High-School Students' Conceptual Understanding of Fluid Dynamics Following Online Learning During the Coronavirus Pandemics

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Abstract. Growing evidence indicates that COVID-19 has influenced student achievement. There are upsetting indications in core subjects like physics that students could be falling further behind pre-pandemic expectancy in some grades. Concerning the pandemic's worrying effects, the primary purpose of this paper is to explore the grade-11 students' understanding of dynamics fluid following online learning during the coronavirus pandemics. One hundred and forty-two grade-11 students took the four-tier diagnostic instrument—Cronbach alpha reliability coefficient estimated for the four-tier diagnostics test at 0.79. Item validities ranged from 0.442 to 0.18. Data were analyzed by computing the percent of correct answers at each tier and alternative conceptions. Dealing with dynamics fluid concepts, 75% of students had misconceptions, 21% did not know the concepts, and 4% lacked knowledge, the high percentage of misconception (78.9%) related to continuity equation dan Bernoulli's principle.

Keywords: High-School Students · Conceptual Understanding · Fluid Dynamics · Online Learning

1 Introduction

It seems that there is no nation in the entire world resistant to coronavirus disease 2019 (COVID-19) threats. As a result of the noxious effects on humanity, COVID-19 calls a global pandemic [1]. Although COVID-19, which emerged in the Chinese region of Wuhan city, was first reported in December 201 [2], the disease surprisingly spread so fast across China and other parts of the world [3]. As of April 2020, the number of worldwide COVID-19 cases has exceeded one million patients and more than 220 thousand mortalities [4]. The speed of spread and the harmful effects on humanity are two of the main reasons the outbreak of the COVID-19 pandemic categorized as the worst global pandemic for decades.

A growing body of research articles reports the failure of online learning systems in elementary and high schools, particularly in underdeveloped countries. For example,

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Rouadi et al. [5] report that online learning does not yield wanted results in Lebanon: an unstable or slow internet connection, power outages, lack of student participation, and the limitations of students' laptops or laptops cellphones. Furthermore, Fauzi et al. [6] state that online learning is less successful in Indonesian schools due to (1) the limitations of online learning support facilities in schools; (2) the internet network cannot reach the student's residence; (3) the unpreparedness of teachers to carry out online learning, particularly on online learning tools, knowledge, and skills of implementing ICT-based learning, and evaluating student learning achievement.

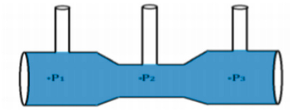
During the pandemic, the suspension of face-to-face instruction in the classroom has led to concerns about students' achievement. Online learning may not be more effective for students' understanding than face-to-face interaction [7]. Moreover, the study conducted by Engzella et al. [8] reported that students made little or no progress while online learning. Nevertheless, the research papers published that the impact of learning disruption on students' conceptual understanding following online learning is hard to find. Therefore, the purpose of this paper is to provide the recent study related to the high school student's conceptual understanding of dynamics fluid after taking physic lessons during the pandemic.

Another formidable challenge is the assessment system since applying effective assessment strategies is essential for online learning [9]. The assessment system to measure student achievement during the pandemic uses online assessment through various strategies such as the google form and google classroom platforms. However, the weakness of the online assessment reported by Yulianto et al. [10] is the validity of the assessment. Although researchers still debate that it is impossible to measure a student's understanding of a subject matter via online assessment [11]. Thus, strategies and instruments to measure students' understanding following online learning have been attending since Robles et al. [12] had raised this issue before online learning was widely adopted.

The diagnostic test is an instrument used to determine whether someone has misconceptions about certain concepts. A diagnostic question is valid and reliable if the answer choices, the reasons for the answer choices, and the confidence in the answer choices can identify misconceptions [13]. Law et al. [14] assert that a powerful diagnostic question can identify students who cannot understand certain parts of physics content and explain how students think to answer the question even though the answer is wrong. Therefore, students' conceptual understanding needs to be identified by the physics teacher via the diagnostic test. Lin [15] indicated that a teacher could use a diagnostic test before or after learning to identify whether his students have misconceptions.

The four-tier diagnostic test is an extension of the three-tier diagnostic test. The extension is the level of confidence in selecting the answer and reason. Moreover, the first-tier is a multiple-choice question with four distractors and an answer key for students to choose from the alternative answer. The second tier is the level of students' confidence in the answer choices. The third level is the students' reasons for answering questions in the form of closed reasons. The fourth level is the level of student confidence in the chosen reason. The advantages of this four-tier diagnostic test are that the teacher can: 1) distinguish the level of confidence in the answers and the level of confidence in the reasons chosen by students, 2) identify parts of the material that require more emphasis, 3) plan better learning to avoid students' misconceptions (Rusilowati, 2015) [16].

Look at the following picture



At what point does the fluid experience the lowest pressure according to Bernoulli's law? (First-tier)

A. Point P1, P2, and P3 B. Point P1 and P3 C. Point P1

D. Point P2 E. Point P3

Confidence rating (*Second-Tier*)

1. Just guessing 2. Very unconfident 3. Unconfident
4. Confident 5. Very confident 6. Absolutely Confident

Reason for the answer (*Third- tier*)

A. Pressure is inversely proportional to the cross-sectional area of the pipe
B. Pressure is directly proportional to the velocity of fluid flow
C. The higher the speed, the lower the pressure
D. The pressure at every point on the pipe is the same
E. Pressure is directly proportional to a cross-sectional area

Confidence rating (*Fourt-tier*)

1. Just guessing 2. Very unconfident 3. Unconfident
4. Confident 5. Very confident 6. Absolutely Confident

Fig. 1. An example of Four-Tier Dynamic Fluid Diagnostic Test

2 Method

2.1 Design Study

This study adopted a descriptive research design since the purpose of this study is to explore the 11th graders' conceptual understanding of fluid dynamics following online learning during the Covid 19 pandemic. Descriptive research design is a part of non-experimental quantitative research designs [17]. Moreover, its' purpose is to explain individuals, events, or conditions by conducting investigations without manipulating any variables [17]. Therefore, this research uses a descriptive research design in order to achieve the intended research objective.

2.2 Sample and Instrument

Convenience sampling criteria determine the students involved in this study. The study conducted was in the 2020–2021 school year and coincided with the COVID-19 pandemic; the criteria to determine the sample were the willingness of students and schools to be involved in this study. Four classes in a public high school located in Bengkulu city (Indonesia) with 142 eleven grade students (17–18 years old) participated in this study who had studied the fluid dynamics content.

Data collection used four-tier diagnostic tests on the concept of fluid dynamics. The first, second, third tier, and fourth tier related to multiple-choice with five answer choices, the student's confidence in answering the question, the reason for the answers to the first tier, and level is the confidence in choosing the answer (see Fig. 1).

The content boundaries of four-tier diagnostic item tests referred to the physics syllabus based on the national curriculum (K-2013) and two standard physics books.

Table 1. Data of content and empirical validity, discrimination index, and difficulty level

Sub- Concepts	No. Qs	Content Validity	Empirical Validity	Discrimination Index		Difficulty Level	
				Value	Criteria	Value	Criteria
Continuity Eq.	1	1.00	0.36	0.56	good	0,43	moderate
Bernoulli Eq.	2	1.00	0.26	0.78	excellent	0,68	moderate
Relationship flow velocity and cross-sectional area	3	1.00	0.44	0.33	good	0,25	difficult
	4	0.90	0.10*	0,56	excellent	0,28	difficult
	5	1.00	0.38	0.22	poor	0.24	difficult
	6	1.00	0.04*	0.33	good	0.22	difficult
Relationship flow velocity and pressure	7	1.00	0.16*	0.44	good	0.69	moderate
	8	0.98	0.25	0.56	good	0.64	moderate
Application of continuity and Bernoulli Eq	9	0.10	0.43	0.56	good	0.45	moderate
	10	0.98	0.12*	0.33	good	0.25	difficult
	11	1.00	0.20	0.22	good	0.14	difficult
	12	1.00	0.30	0.56	good	0.64	moderate
	13	1.00	0.19	0.44	good	0.12	moderate
	14	0,98	0.18	0.55	good	0.64	moderate
	15	0,93	0.23	0.44	good	0.60	moderate

Note: * invalid due to r_pbis > r_(table) (=0.1648); Items 4, 6, 7, and 10 are taken out from the item pool.

The study focuses on the continuity equation, the Bernoulli equation, the relationship between flow velocity and cross-sectional area, the relationship between flow velocity and pressure, and the application of continuity and Bernoulli equations.

This study's four-tier diagnostic test instrument was the adaptation of four-tier diagnostics developed by [18, 19]. The objectives of a validated instrument are to determine the content and construct validity prior to performing an empirical validity test (see Table 1). Content validity is determined through an expert judgment process to produce a content validity ratio by five panels of subject matter consisting of 3 lecturers dan two physics teachers. Following empirical validity, the predictive validity test used biserial point correlation, discrimination index, difficulty level, and Alpha Cronbach specified item validity and instrument reliability.

Based on Table 1, eleven items were valid, but items 4, 6, 7, and 10 were invalid. Hence, all four questions can not identify the conceptual understanding of eleven graders about the dynamic fluid concept. The reliability test uses the Kuder-Richardson (KR-20) formula. The reliability test results are reliable if the coefficient value of r11 > 0.70 [17].

The reliability test results obtained from the calculation of student answer choice data in the first tier are 0.980, so that r_{11} (0.980) > 0.70.

2.3 Data Collecting in School During Pandemic

During data collection, the learning process took place online and offline. As a result of the half number of students allowed to come to school, data collection could not be performed simultaneously in one day. However, students answered the four-tier diagnostic tests when taking part in offline learning with strict health protocols. One hundred forty-two students involved in this study took diagnostic tests under the researcher's supervision to ensure that 142 students answered from first-tier to four-tier. They spent 50 min answering the four-tier diagnostic test.

2.4 Data Analyses

Data analyses use a quantitative technique that relies on frequency and percentage in reporting the findings. The usage of Microsoft Excel datasets was to compute the four-tier scores of students. The scoring for every tier follows the following method.

1. The correct answer codes 1 and 0 if the wrong answer for the first tier.
2. The correct answer (first-tier) and the correct choice of reason (third-tier) codes 1 and 0 if both are incorrect.
3. The confidence rating is high on the second-tier and fourth-tier if a scale of 4 or 5 or 6 is selected. On the contrary, if the confidence rating is low, a scale of 1 or 2 or 3 is selected.

The emphasis of analyses is to compute students' correct answers in first dan third-tier. Students can classify students as understanding concepts, lack of knowledge, and misconceptions based on students' answers. Table 2 presents the interpretation of answering the four-tier dynamic fluid diagnostics test adapted from Farayani et al. [16–20].

3 Result and Discussion

The data collected to have the intended aim was from 11 four-tier diagnostic tests that satisfy the content and empirical validity and reliability. Data were analyzed to explore the conceptual understanding based on the answer choices given by the 142 eleven graders. The majority of a category of students' conceptual understanding shown in Table 3 is misconceptions followed by lack of knowledge and understanding concept.

A total of 112 students identified misconceptions with the most combinations of misconception answers. Of the 11 questions tested, the highest misconception (78.9%) questioned no. 2 related to Bernoulli's principle (see Fig. 1). The first tier answered incorrectly, the second tier had a high level of confidence, the third tier chose the wrong reason, and the fourth tier had a high level of confidence (see Table 2).

Most students chose option B on question no. 2; "the lowest pressure is at points P1and point P3", which pipe has a larger cross-sectional area than point P2. In other words, students assume that a large pipe produces low pressure. This idea contradicts Bernoulli's principle; when the pipe has a small diameter (point P2), the fluid velocity will be high and the pressure low.

Table 2. Category of student conceptual understanding and answer combination

Category	Answer	Answer Combination		
		Confidence of answer	Reason	Confidence of reason
Understanding Concept	True	High	True	High
Lack of knowledge	True	Low	True	Low
	True	High	True	Low
	True	Low	True	High
	True	Low	False	Low
	False	Low	True	Low
	False	Low	False	Low
	True	High	False	Low
	False	Low	True	High
Misconception	True	Low	False	High
	True	High	False	High
	False	High	True	Low
	False	High	True	High
	False	High	False	Low
	False	Low	False	High
	False	High	False	High

The results indicated that students could not entirely understand the concept of dynamic fluid, mainly the continuity equation and Bernoulli's law. Students have misconceptions because they assume that the fluid velocity dependent on the cross-sectional area. Fluid flows rate at a small cross-sectional area will also slightly discharge.

Dewi et al. [19] reported that students could not understand the relationship between the cross-sectional area (A) with velocity (v) and pressure (P) correctly. Based on Bernoulli's principle, the pressure is low when the fluid velocity is high [21]. Students can still not relate the cross-sectional area, velocity, and pressure to Bernoulli's principle. Predominantly, students' understanding is still partial regarding a phenomenon because students only memorize formulas and do no practical work.

Approximately 75% of students experience misconceptions after studying dynamic fluids during the COVID-19 pandemic caused by the changes in the learning system from face-to-face in class to online learning. Students' independence in learning is highly demanded in online learning because interaction with teachers is limited in the

Table 3. Frequency and Percentage student (N = 142) understanding for each item

Sub-concepts	No. Qs	Students' Category					
		UC		LK		MC	
		Freq	%	Freq	%	Freq	%
Continuity Equition	1	8	5.6	35	24.7	99	69.7
Hukum Bernoulli law	2	2	1.4	28	19.7	112	78.9
Correlation flow velocity and cross-section	3	13	9.2	34	23.9	95	66.9
	5	20	14.1	44	31.0	78	54.9
Correlation flow velocity and fluid pressure	8	6	4.2	59	41.5	77	54.9
Application of continuity and Bernoulli law	9	14	9.9	27	19.0	101	71.1
	11	5	3.5	58	40.8	79	55.6
	12	11	7.7	54	38.0	77	54.2
	13	4	2.8	50	35.2	88	62.0
	14	3	2.1	29	20.4	110	77.5
	15	2	1.4	51	35.9	79	55.6

Note: UC: Understanding Concept; LK: Lack of knowledge; MC: Misconception

online learning system. Klein et al. [22] conducted a study that involved 578 physics students at five universities in Germany, Austria, and Croatia concluded that students' self-regulation skills were positively correlated ($r = 0.63$, $p < 0.001$) with learning achievement.

Online learning has various advantages. For example, learning can occur anywhere and anytime, flexible learning time, cheaper education mode (affordability) in terms of transportation costs, accommodation, education costs. However, the study stated that the lack of frequent interaction between students and teachers, technical problems, and difficulties in understanding concepts to be achieved were the main obstacles in online learning [23].

To explore the process of learning physics online during the Covid-19 outbreak, interviews with two physics teachers and administered questionnaires to students. From the results of interviews questionnaires filled out by students, the learning process during Covid-19 affects students' knowledge or understanding of the subject matter.

4 Conclusion

Since none of the students answered correctly on the first, second, third, and fourth, none fully understood the concept of dynamic fluid. The four-tier diagnostic test results provide information to physics teachers that online learning during the pandemic and the reduction in study time are causes why most students experience a lack of knowledge, lack of understanding, and misconceptions. These upsetting indications in core subjects like physics could be falling further behind pre-pandemic expectancy.

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