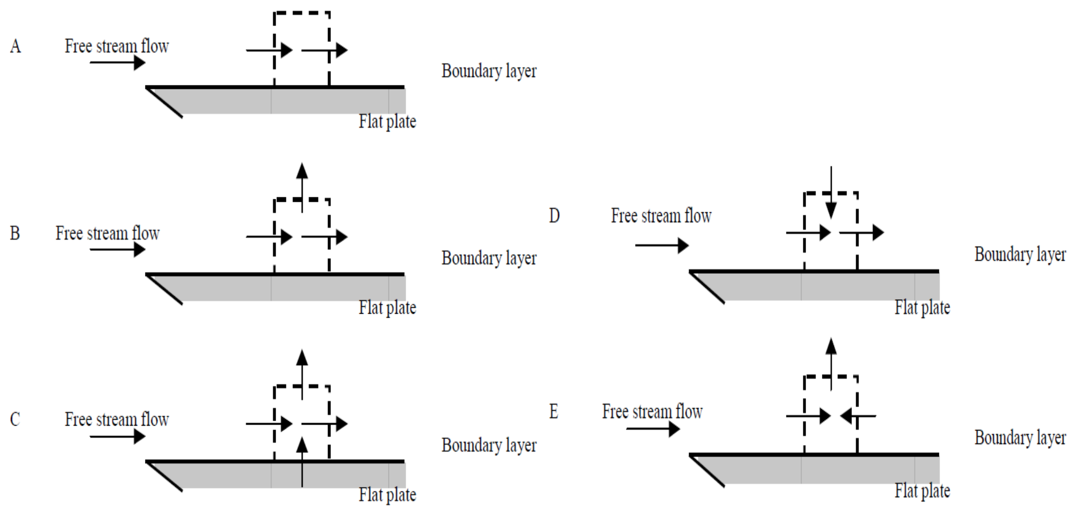
B. The velocity VA at location A equals 2 VB

C. The velocity VA at location A equals 1.5 VB

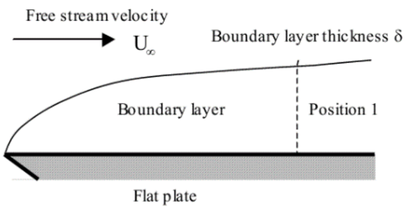
D. The velocity VA at location A equals VB

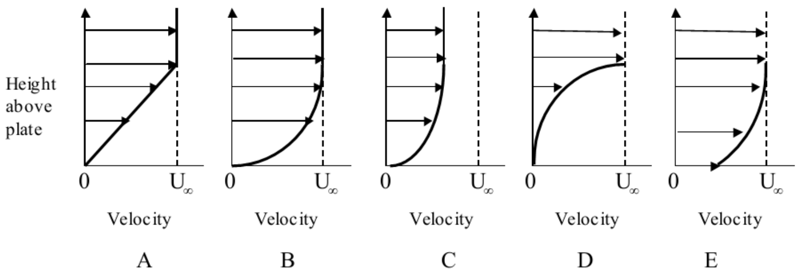


16. Air flows over a flat plate as shown below. A control volume (fixed volume in space through which the fluid flows) is shown by the dotted lines. The direction of the airflow through each surface of the control volume is shown by an arrow, with the velocity being positive in the direction of the arrow. Circle the letter of the figure that best represents the directions of the airflow through the control volume.



17. Air flows over a flat plate as shown below. The flow is laminar and a boundary layer forms on the plate. Circle the letter of the statement that best represents the velocity profiles inside the boundary layer at position 1.





A. Velocity profile A

B. Velocity profile B

C. Velocity profile C

D. Velocity profile D

E. Velocity profile E

18. Circle the letter of the correct statement about pressure in a fluid.

   A. Pressure is a body force

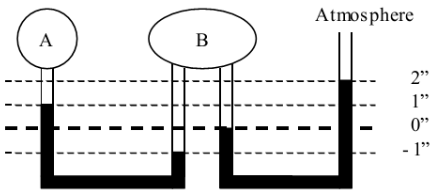
   B. Pressure acts normal to a surface

   C. Pressure is a frictional force

   D. Pressure acts parallel to a surface

   E. Pressure is the reaction force

19. Two tanks filled with air and connected by water-filled manometers are shown below. The water levels are as shown. Circle the letter of the correct answer for the gauge pressure (the pressure relative to atmospheric) for Tank A.



A. PA equals + 3" water

B. PA equals + 1" water

C. PA equals + 0 " water

D. PA equals – 1 " water

E. PA equals – 3 " water

20. Water flows vertically up through a pipe and enters a section where the cross-sectional area is smaller. Viscosity and pipe friction effects are negligible but gravitational effects are not negligible. Circle the letter of the correct statement about the pressure P2 and velocity V2.

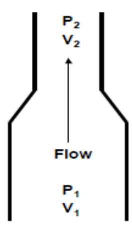
A. P2 equals P1 and V2 equals V1

B. P2 is greater than P1 and the V2 is greater than V1

C. P2 is greater than P1 and the V2 is less than V1

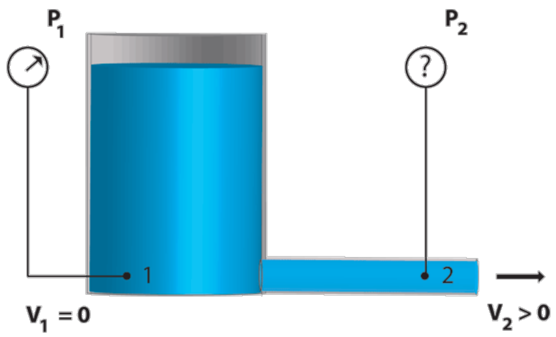
D. P2 is less than P1 and the V2 is greater than V1

E. P2 is less than P1 and the V2 is less than V1



21. Water flows from a tank through a pipe section as shown below. Points 1 and 2 are located at the same vertical height and the pressure gauges are mounted at the same vertical position.

If the water velocity at point 1 is negligible, frictional losses are essentially zero, and there are no entrance/exit effects in the tank and pipe, how is the pressure at points 1 and 2 related?



A. $P_1 = P_2$ because friction is negligible in the flowing fluid

B. $P_1 < P_2$ because of the force required to push fluid into the pipe

C. Can't Determine Without Knowing The Fluid Density And Viscosity

D. $P_1 > P_2$ because pressure decreases as velocity increases according to the Bernoulli principle

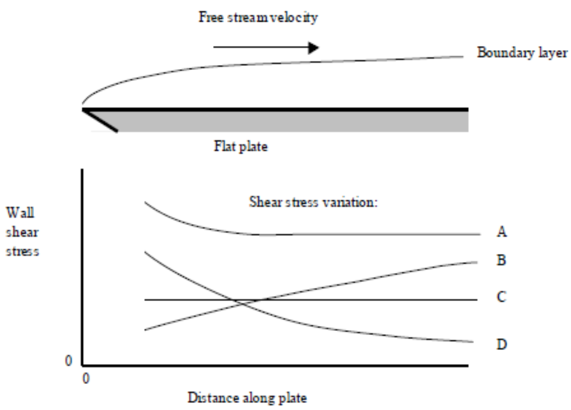
22. Air flows over a flat plate as shown below and forms a laminar boundary layer on the surface of the plate. Circle the letter of the statement that best represents the variation of the shear stress (force per unit area) at the wall with distance along with the plate.

A. Shear stress variation A

B. Shear stress variation B

C. Shear stress variation C

D. Shear stress variation D



23. Air flows through a well-insulated pipe and enters a section where the cross-sectional area is larger. Viscosity, friction, and gravitational effects are negligible. Circle the letter of the correct statement regarding the temperatures and pressures of the airflow.

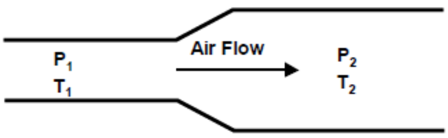
A. The pressure P2 equals P1 and the temperature T2 equals T1

B. The pressure P2 is greater than P1 and the temperature T2 is greater than T1

C. The pressure P2 is greater than P1 and the temperature T2 is less than T1

D. The pressure P2 is less than P1 and the temperature T2 is greater than T1

E. The pressure P2 is less than P1 and the temperature T2 is less than T1



24. Circle the letter of the correct statement about fluid viscosity.

A. Viscosity is not a property of the fluid.

B. Viscous forces are unimportant for airflows.

C. Viscous forces act normal to a surface.

D. Viscosity is a measure of a fluid’s resistance to flow.

F. Viscous Forces Are Much Smaller Than Pressure Forces.

25. Air flows over the various shapes shown in the cross-section below. The air velocity is the same for each of the shapes and the relative dimensions are as given in the sketch. Circle the letter of the shape that has the highest skin friction drag force (force due to viscous friction).

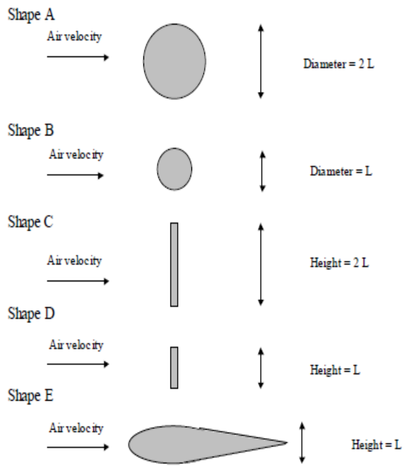
A. Shape A

B. Shape B

C. Shape C

D. Shape D

E. Shape E



26. A pitot-static tube connected to two differential pressure gauges as shown below is placed in an air stream. Circle the letter of the correct statement for the pressures sensed by holes A and B

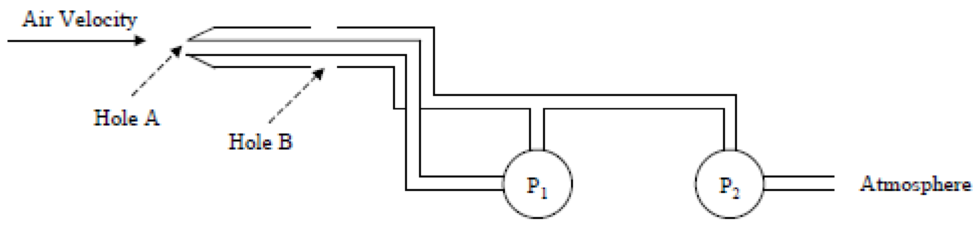
A. Hole A senses static pressure and hole B senses dynamic (velocity) pressure

B. Hole A senses dynamic (velocity) pressure and hole B senses static pressure

C. Hole A senses dynamic (velocity) pressure and hole B senses atmospheric pressure

D. Hole A senses static pressure and hole B senses total (stagnation) pressure

E. Hole A senses total (stagnation) pressure and hole B senses static pressure


Air Velocity
Hole A
Hole B
P1
P2
Atmosphere

APPENDIX F: ATTITUDES-RELATED TEST (ART)

Table F.1: Attitudes-related test (ART)

Information about students' understanding and attitudes about the Multiple Representation Approach.

Instructions

There is no wrong answer; each response will be treated as a correct one. Your opinion is what is required in this study.

Do not think too long about each statement. It should take you around 10 minutes to complete.

For each statement, put a tick (/) to show your level of agreement; Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, and Strongly Agree. Do not tick across two boxes.

No.	Statement	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree
	Scale	1	2	3	4	5
No.	Item Statement on Attitude Towards Multiple Representation Approach					
1	Using multiple representations will help me to better understand.					
2	Using multiple representations requires a lot of mental effort.					
3	Using multiple representations will improve my problem-solving skills.					
4	Multiple representations encourage me to learn a fluid mechanics topic to the best of my ability.					
5	The MR approach will be difficult for me to master.					
No	Advantages of a Multi-Representation Strategy					
1.	Finding a solution is easier with multiple representations.					
2.	Multiple representations can increase my interaction with my environment.					
3	Learning with multiple representations will provide me with better learning opportunities than traditional methods.					
	A lot of mental effort is required to use Mr. on the computer system.					

5.	There are many challenges associated with using MR technologies.					
6.	I will be more efficient with the help of MR.					
7	MR will allow me to accomplish more work than otherwise possible.					
No.	Multi-representational learning as a desire to learn					
1	Interacting with a variety of techniques, such as video, virtual labs, computer simulations, and so on, is often interesting.					
2	Multiple representations are more engaging than traditional lecture methods.					
3	I enjoy working with multiple representations.					
4	Multiple representations are my favourite way to learn.					
5	Multiple representations stimulate my interest in learning.					
6	I am inspired to do my best in class by the Multiple Representation Approach.					

APPENDIX G: PILOT TEST AND RELIABILITY RESULTS

Table G.1: OEQ pilot test and reliability results

Reliability Statistics			
Cronbach's Alpha	Part 1	Value	.a
		N of Items	1b
	Part 2	Value	.a
		N of Items	1c
	Total N of Items		2
Correlation Between Forms			.666
Spearman-Brown Coefficient	Equal Length		.799
	Unequal Length		.799
Guttmann Split-Half Coefficient			.793
a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item coding.			
b. The item is: Odd			
c. The item is: Even			

Item Statistics

Item Statistics			
	Mean	Std. Deviation	N
Odd Items	.2813	.20863	8
Even Items	.3125	.17678	8

Inter-Item Correlation Matrix

Inter-Item Correlation Matrix		
	Odd Item	Even Item
Odd Items	1.000	.666
Even Items	.666	1.000

Inter-Item Covariance Matrix

Inter-Item Covariance Matrix		
	Odd	even
Odd Items	.044	.025
Even Items	.025	.031

Table G-2: FMCI pilot test and reliability results

Reliability Statistics			
Cronbach's Alpha	Part 1	Value	.a
		N of Items	1b
	Part 2	Value	.a
		N of Items	1c
	Total N of Items		2
Correlation Between Forms			.771
Spearman-Brown Coefficient	Equal Length		.870
	Unequal Length		.870
Guttmann Split-Half Coefficient			.854
a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item coding.			
b. The item is: Odd			
c. The item is: Even			

Item Statistics

Item Statistics			
	Mean	Std. Deviation	N
Odd Items	.2692	.12339	12
Even Items	.2692	.16013	12

Inter-Item Correlation Matrix

Inter-Item Correlation Matrix		
	Odd Item	Even Item
Odd Items	1.000	.771
Even Items	.771	1.000

Inter-Item Covariance Matrix

Inter-Item Covariance Matrix		
	Odd Item	Even Item
Odd Items	.015	.015
Even Items	.015	.026

Table G-3: ART pilot test and reliability results

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories of q1 occur with equal probabilities.	One-Sample Chi-Square Test	.002	Reject the null hypothesis.
2	The categories of q2 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
3	The categories of q3 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
4	The categories of q4 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
5	The categories of q5 occur with equal probabilities.	One-Sample Chi-Square Test	.019	Reject the null hypothesis.
6	The categories of q6 occur with equal probabilities.	One-Sample Chi-Square Test	.001	Reject the null hypothesis.
7	The categories of q7 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
8	The categories of q8 occur with equal probabilities.	One-Sample Chi-Square Test	.001	Reject the null hypothesis.
9	The categories of q9 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
10	The categories of q10 occur with equal probabilities.	One-Sample Chi-Square Test	.006	Reject the null hypothesis.
11	The categories of Q11 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.
12	The categories of Q12 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

APPENDIX H: OEQ PRE-INTERVENTION I RESULTS

Table H.1: OEQ pre-intervention I paired-samples t-test on pressure measurement

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair I	M1	.01563	.16725	.02957	-.04468	.07593	.528	31	.601
Pair II	M2	-.03906	.20190	.03569	-.11186	.03373	-1.094	31	.282
Pair III	M3	.02344	.21402	.03783	-.05372	.10060	.619	31	.540

Table H.2: OEQ pre-intervention-I paired-samples t-test on fluid flow

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair I	M1	.02344	.16013	.02831	-.03430	.08117	.828	31	.414
Pair II	M2	00781	.19050	.03966	-.07308	.08871	.197	31	.845
Pair III	M3	-.02344	.19427	.03434	-.09348	.04660	-.682	31	.500

Table H.3: OEQ pre-intervention-I paired-samples t-test on Bernoulli's principle

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair I	M1	-.06250	.16801	.02970	-.12307	-.00193	-2.104	31	.044

Pair II	M2	-.01563	.18984	.03356	-.08407	.05282	-.466	31	.645
Pair III	M3	.07813	.21475	.03796	.00070	.15555	2.058	31	.048

APPENDIX I: FMCI PRE-INTERVENTION-I RESULTS

Table I-1: FMCI pre-intervention-I paired-samples t-test result on pressure measurement

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair I	M1	.02625	.15957	.02821	-.03128	.08378	.931	31	.359
Pair II	M2	.02094	.20416	.03609	-.05267	.09454	.580	31	.566
Pair III	M3	-.04719	.19393	.03428	-.11711	.02273	-1.376	31	.179

Table I-2: FMCI pre-intervention-I Paired-samples t-test on fluid flow

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.04062	.17572	.03106	-.02273	.10398	1.308	31	.201
Pair II	M2	-.01250	.13854	.02449	-.06245	.03745	-.510	31	.613
Pair III	M3	-.02812	.15706	.02776	-.08475	.02850	-1.013	31	.319

Table I-3: FMCI pre-intervention-I paired-samples t-test result on Bernoulli's principle

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.03719	.16183	.02861	-.02116	.09553	1.300	31	.203
Pair II	M2	.00344	.20963	.03706	-.07214	.07902	.093	31	.927

Pair III	M3	-.03594	.17610	.03113	-.09943	.02755	-1.154	31	.257

APPENDIX J: INTERVENTION-I: ITERATION I

Table J-1: Intervention-I on pressure measurement concept

<table>
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Lesson 1: 1hrs

Learning goals

Students will be able to:

- **Describe the fluid pressure and height of a fluid; you already know the concept of pressure measurement?**
- **Explain physical quantities such as area a, pressure P, and height H.**

</td></tr>
<tr><td>Time</td><td>Phases</td><td>MR representations:</td><td>Traditional representation:</td></tr>
<tr><td></td><td></td><td>Use (Text, pictures, diagrams, and symbolic or mathematical formulas).</td><td>Use: (Blackboard, textbook (Serwey, 2004 pp: 390-395).</td></tr>
<tr><td>5'</td><td>Introduction</td><td>Introduce the lesson.</td><td>Introduce the lesson.</td></tr>
<tr><td>35'</td><td>presentation</td><td>

Display the lesson on:

Describe the relationship between pressure, force, and area.

- P=F/A.
- Pressure Variation with Depth (water pressure rises with depth, as divers are well aware).
- Similarly, as altitude increases, atmospheric pressure decreases; as a result, aircraft flying at high altitudes must have pressurised cabins for the comfort of their passengers.
- Atmospheric pressure.
- Pressure in the atmosphere.
- Examine the connections between pressure and momentum.
- The pressure of a fluid is due to the force resulting from the change in momentum of the fluid molecules that collide with the wall.
- Dp/Dt = mDv/Dt = F.
- The sum of the instantaneous normal components of the forces of the collision gives rise to the average pressure on the wall.

</td><td>

The lesson was provided on:

- Variation of Pressure with Depth: As divers well know, water pressure increases with depth.
- Likewise, atmospheric pressure decreases with increasing altitude; for this reason, aircraft flying at high altitudes must have pressurised cabins for the comfort of their passengers.
- The definition of barometric pressure.
- Atmospheric pressure definitions.
- The densities of various substances vary. The pressure exerted by the liquid on the bottom face of the sample is P, and the pressure on the top face is P0.

$$\sum \vec{\mathbf{F}} = PA\hat{\mathbf{j}} - P_0A\hat{\mathbf{j}} - Mg\hat{\mathbf{j}} = 0$$

$$PA - P_0A - \rho Ahg = 0$$

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- Demonstrate how the pressure in a liquid rises with depth.
- The densities of various substances (the densities of various substances vary slightly with temperature) because a substance's volume is temperature dependent.
- The pressure exerted by the liquid on the sample's bottom face is P, while the pressure on the top face is P0.

$$\sum \vec{\mathbf{F}} = PA\hat{\mathbf{j}} - P_0A\hat{\mathbf{j}} - Mg\hat{\mathbf{j}} = 0$$

$$PA - P_0A - \rho Ahg = 0$$

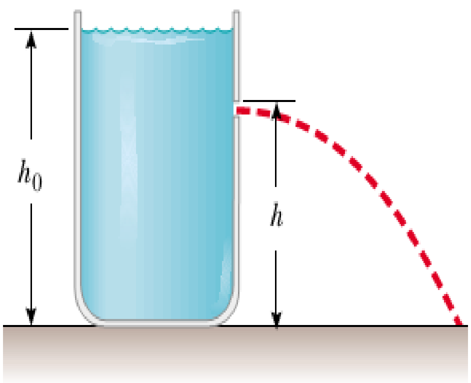
Pascal's law:

$$F = P_{avg}A = (\tfrac{1}{2}\rho gH)(Hw) = \tfrac{1}{2}\rho gwH^2$$

$$F = \int P\,dA = \int_0^H \rho g(H-y)w\,dy = \tfrac{1}{2}\rho gw$$

Explain pressure at different heights by demonstrating a pressure container with a fixed volume.

$$P_0 = \rho_{Hg}gh \rightarrow h = \frac{P_0}{\rho_{Hg}g}$$



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Pascal's law:

$$F = P_{avg}A = (\tfrac{1}{2}\rho gH)(Hw) = \tfrac{1}{2}\rho gwH^2$$

$$F = \int P\,dA = \int_0^H \rho g(H-y)w\,dy = \tfrac{1}{2}\rho gw$$

But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes.

However, the teacher used only mathematical equations and text.

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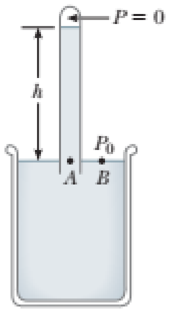

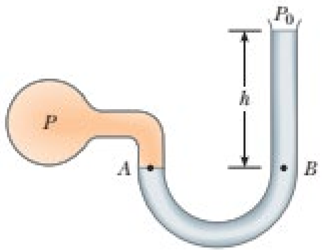

Explain how pressure differs at different heights.

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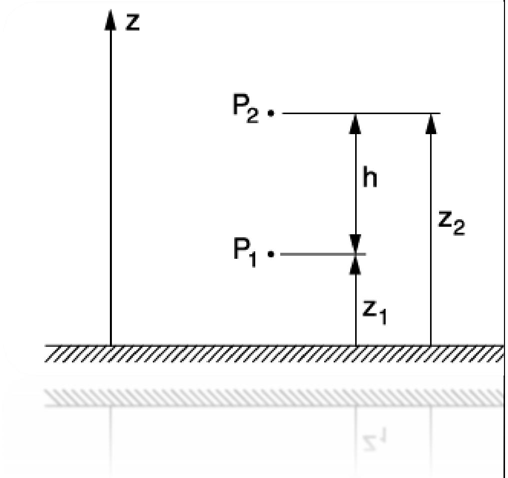


$$P_0 = \rho_{Hg} g h \quad \rightarrow \quad h = \frac{P_0}{\rho_{Hg} g}$$

- Discuss what would happen if it was punched at h0, h1, and somewhere between them.
- The students will now work in their working books to complete the activity.
- To teach students, the teacher used a variety of representations such as text, pictures, graphs, mathematical equations, diagrams, and simulations.

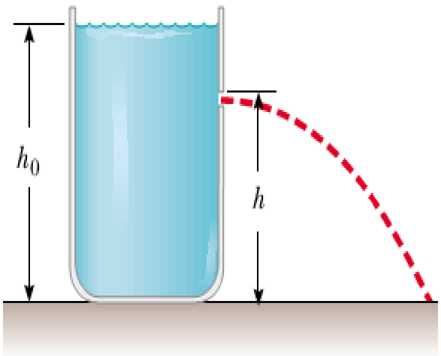
5'	summary	Summarise about: • Area and pressure force. • Pressure and momentum. • Interaction between pressure and internal force. • Pressure at different heights.	
5'	Evaluation	Classwork: A hole is punched at a height of h in the side of a plastic container of a height of h0. The container is full of water, and the water is to shoot as far as possible horizontally.  The students need to: • This explains pressure at different heights. • This explains why the pressure reading varies. • Give corrections for their responses so that students will learn the correct answer.	Classwork: A hole is punched at a height of h in the side of a plastic container of a height of h0. The container is full of water, and the water is to shoot as far as possible horizontally. The students need to This explains pressure at different heights. This explains why the pressure reading varies. Give corrections for their responses so that students will learn the correct answer.

Table J-2: Intervention-I on fluid flow concept

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Lesson 1: 2 hrs.

Learning goals

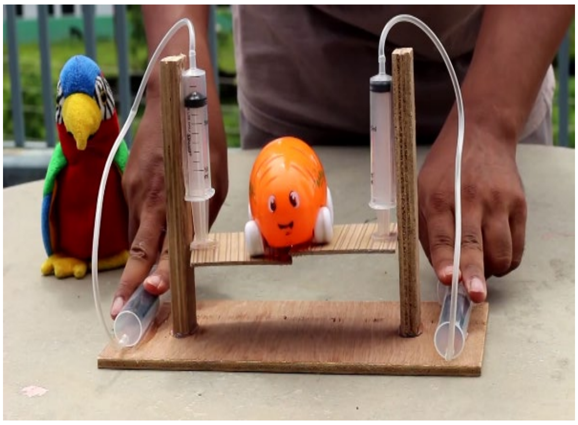
Students will be able to:

- **Describe the flow of fluid in the tube.**
- **Describe the fluid flow rate and cross-sectional area.**
- **Understand physical quantities like cross-sectional area A, pressure P, and velocity V.**

.
</td></tr>
<tr><td>Time</td><td>Phases</td><td>MR representations:</td><td>Traditional representation:</td></tr>
<tr><td></td><td></td><td>Use (Text, pictures, diagrams, and symbolic or mathematical formulas).</td><td>Use: (Blackboard, textbook (Serwey, 2004 pp: 399-402).</td></tr>
<tr><td>5'</td><td>Introduction</td><td>Introduce the lesson.</td><td>Introduce the lesson.</td></tr>
<tr><td>35'</td><td>presentation</td><td>

Explain the concepts of fluid flow, flow rate, and cross-sectional area.

- Two main types of fluid flow (steady, or laminar).
- If a fluid flow, each particle of the fluid follows a smooth path such that the paths of different particles never cross each other, as shown in Figure below.
- Demonstrate how fluid flows in a tube to lift a weight.



- The pressure difference in different areas of a pipe.
- The relationship between cross-sectional area and the density of a fluid.
- Turbulent flow is irregular flow characterised by small whirlpool-like regions as shown in Figure.
</td><td>

Present the lesson orally and by writing on the blackboard.

However, unlike in MR, no video simulation, virtual lab, or animation is used here. Rather than using only chalk and talking on a blackboard,

- Two main types of fluid flow (steady, or laminar).
- The relationship between cross-sectional area and the density of a fluid.
- The term viscosity is commonly used in the description of fluid flow to characterise the degree of internal friction in the fluid.
- This internal friction, or viscous force, is associated with the resistance that two adjacent layers of fluid have
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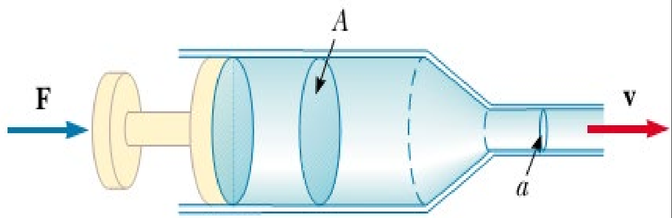
</table>

- The term **viscosity** is commonly used in the description of fluid flow to characterise the degree of internal friction in the fluid.
- This internal friction, or *viscous force*, is associated with the resistance that two adjacent layers of fluid have to move relative to each other.
- Viscosity causes part of the fluid's kinetic energy to be
  converted to internal energy.
- The fluid is non-viscous.
- In a non-viscous fluid, internal friction is neglected.
- An object moving through the fluid experiences no viscous force.
- **The flow is steady.** In steady (laminar) flow, all particles passing through a point have the same velocity.
  3. **The fluid is incompressible.**
- The density of an incompressible fluid is constant.
  4. **The flow is irrotational.** In irrotational flow, the fluid has no angular momentum at any point.
- If a small paddle wheel is placed anywhere in the fluid does not rotate about the wheel's centre of mass, the flow is irrotational.
  The path taken by a fluid particle under steady flow is called a **streamline.**

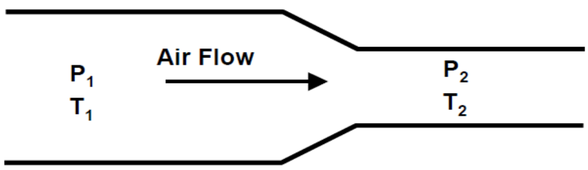
$$A_1v_1 = A_2v_2 = \text{constant}$$

- It states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.



The relationships between fluid density and the average velocity of a fluid flowing through a pipe.

• The average velocity and area of a pipe's fluid flow



to move relative to each other.

- In a non-viscous fluid, internal friction is neglected.
- An object moving through the fluid experiences no viscous force.
- The flow is steady. In steady (laminar) flow, all particles passing through a point have the same velocity.
- 3. The fluid is incompressible.
- The density of an incompressible fluid is constant.
- 4 The flow is irrotational. In irrotational flow, the fluid has no angular momentum at any point.
- The path taken by a fluid particle under steady flow is called a streamline.

$$A_1v_1 = A_2v_2 = \text{constant}$$

- This expression is called the equation of continuity for fluids.
- It states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.

But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes. Only mathematical equations and text.

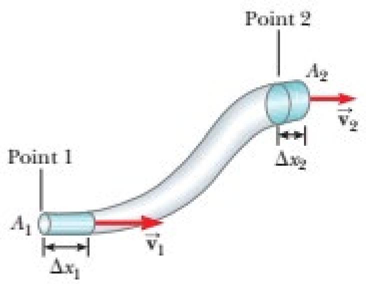
		 $A_1 v_1 = A_2 v_2 = \text{constant}$ The students will now work in their working book to complete the activity.	
5'	summary	Summarises about: Fluid flow; Flow rate and cross-sectional area;	
5'	Evaluation	Classwork: The barrel of the syringe has a cross-sectional area A, and the needle has a cross-sectional area a. • Why does the pressure vary? • What picture cues are associated with a change in pressure? • Describe what you see about the pressure difference in the two tubes • Give corrections for their responses so that students will learn the correct answer.	Classwork: The barrel of the syringe has a cross-sectional area of A, and the needle has a cross-sectional area of a. • Why does pressure vary?

Table J-3: Intervention-I on Bernoulli principle concept

Lesson 1 lasts 1 hour.

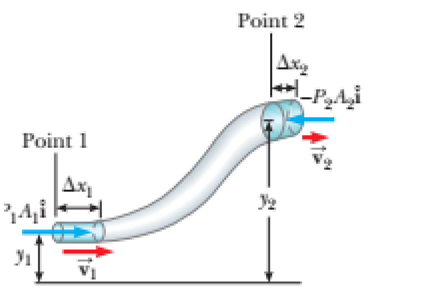
Learning goals

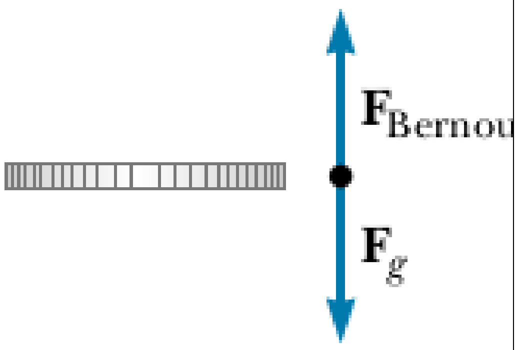
Students will be able to:

- **Describe Bernoulli's principle;**
- **Explain drag force (pressure difference force).**
- **Describe the skin friction drag force (the force caused by viscous friction).**
- **Discuss the air velocity and the shapes of the materials;**

Describe the effects of viscosity, friction, and gravity

Time	Phases	MR representations:	Traditional representation:
		Use (Text, pictures, diagrams, and symbolic or mathematical formulas).	Use: (Blackboard, textbook (Serwey, 2004 pp: 402-405).
5'	Introduction	Introduce the lesson	Introduce the lesson
35'	presentation	Display the lesson on: • Students, you have probably experienced driving on a highway and having a large truck pass you at high speed. In this situation, you may have had the frightening feeling that your car was being pulled in toward the truck as it passed. • We will investigate the origin of this effect in this section. • As a fluid moves through a region where its speed or elevation above the earth's surface changes, the pressure in the fluid varies with these changes. The relationship between fluid speed, pressure, and elevation was first derived in 1738 by Swiss physicist Daniel Bernoulli. • Consider the flow of an ideal fluid segment through a nonuniform pipe in a time interval t, as shown in the Figure below.	Display the lesson on: • Students, you have probably experienced driving on a highway and having a large truck pass you at high speed. In this situation, you may have had the frightening feeling that your car was being pulled in toward the truck as it passed. • We will investigate the origin of this effect in this section. • As a fluid moves through a region where its speed or elevation above the earth's surface changes, the pressure in the fluid varies with these changes. The relationship between fluid speed, pressure, and elevation was first derived in 1738 by Swiss physicist Daniel Bernoulli. • The change in the kinetic energy of the segment of fluid is $\Delta K = (\frac{1}{2}mv_2^2 + K_{uns}) - (\frac{1}{2}mv_1^2 + K_{uns}) = \frac{1}{2}mv_2^2 -$ $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2$

		 • At the beginning of the time interval, the segment of fluid consists of the blue-shaded portion (portion 1) on the left and the unshaded portion. • During the time interval, the left end of the segment moves to the right by a distance of x1, which is the length of the blue-shaded portion on the left. • Meanwhile, the right end of the segment moves to the right by a distance of x 2, which is the length of the blue-shaded portion (portion 2) at the upper right of the figure below. • Therefore, at the end of the time interval, the segment of fluid consists of the unshaded portion and the blue-shaded portion at the upper right. • Part of this work goes into changing the kinetic energy of the segment of fluid, and part goes into changing the gravitational potential energy of the segment–Earth system. • Because we are assuming streamlined flow, the kinetic energy runs of the unshaded segment in the Figure below remain constant over time. • Therefore, the change in the kinetic energy of the segment of fluid is $\Delta K = (\frac{1}{2}mv_2^2 + K_{uns}) - (\frac{1}{2}mv_1^2 + K_{uns}) = \frac{1}{2}m$ $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 +$ $P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$ Describe the drag force (pressure difference force); Describe the skin friction drag force (the force caused by viscous friction).	$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$ But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes. Only mathematical equations and text.

		 Discuss air velocity and the shapes of the materials. Describe the effects of viscosity, friction, and gravity.	
5'	Summary	Summary of the lesson about • Bernoulli's principle; • Drag force (force due to pressure difference); • Skin friction drag force (viscous friction drag force); • The air velocity and material shapes effects of viscosity, friction, and gravitation; • Demonstrate a fire extinguisher .	
5'	Evaluation	Classwork: The students will now work in their workbooks to complete the activity in their workbooks individually. Classwork: Water is forced out of a fire extinguisher by air pressure, as shown in the figure. • What image best depicts the drag force? • What picture cues are associated with Bernoulli's principle? • Give corrections for their responses so that students will learn the correct answer.	Classwork: Water is forced out of a fire extinguisher by air pressure. How would you describe drag force? What do you associate with Bernoulli's principle?

APPENDIX K: OEQ POST-TEST-I RESULTS

Table K-1: OEQ post-test-I paired-samples t-test result on pressure measurement

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.10156	.19939	.03525	.02968	.17345	2.881	31	.007
Pair II	M2	-.10156	.20926	.03699	-.17701	-.02612	-2.746	31	.010
Pair III	M3	.00000	.16801	.02970	-.06057	.06057	.000	31	1.00

Table K.2: OEQ post-test-I paired-samples t-test result on fluid flow

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.03906	.19165	.03388	-.03004	.10816	1.153	31	.258
Pair II	M2	.03906	.14354	.02537	-.01269	.09081	1.539	31	.134
Pair III	M3	-.07813	.13377	.02365	-.12635	-.02990	-3.204	31	.002

Table K.3: OEQ post-test-I paired-samples t-test result on Bernoulli's principle

Paired-Samples Test							
	Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			

					Lower	Upper			
Pair I	M1	-.07031	.23101	.04084	-.15360	.01297	-1.722	31	.095
Pair II	M2	-.07031	.13067	.02310	-.11742	-.02320	-3.044	31	.005
Pair III	M3	.14063	.20018	.03539	.06845	.21280	3.974	31	.000

APPENDIX L: FMCI POST-TEST-I RESULTS

Table L.1: FMCI post-test-I paired-samples t-test result on pressure measurement

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
					Lower	Upper			
Pair I	M1	.11188	.19729	.03488	-.13080	.03705	-1.139	31	.263
Pair II	M2	-.09229	.15761	.02786	-.14912	-.03547	-3.212	31	.002
Pair III	M3	-.01906	.18814	.03326	-.08689	.04877	-.573	31	.571

Table L.2: FMCI post-test-I paired-samples t-test result on fluid flow

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.10937	.22911	.04050	.02677	.19198	2.701	31	.011
Pair II	M2	-.08750	.18622	.03292	-.15464	-.02036	-2.658	31	.012
Pair III	M3	-.02188	.13616	.02407	-.07096	.02721	-.909	31	.370

Table L.3: FMCI post-test-I paired-samples t-test result on Bernoulli’s principle

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.12010	.22321	.03946	.03963	.20058	3.044	31	.005
Pair II	M2	-.08365	.18315	.03238	-.14968	-.01761	-2.584	31	.015

Pair III	M3	-.03687	.22585	.03993	-.11830	.04455	-.924	31	.363

APPENDIX M: OEQ ANCOVA RESULTS

Table M.1: OEQ ANCOVA results on pressure measurement

Dependent Variable: POST PRESSURE						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.167a	2	.083	4.774	.015	.128
Intercept	2.999	1	2.999	160.912	.000	.725
PRE-PRESSURE	.002	1	.002	.093	.762	.002
GROUP	.156	1	.156	8.381	.005	.121
Error	1.137	61	.019			
Total	18.063	64				
Corrected Total	1.304	63				
a. R Squared =.128 (Adjusted R Squared =.099)						

Table M.2: OEQ ANCOVA results on fluid flow

Dependent Variable: POST FLUID						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.032a	2	.016	1.096	.341	.035
Intercept	2.540	1	2.540	171.417	.000	.738
PREFLUID	.008	1	.008	.545	.463	.009
GROUP	.016	1	.016	1.059	.307	.017
Error	.904	61	.015			
Total	17.188	64				
Corrected Total	.937	63				
a. R Squared =.035 (Adjusted R Squared =.003)						

Table M-3: OEQ ANCOVA results on Bernoulli principle

Dependent Variable: POST BERNOULLI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.320a	2	.160	9.387	.000	.235
Intercept	2.203	1	2.203	129.284	.000	.679
PREBERNOLI	.004	1	.004	.206	.652	.003
GROUP	.318	1	.318	18.670	.000	.234
Error	1.039	61	.017			
Total	20.500	64				
Corrected Total	1.359	63				
a. R Squared =.235 (Adjusted R Squared =.210)						

APPENDIX N: FMCI ANCOVA RESULTS

Table N-1: FMCI ANCOVA results on pressure measurement

Dependent Variable: P POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.255a	2	.128	4.790	.013	.133
Intercept	3.075	1	3.075	112.932	.000	.649
PPREFMCI	.055	1	.055	2.025	.160	.032
GROUP	.183	1	.183	6.703	.012	.099
Error	1.661	61	.027			
Total	20.149	64				
Corrected Total	1.916	63				
a. R Squared =.133 (Adjusted R Squared =.105)						

Table N-2: FMCI ANCOVA results on fluid flow

Dependent Variable: F POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.647a	2	.324	18.801	.000	.381
Intercept	1.600	1	1.600	92.943	.000	.604
FPREFMCI	.007	1	.007	.426	.516	.007
GROUP	.600	1	.600	34.927	.000	.363
Error	1.050	61	.017			
Total	18.920	64				
Corrected Total	1.698	63				
a. R Squared =.381 (Adjusted R Squared =.361)						

Table N-3: FMCI ANCOVA results on Bernoulli principle

Dependent Variable: B POST-FMCI						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.326a	2	.163	7.392	.001	.195
Intercept	3.053	1	3.053	138.284	.000	.694
BPREFMCI	.096	1	.096	4.330	.042	.066
GROUP	.196	1	.196	8.858	.004	.127
Error	1.347	61	.022			
Total	21.015	64				
Corrected Total	1.673	63				
a. R Squared =.195 (Adjusted R Squared =.169)						

APPENDIX P: PRE-TEST-II OEQ RESULTS

Table P-1: OEQ pre-intervention-II paired-samples t-test result on pressure measurement

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	-.04688	.22394	.03959	-.12762	.03387	-1.184	31	.245
Pair II	M2	-.01563	.14110	.02494	-.06650	.03525	-.626	31	.536
Pair III	M3	.06250	.20080	.03550	-.00990	.13490	1.761	31	.088

Table P-2: OEQ pre-intervention-II paired-samples t-test result on fluid flow

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	-.07813	.19508	.03448	-.14846	-.00779	-2.265	31	.031
Pair II	M2	.14063	.21001	.03712	.06491	.21634	3.288	31	.006
Pair III	M3	-.06250	.23760	.04200	-.14816	.02316	-1.488	31	.147

Table P-3: OEQ pre-intervention-II paired-samples t-test result on Bernoulli's principle

	Paired differences				t	df	Sig. (2-tailed)
	Mean	Std. error mean	95% Confidence interval of the difference				
			Lower	Upper			

Pair I	M1	-.04688	.04115	-.13080	.03705	-1.139	31	.263
Pair II	M2	.03906	.04217	-.04693	.12506	.926	31	.361
Pair III	M3	.00781	.03966	-.07308	.08871	.197	31	.845

APPENDIX Q: PRE-TEST-II FMCI RESULTS

Table Q-1: FMCI pre-intervention-II paired-samples t-test result on pressure measurement

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.11188	.19729	.03488	-.13080	.03705	-1.139	31	.263
Pair II	M2	-.09229	.15761	.02786	-.14912	-.03547	-3.212	31	.002
Pair III	M3	-.01906	.18814	.03326	-.08689	.04877	-.573	31	.571

Table Q-2: FMCI pre-intervention-II paired-samples t-test result on fluid flow

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.20000	.19838	.03966	-.07308	.08871	.197	31	.845
Pair II	M2	-.15312	.20318	.03592	-.22638	-.07987	-4.263	31	.000
Pair III	M3	-.03750	.12889	.04217	-.04693	.12506	.926	31	.361

Table Q-3: FMCI pre-intervention-II paired-samples t-test result on Bernoulli's principle

Paired-Samples Test							
	Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			

					Lower	Upper			
Pair I	M1	.12010	.22321	.03946	.03963	.20058	3.044	31	.006
Pair II	M2	-.08365	.18315	.03238	-.14968	-.01761	-2.584	31	.015
Pair III	M3	-.03687	.22585	.03993	-.11830	.04455	-.924	31	.363

APPENDIX R: INTERVENTION-II: SECOND ITERATION

Table R-1: Intervention-II on pressure measurement concept

Lesson 1: 1hrs

Learning goals

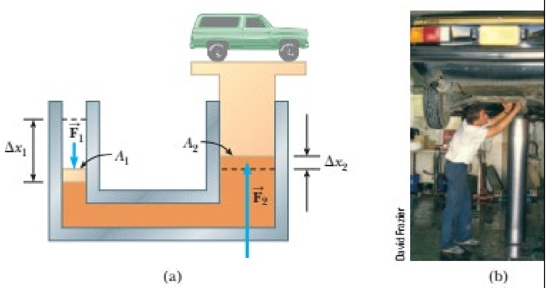
Students will be able to

Describe a fluid's fluid pressure and height;

You know the concept of pressure measurement?

Explain physical quantities such as area A, pressure P, and height H.

Time	Phases	MR representations:	Traditional representation:
		Use (Text, pictures, diagrams, and symbolic or mathematical formulas).	Use: (Blackboard, textbook (Serwey, 2004 pp: 390-395).
5'	Introduction	Introduce the lesson.	Introduce the lesson
35'	presentation	Display the lesson on: Describe the relationship between pressure, force, and area. • P=F/A. • Pressure Variation with Depth (water pressure rises with depth, as divers are well aware). • Similarly, as altitude increases, atmospheric pressure decreases; as a result, aircraft flying at high altitudes must have pressurised cabins for the comfort of their passengers. • Atmospheric pressure. • Pressure in the atmosphere. • Examine the connections between pressure and momentum. • The pressure of a fluid is due to the force resulting from the change in momentum of the fluid molecules that collide with the wall. • Dp/Dt = mDv/Dt = F. • The sum of the instantaneous normal components of the forces of the collision gives rise to the average pressure on the wall. • Demonstrate how the pressure in a liquid rises with depth.	The lesson was provided on: • Variation of Pressure with Depth: As divers well know, water pressure increases with depth. • Likewise, atmospheric pressure decreases with increasing altitude; for this reason, aircraft flying at high altitudes must have pressurised cabins for the comfort of their passengers. • The definition of barometric pressure. • Atmospheric pressure definitions. • The densities of various substances vary. The pressure exerted by the liquid on the bottom face of the sample is P, and the pressure on the top face is P0.

		• The densities of various substances (the densities of various substances vary slightly with temperature) because a substance's volume is temperature dependent. • The pressure exerted by the liquid on the sample's bottom face is P, while the pressure on the top face is P0. $\sum \vec{\mathbf{F}} = PA\hat{\mathbf{j}} - P_0A\hat{\mathbf{j}} - Mg\hat{\mathbf{j}} = 0$ $PA - P_0A - \rho Ahg = 0$ **Pascal's law:** $F = P_{avg}A = (\frac{1}{2}\rho gH)(Hw) = \frac{1}{2}\rho gwH^2$ $F = \int P\,dA = \int_0^H \rho g(H-y)w\,dy = \frac{1}{2}\rho gwH^2$ Explain pressure at different heights by demonstrating a pressure container with a fixed volume.  (a) (b) $P_0 = \rho_{Hg}gh \rightarrow h = \frac{P_0}{\rho_{Hg}g}$	$\sum \vec{\mathbf{F}} = PA\hat{\mathbf{j}} - P_0A\hat{\mathbf{j}} - Mg\hat{\mathbf{j}} = 0$ $PA - P_0A - \rho Ahg = 0$ **Pascal's law:** $F = P_{avg}A = (\frac{1}{2}\rho gH)(Hw) = \frac{1}{2}\rho gwH^2$ $F = \int P\,dA = \int_0^H \rho g(H-y)w\,dy = \frac{1}{2}$ But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes. However, the teacher used only mathematical equations and text.

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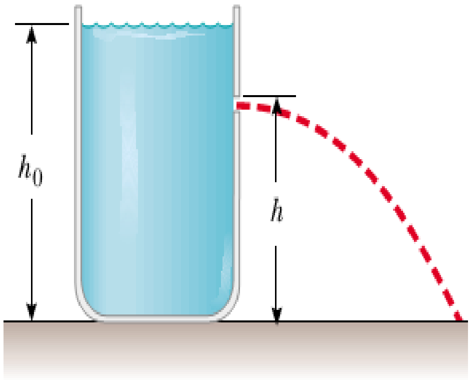
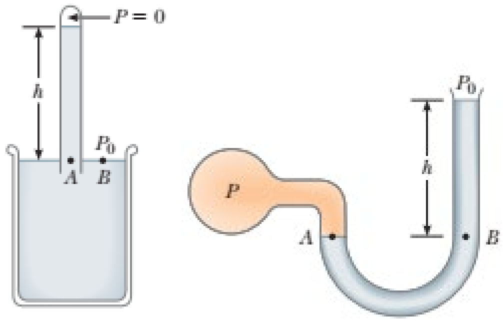
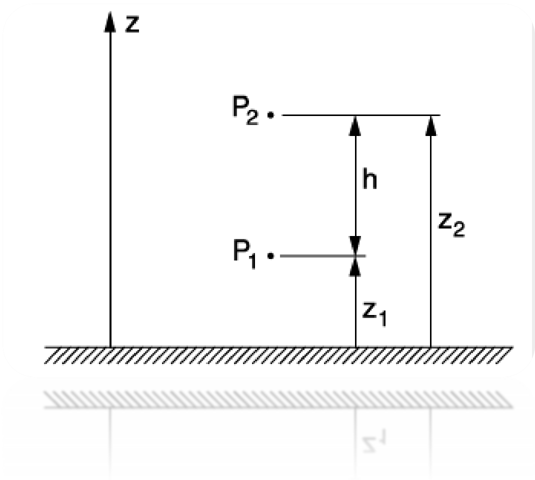




Explain how pressure differs at different heights.

.



$$P_0 = \rho_{Hg} g h \quad \rightarrow \quad h = \frac{P_0}{\rho_{Hg} g}$$

- Discuss what would happen if it was punched at h0, h1, and somewhere between them.
- The students will now work in their working books to complete the activity.
- To teach students, the teacher used a variety of representations such as text,

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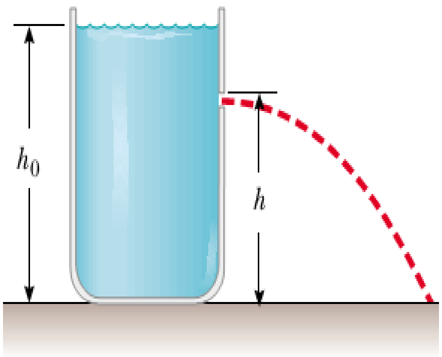
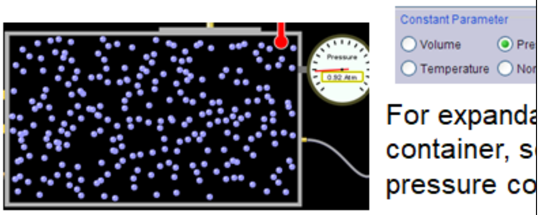
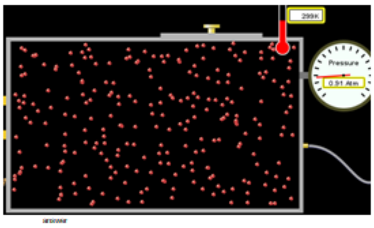
		pictures, graphs, mathematical equations, diagrams, and simulations.	
5'	summary	Summarise about: • Area and pressure force. • Pressure and momentum. • Interaction between pressure and internal force. Pressure at different heights.	
5'	Evaluation	Activity: A hole is punched at a height of h in the side of a plastic container of a height of h0. The container is full of water, and the water is to shoot as far as possible horizontally.  The students need to: • This explains pressure at different heights. • This explains why the pressure reading varies. Give corrections for their responses so that students will learn the correct answer. The students need to This explains pressure at different heights. This explains why the pressure reading varies.	Classwork: A hole is punched at a height of h in the side of a plastic container of a height of h0. The container is full of water, and the water is to shoot as far as possible horizontally. The students need to This explains pressure at different heights. This explains why the pressure reading varies. Give corrections for their responses so that students will learn the correct answer.





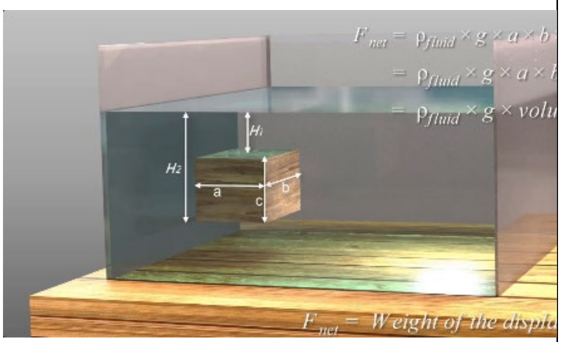
Set P constant, open the top T and V both decrease, V constant, press the pump to add molecules P and T both increase

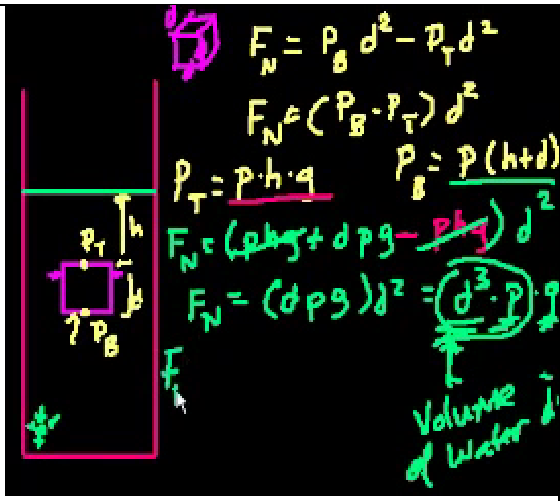
Set None constant, and push the side of the container, so the volume goes down (P & T will rise). I was assuming the air pocket was elastic.

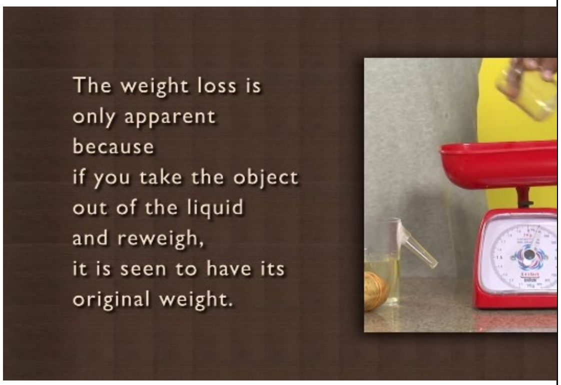
Set V to a constant value and then add heat (pressure is F/A, so more P means more F required).

Set none to constant, and decrease P by increasing V.

Students will have to think that the pressure of the balloon equals the atmospheric pressure and that the balloon has reached its maximum size.







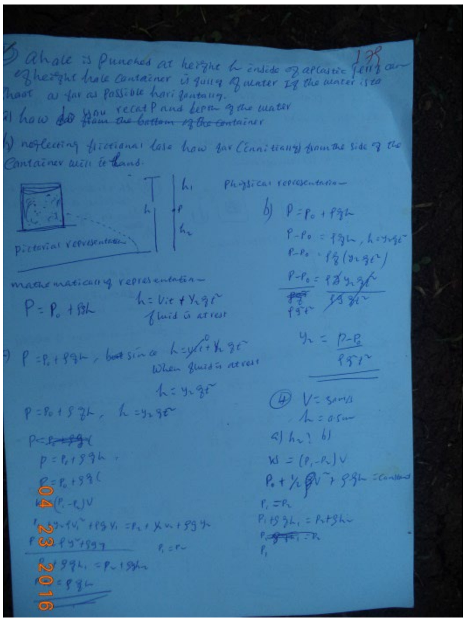
I expect them to describe the whole event. As they go up the mountain, the outside pressure decreases and the balloon stretches until it reaches its max. The temperature does not change. Other users may need to know that Denver is approximately 5500 feet above sea level and Evergreen is approximately 7800 feet above sea level.

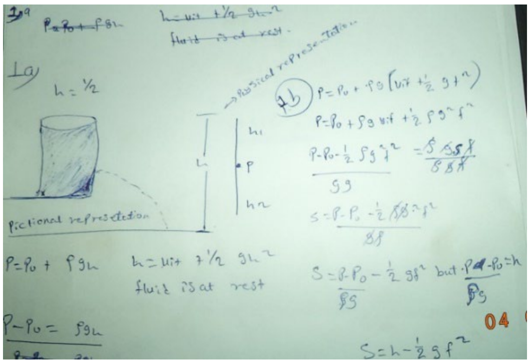
OR, you can answer this question using the balloons and buoyancy simulation.

I tried to simulate this by having V constant, and I put in molecules to make the pressure about 2.3 and adjusted the temperature to 275. Then I changed T from 275 to 300.

I saw the pressure change very little, so the students would decide there had been a leak. 30+14.7=45 (3 ATM)

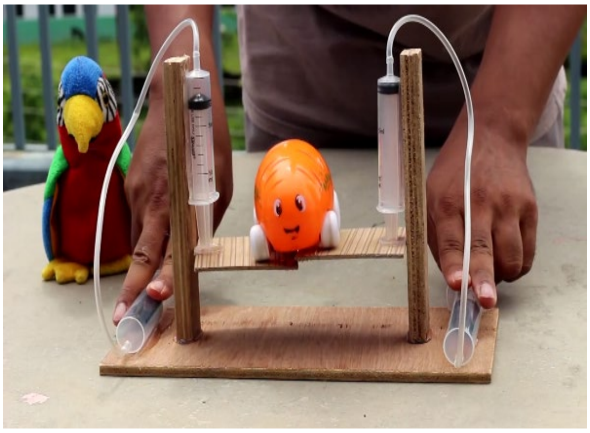
The students will now work in their working books to complete the activity.





Give corrections for their response so that students will take the correct answer.

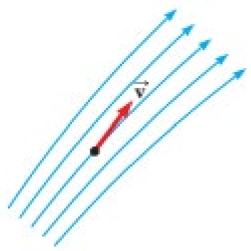
Table R-2: Intervention-II on fluid flow concept

Lesson 1: 2 hrs. Learning goals Students will be able to: • Describe the flow of fluid in the tube. • Describe the fluid flow rate and cross-sectional area. • Understand physical quantities like cross-sectional area A, pressure P, and velocity V.			
Time	Phases	MR representations:	Traditional representation:
		Use (Text, pictures, diagrams, and symbolic or mathematical formulas)	Use: (Blackboard, textbook (Serwey, 2004 pp: 399-402).
5'	Introduction	Introduce the lesson	Introduce the lesson
35'	presentation	Explain the concepts of fluid flow, flow rate, and cross-sectional area. • Two main types of fluid flow (steady, or laminar). • If a fluid flow, each particle of the fluid follows a smooth path such that the paths of different particles never cross each other, as shown in Figure below. • Demonstrate how fluid flows in a tube to lift a weight. .  • The pressure difference in different areas of a pipe. • The relationship between cross-sectional area and the density of a fluid. • Turbulent flow is irregular flow characterised by small whirlpool-like regions as shown in Figure.	Present the lesson orally and by writing on the blackboard. However, unlike in MR, no video simulation, virtual lab, or animation is used here. Rather than using only chalk and talking on a blackboard, • Two main types of fluid flow (steady, or laminar). • The relationship between cross-sectional area and the density of a fluid. • The term viscosity is commonly used in the description of fluid flow to characterise the degree of internal friction in the fluid. • This internal friction, or viscous force, is associated with the resistance that two adjacent layers of fluid have

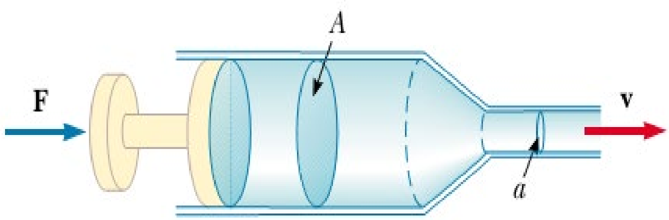
- The term **viscosity** is commonly used in the description of fluid flow to characterise the degree of internal friction in the fluid.
- This internal friction, or *viscous force*, is associated with the resistance that two adjacent layers of fluid have to move relative to each other.
- Viscosity causes part of the fluid's kinetic energy to be
converted to internal energy.
- The fluid is non-viscous.
- In a non-viscous fluid, internal friction is neglected.
- An object moving through the fluid experiences no viscous force.
- **The flow is steady.** In steady (laminar) flow, all particles passing through a point have the same velocity.
3. **The fluid is incompressible.**
- The density of an incompressible fluid is constant.
4. **The flow is irrotational.** In irrotational flow, the fluid has no angular momentum at any point.
- If a small paddle wheel is placed anywhere in the fluid does not rotate about the wheel's centre of mass, the flow is irrotational.
The path taken by a fluid particle under steady flow is called a **streamline.**

$$A_1v_1 = A_2v_2 = \text{constant}$$

- This expression is called the **equation of continuity for fluids.**



- It states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.



to move relative to each other.
- In a non-viscous fluid, internal friction is neglected.
- An object moving through the fluid experiences no viscous force.
- The flow is steady. In steady (laminar) flow, all particles passing through a point have the same velocity.
- 3. The fluid is incompressible.
- The density of an incompressible fluid is constant.
- 4 The flow is irrotational. In irrotational flow, the fluid has no angular momentum at any point.
- The path taken by a fluid particle under steady flow is called a streamline.

$$A_1v_1 = A_2v_2 = \text{constant}$$

- This expression is called the equation of continuity for fluids.
- It states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.

But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes. Only mathematical equations and text.

<table>
<tr>
<td></td>
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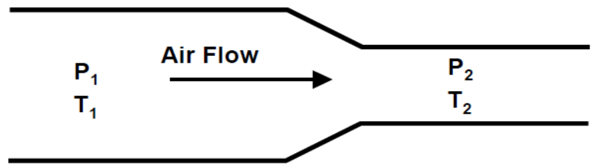
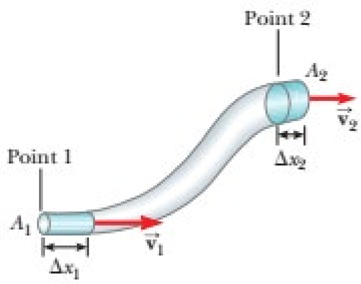
<td>The relationships between fluid density and the average velocity of a fluid flowing through a pipe.

• The average velocity and area of a pipe's fluid flow

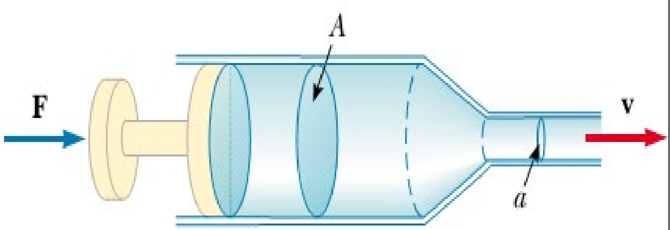
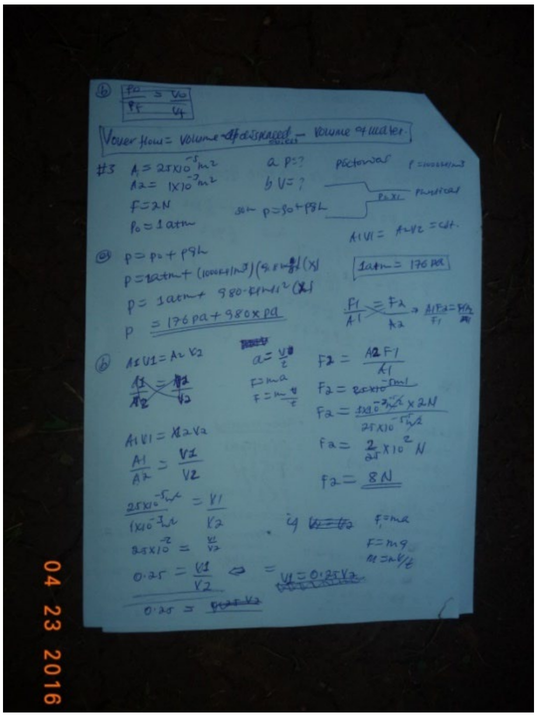


$$A_1 v_1 = A_2 v_2 = \text{constant}$$
The students will now work in their working book to complete the activity.</td>
<td></td>
</tr>
<tr>
<td>5'</td>
<td>Summary</td>
<td colspan="2">Summarises about:

Fluid flow;

Flow rate and cross-sectional area;</td>
</tr>
</table>

5'	Evaluation	Activity: The barrel of the syringe has a cross-sectional area A, and the needle has a cross-sectional area a.  • Why does the pressure vary? • What picture cues are associated with a change in pressure? • Describe what you see about the pressure difference in the two tubes • Give corrections for their responses so that students will learn the correct answer. 	Classwork: The barrel of the syringe has a cross-sectional area of A, and the needle has a cross-sectional area of a. • Why does pressure vary?

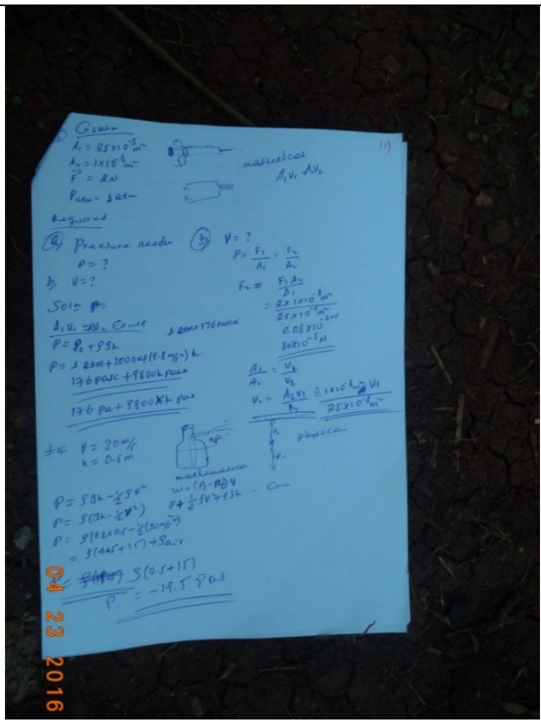
		 Give corrections for their response so that students will take the correct answer.	

Table R-3: Intervention-II on Bernoulli principle concept

Lesson 1 lasts 1 hour.

Learning goals

Students will be able to:

- Describe Bernoulli’s principle.
- Explain drag force (pressure difference force).
- Describe the skin friction drag force (the force caused by viscous friction).
- Discuss the air velocity and the shapes of the materials.

- Describe the effects of viscosity, friction, and gravity.

Time	Phases	MR representations:	Traditional representation:
		Use (Text, pictures, diagrams, and symbolic or mathematical formulas)	Use: (Blackboard, textbook (Serwey, 2004 pp: 402-405).
5’	Introduction	Introduce the lesson	Introduce the lesson
35’	presentation	Display the lesson on: • Students, you have probably experienced driving on a highway and having a large truck pass you at high speed. In this situation, you may have had the frightening feeling that your car was being pulled in toward the truck as it passed. • We will investigate the origin of this effect in this section. • As a fluid moves through a region where its speed or elevation above the earth’s surface changes, the pressure in the fluid varies with these changes. The relationship between fluid speed, pressure, and elevation was first derived in 1738 by Swiss physicist Daniel Bernoulli. • Consider the flow of an ideal fluid segment through a nonuniform pipe in a time interval t, as shown in the Figure below.	Display the lesson on: • Students, you have probably experienced driving on a highway and having a large truck pass you at high speed. In this situation, you may have had the frightening feeling that your car was being pulled in toward the truck as it passed. • We will investigate the origin of this effect in this section. • As a fluid moves through a region where its speed or elevation above the earth’s surface changes, the pressure in the fluid varies with these changes. The relationship between fluid speed, pressure, and elevation was first derived in 1738 by Swiss physicist Daniel Bernoulli. • The change in the kinetic energy of the segment of fluid is $\Delta K = (\frac{1}{2}mv_2^2 + K_{uns}) - (\frac{1}{2}mv_1^2 + K_{uns}) = \frac{1}{2}mv_2^2 -$ $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2$

<table>
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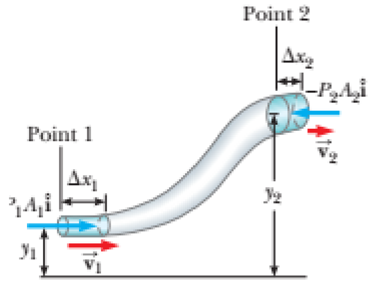
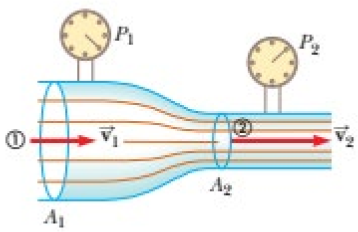


- At the beginning of the time interval, the segment of fluid consists of the blue-shaded portion (portion 1) on the left and the unshaded portion.
- During the time interval, the left end of the segment moves to the right by a distance of x1, which is the length of the blue-shaded portion on the left.
- Meanwhile, the right end of the segment moves to the right by a distance of x 2, which is the length of the blue-shaded portion (portion 2) at the upper right of the figure below.
- Therefore, at the end of the time interval, the segment of fluid consists of the unshaded portion and the blue-shaded portion at the upper right.
- Part of this work goes into changing the kinetic energy of the segment of fluid, and part goes into changing the gravitational potential energy of the segment–Earth system.
- Because we are assuming streamlined flow, the kinetic energy runs of the unshaded segment in the Figure below remain constant over time.



- Therefore, the change in the kinetic energy of the segment of fluid is

$$\Delta K = (\tfrac{1}{2}mv_2^2 + K_{uns}) - (\tfrac{1}{2}mv_1^2 + K_{uns}) = \tfrac{1}{2}mv$$

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

$$P + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

</td>
<td>

$$P + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

But here (in the traditional lecture method), there is no use of pictures, graphs, diagrams, or simulations, which are used in Multiple Representation classes. Only mathematical equations and text.

</td>
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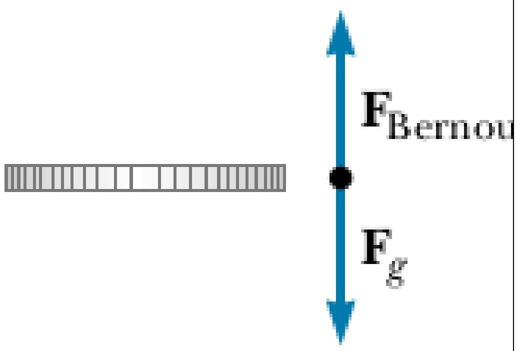
</table>

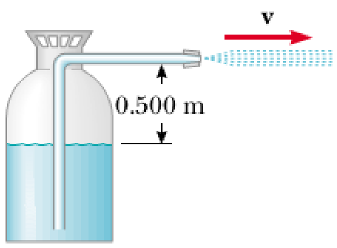
Describe the drag force (pressure difference force);

Describe the skin friction drag force (the force caused by viscous friction).



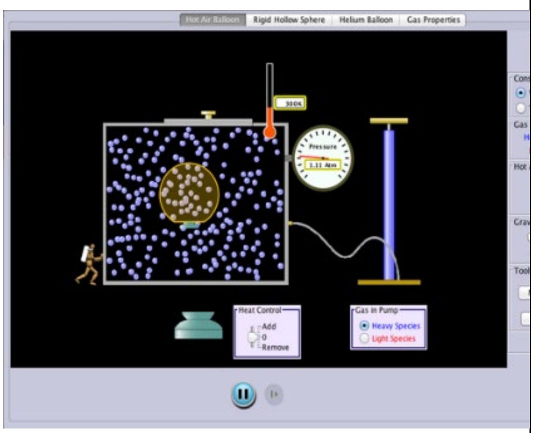
Discuss air velocity and the shapes of the materials.

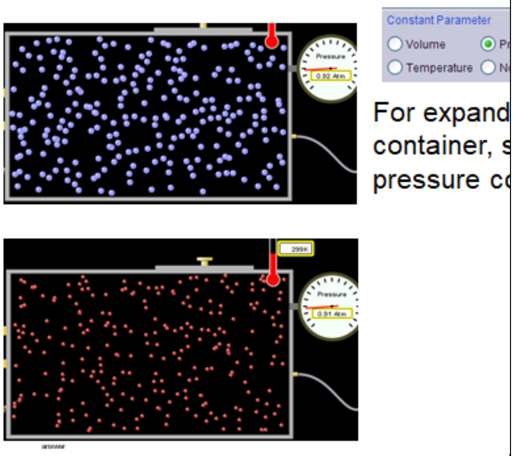
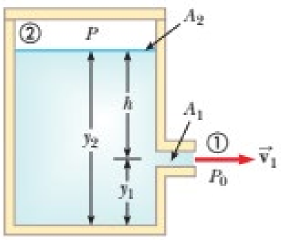
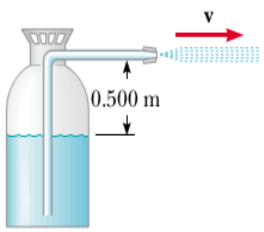
Describe the effects of viscosity, friction, and gravity.

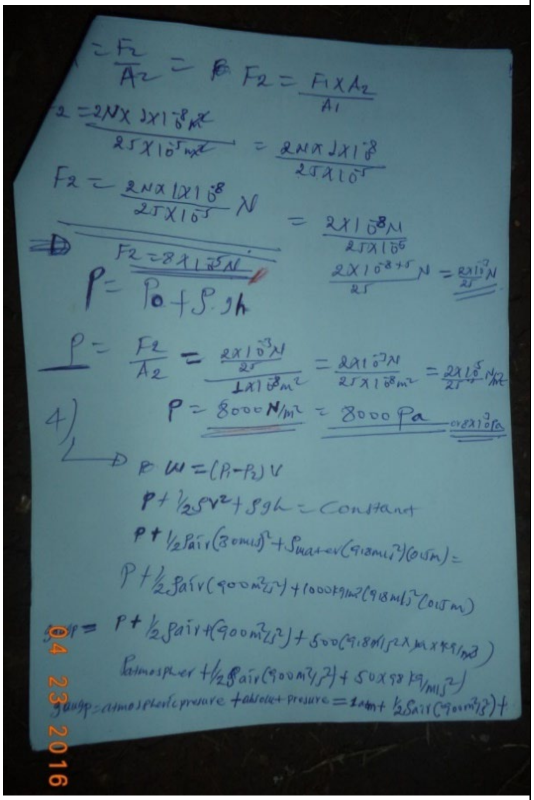
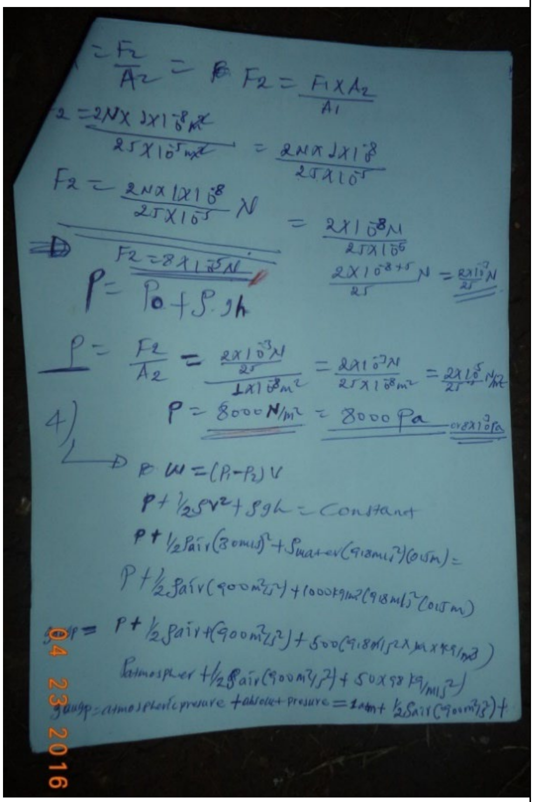


Describe Bernoulli’s principle;

Discuss the air velocity and the shapes of the materials;



		 Describe Viscosity, friction, and gravitational effects.	
5'	Summary	Summary of the lesson about • Bernoulli's principle; • Drag force (force due to pressure difference); • Skin friction drag force (viscous friction drag force); • The air velocity and material shapes effects of viscosity, friction, and gravitation; • Demonstrate a fire extinguisher  .	
5'	Evaluation	Activity: The students will now work in their workbooks to complete the activity in their workbooks individually. Classwork: Water is forced out of a fire extinguisher by air pressure, as shown in the figure.  . • What image best depicts the drag force?	Classwork: Water is forced out of a fire extinguisher by air pressure. How would you describe drag force? What do you associate with Bernoulli's principle?

		• What picture cues are associated with Bernoulli's principle? Give corrections for their responses so that students will learn the correct answer.   	

		Give corrections for their response so that students will take the correct answer.	

APPENDIX S: OEQ POST-TEST-II: PAIRED-SAMPLES T-TEST RESULTS

Table S.1: OEQ post-test-II paired-samples t-test result on pressure measurement

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.17969	.24785	.04381	.09033	.26905	4.101	31	.000
Pair II	M2	-.14063	.23706	.04191	-.22610	-.05515	-3.256	31	.002
Pair III	M3	-.04688	.20515	.03627	-.12084	.02709	-1.293	31	.206

Table S-2: OEQ post-test-II paired-samples t-test result on fluid flow

Paired-Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.18750	.17961	.03175	.12275	.25225	5.906	31	.000
Pair II	M2	-.10156	.23640	.04179	-.18679	-.01633	-3.330	31	.002
Pair III	M3	-.08594	.20683	.03656	-.16051	-.01137	-2.350	31	.025

Table S-3: OEQ post-test-II paired-samples t-test result on Bernoulli's principle

Paired-Samples Test							
	Paired Differences				t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			

					Lower	Upper			
Pair I	M1	.15625	.20820	.03680	.08119	.23131	4.245	31	.000
Pair II	M2	-.09375	.22674	.04008	-.17550	-.01200	-4.339	31	.000
Pair III	M3	-.06250	.20080	.03550	-.13490	.00990	-1.761	31	.088

APPENDIX T: FMCI POST-TEST-II: PAIRED-SAMPLES T-TEST RESULTS

Table T-1: FMCI post-test-II paired-samples t-test result on pressure measurement

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.20906	.20255	.03581	.13603	.28209	5.839	31	.000
Pair II	M2	-.11281	.16514	.02919	-.17235	-.05327	-3.864	31	.001
Pair III	M3	-.09344	.11807	.02087	-.13600	-.05087	-4.777	31	.000

Table T-2: FMCI post-test-II paired-samples t-test result on fluid flow

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.20938	.22340	.03949	.12883	.28992	5.302	31	.000
Pair II	M2	-.10937	.17663	.03122	-.17306	-.04569	-3.503	31	.002
Pair III	M3	-.10937	.11461	.02026	-.15070	-.06805	-5.399	31	.000

Table T-3: FMCI post-test-II paired-samples t-test result on Bernoulli's principle

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair I	M1	.16219	.18295	.03234	.09623	.22815	5.015	31	.000
Pair II	M2	-.12969	.18750	.03315	-.19729	-.06208	-3.913	31	.000

Pair III	M3	-.06781	.16174	.02859	-.12613	-.00950	-2.372	31	.024

APPENDIX U: OEQ ANCOVA RESULTS OF ITERATION II

Table U-1: OEQ ANCOVA results of pressure measurement

Dependent variable: Post-test						
Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected Model	.532a	2	.266	9.042	.000	.229
Intercept	4.376	1	4.376	148.724	.000	.709
Pre-test	.016	1	.016	.529	.470	.009
Group	.478	1	.478	16.250	.000	.210
Error	1.795	61	.029			
Total	25.188	64				
Corrected Total	2.327	63				
a. R Squared =.229 (Adjusted R Squared =.203)						

Table U-2: OEQ ANCOVA results of fluid flow

Dependent variable: Post-test						
Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected Model	.603a	2	.302	15.208	.000	.333
Intercept	2.538	1	2.538	128.006	.000	.677
Pre-test	.041	1	.041	2.046	.158	.032
Group	.603	1	.603	30.407	.000	.333
Error	1.209	61	.020			
Total	24.375	64				
Corrected Total	1.812	63				
a. R Squared =.333 (Adjusted R Squared =.311)						

Table U-3: OEQ ANCOVA results of Bernoulli principle

Dependent Variable: POST-BERNOULLI						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.647a	2	.324	18.801	.000	.381
Intercept	1.600	1	1.600	92.943	.000	.604
Pre-test	.007	1	.007	.426	.516	.007
Group	.600	1	.600	34.927	.000	.363
Error	1.050	61	.017			
Total	18.920	64				
Corrected Total	1.698	63				
a. R Squared =.381 (Adjusted R Squared =.361)						

APPENDIX V: FMCI ANCOVA SECOND ITERATION

Table V-1: FMCI ANCOVA results of pressure measurement

Dependent Variable: P POST-FMCI						
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	.707a	2	.354	10.173	.000	.250
Intercept	2.942	1	2.942	84.734	.000	.581
Pre-test	.008	1	.008	.230	.633	.004
Group	.702	1	.702	20.181	.000	.249
Error	2.121	61	.035			
Total	25.355	64				
Corrected Total	2.828	63				
a. R Squared =.250 (Adjusted R Squared =.226)						

Table V-2: FMCI ANCOVA results of fluid flow

Dependent Variable: F POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.736a	2	.368	14.704	.000	.321
Intercept	1.960	1	1.960	76.718	.000	.557
Pre-test	.035	1	.035	1.359	.248	.022
Group	.736	1	.736	28.802	.000	.321
Error	1.559	61	.026			
Total	27.170	64				
Corrected total	2.295	63				
a. R Squared =.321 (Adjusted R Squared =.299)						

Table V-3: FMCIANCOVA results of Bernoulli principle

Dependent Variable: B POST-FMCI						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	.591a	2	.296	13.036	.000	.299
Intercept	2.466	1	2.466	108.708	.000	.641
Pre-test	.171	1	.171	7.518	.008	.110
Group	.411	1	.411	18.136	.000	.229
Error	1.384	61	.023			
Total	23.586	64				
Corrected total	1.975	63				
R Squared =.299 (Adjusted R Squared =.276)						

APPENDIX X: LANGUAGE EDITOR'S LETTER

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19 January 2022

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THE USE OF MULTIPLE REPRESENTATION APPROACH IN ENHANCING THE LEARNING OF FLUID MECHANICS IN UNDERGRADUATE PHYSICS CLASSES IN ETHIOPIA

BY

ASHENAFI LEGESE SEGNI

I declare that I have edited and proofread this thesis. My involvement was restricted to language usage and spelling, completeness and consistency and referencing style. I did no structural re-writing of the content.

I am qualified to have done such editing, being in possession of a Bachelor's degree with a major in English, having taught English to matriculation, and having a Certificate in Copy Editing from the University of Cape Town. I have edited more than 300 Masters and Doctoral theses, as well as articles, books and reports.

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APPENDIX Y: CERTIFICATE OF PARTICIPATION


Certificate of Participation

The Ethiopian Physical Society

This Certificate is awarded to

ASHENAFI LEGESSE

In recognition of his/her presentation at the 10th National Conference of the Ethiopian Physical Society held in the premises of Debre Markos University on February 5-6, 2016.

Signature

06 February, 2016

Date

Dr Chernet Amente

President of the Ethiopian Physical Society

01 07 201

APPENDIX Z: TURNITIN REPORT

thesis final 2022

ORIGINALITY REPORT

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7	dirzon.com Internet Source	<1%

Curriculum Vitae

Personal Information	
Name Address Telephone E-Mail Nationality(-Ies) Gender	Ashenafi, Legesse, Segni Jimma, P.O. Box 378 0911-61-56-48 or 0912-45-32-38 (mobile) ashenafilegese@ju.edu.org or ashelynap@gmail.com Ethiopian Male
Education & Training	
Dates Qualification Title Awarded Name of the Organisation That Provides	October 2, 2002–July 1, 2006 Bachelor's Degree, B. Ed. Degree in Physics, Jimma University
Dates Title Of Qualification Awarded & Name Of Organisation Providing	From January 1, 2008, to April 30, 2010, Master's Degree M. Ed. Degree in Physics. Addis Ababa University.
Training	
Dates Title Of Qualification Awarded Principal Subjects/ Covered	February 8–12, 2012 Training of Trainers on Fundamental Concepts of National Quality infrastructure for university lecturers Certificate

	Ethiopian Meteorological Agency.
Dates Title Of Qualification Awarded Principal Subjects/ Organiser	March 28th - April 3rd, 2013 Training of Trainers on Instrumentation, Quality Control and Improvement for University Lecturers Certificate Ethiopia Metrology Agency
Research Conferences	
Dates Conference Name Title Of Presentation Awarded Principal Subjects/ Organiser	February 2014 The 8th Annual Conference of the Ethiopian Physical Society (EPS) Categorisations of thermodynamics students' alternative conception Certificate Addis Ababa University.
Dates Conference Name Title Of Presentation Awarded Principal Subjects/ Organiser	March 2015 9th Annual Conference of Ethiopia Physical Society (EPS) The use of Multiple Representation in teaching fluid thermodynamics: Certificate Addis Ababa University

Dates Conference Name Title Of Presentation Awarded Principal Subjects/ Organiser	February 2016 10th Annual Conference of Ethiopia Physical Society (EPS) Categorisations of fluid mechanics students' alternative conception: Certificate Debre Markos University,
Dates Conference Name Title Of Presentation Awarded Organised At	February 2017 11th Annual Conference of Ethiopia Physical Society (EPS) Designing instructional approach for fluid mechanics using multiple representations: Certificate Dire Dhawa University

Dates Conference Name Title Of Presentation Awarded Organised At	March 2019 13th Annual Conference of Ethiopia Physical Society (EPS) The use of Multiple Representations in teaching fluid mechanics: Certificate Adama University
Dates Conference Name Title Of Presentation Awarded Organised At	February 2021 15th Annual Conference of Ethiopia Physical Society (EPS) Categorisations of undergraduate students' alternative conception of buoyancy force: Certificate Walkite University
Work Experience	
Dates	November 2006 - October 2010 (for 3 years)
Occupation Or Position Held Company Name	Teacher and Coordinator Addis Ababa education office
Dates	April 2009 – September 10 2019 (for 9 years)
Occupation Or Position Held Company Name	Lecturer and Researcher Mizan-Tepi University
Dates	September 2019 – Up to now (more than 2 years and still)
Occupation Or Position Held Company Name	Senior Lecturer and Researcher Jimma University
Main Activities & Responsibilities	• Preparation of teaching material and related activities • Classical Mechanics II: • Research method and Senior Project: • Edition three of Teaching Modules • Preparation of five syllabi of Physics
Additional Experience	
Occupation Or Position	Entrepreneur, Book writer, and long and short-term trainer
Personal Skills & Competence	• Science laboratory installation • Preparation of Science lab kits • Mobile Hardware & Software Maintenance • Computer Hardware & Software Maintenance

Language(S)-Self Assessment Level Oromiffa Amharic English	Listening / Reading / Speaking / Writing Proficient / Proficient / Proficient / Proficient Proficient / Proficient / Proficient / Proficient Proficient / Proficient / Proficient / Proficient
Computer Skills & Competences	MS Office, Video & Audio Editor, Adobe PhotoShop IBM SPSS, STATA, PhET, Math Lab, FORTRAN, etc.
Additional Information/ References	Professor Jeanne Kriek Address: kriekj@unisa.ac.za, University of South Africa, Dr Tolu Biressa Address: tolubiresa@ju.et.org Jimma University

Language	Listening	Reading	Speaking	Writing
Oromiffa	Proficient	Proficient	Proficient	Proficient
Amharic	Proficient	Proficient	Proficient	Proficient
English	Proficient	Proficient	Proficient	Proficient