Exploring K-11 Students' Conception using a Four-Tier Diagnostic Test on Static Fluid: a Case Study

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Abstract

The aim of this study was to explore the students' conception using a four-tier diagnostic test on static fluid. A case study has been implemented through a single case, namely embedded design. Participants of this study were rougly 30 K-11 students (12 boys and 18 girls), and their average age was 16-17 years old. The instrument utilized a 12 item Four Tier Static Fluid Test (FTSF-Test) which covered three concepts: hydrostatic pressure, Pascal law, and Archimedes law, which was validated by the experts. To identify students conceptions, we already described that the test was able to investigate the categories of students into student conception on static fluid concepts. The research result shows that the percentage of the average category of the students were scientific knowledge (19.4%), lack of concept knowledge (37.5%), which was likely to have misconceptions (40.6%) and had an error of about (2.5%). Based on these results, it can be concluded that there are still many students in the classroom context who have misconceptions and it can be very useful as a basis for further research.

Keywords: *Students' conception, Four-tier test, Static fluid*

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1. Introduction

Studies on students' conceptual understanding of numerous areas in knowledge have been a significant aspect of study in science learning, especially on physics concepts. Students' everyday lives and experiences, their schemes of belief and learning surroundings, their efforts to understanding concepts using their as yet unformed conceptual skills and other factors, conflict with the environment of science itself as well as with the process of how scientific knowledge occurs (Ozkan & Selcuk, 2015). In this process, students might assign incorrect meanings to a scientific fact. The study in science education indicates that students develop their own concepts about basic science concepts formerly coming to science lessons (Driver et al., 1994; Demircioglu, 2009; Aslan & Demircioglu, 2014; Shen, Chang, & Liu, 2015). The conception built by students is not in accordance with the conception of scientific knowledge which is known as 'misconceptions' (Kose, 2008; Liu & Fang, 2016; Fariyani, Rusilowati, & Sugianto, 2017). Misconceptions block the adjustment of developed knowledge (Ercan, Tasdere, & Ercan, 2010; Ozkan & Selcuk, 2015). So misconceptions are tough to change with scientific ones and students might refuse accepting new conceptions and it is a problem for student learning and to make meaningful understanding of approximate concepts in physics (Hynd et al, 2015; Suhandi et al, 2017). Thus, students' misconceptions can be stronger and more resistant in being corrected with scientific ones (Larkin & Jorgensen, 2016; Hermita et al., 2017; Oliver et al., 2017).

In addition, Kaltakci and Didis (2007) recorded the belongings of misconceptions as: (1) powerfully apprehended, unchanging cognitive assemblies (2) differ from scientists' conceptions (3) disturb how students comprehend natural occurrences and scientific descriptions (4) must be removed. Student misconceptions need to change the wrong conception to the correct understanding. For this reason, it becomes important to measure the misconceptions of a student as soon as possible (Canu, Hosson, & Quque, 2016; Hermita et al., 2017). According to Kaltakci-Gurel, Eryilmaz, and McDermott (2017), the precise diagnosing of students' misconceptions has derived to be the main primary phase in the path of developing an acceptance of student knowledge. Students' misconceptions can be sensed through a diagnostic instrument (Fazio & Battaglia, 2018). Many studies have developed and implemented different diagnostic instruments as was the case with Chang et al (2007); Eryilmaz (2010); Caleon and Subramaniam (2010); Kaltakci and Didis (2007).

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Kaltakci, Eryilmaz, and McDemott (2015) presented the importance of diagnostic assessment in science and offering an indication of the diagnostic instruments to assess misconceptions in the science education research literature since the 1980s in a comparative manner. However, a distinct diagnostic instrument has some aids, as well as faintness was completed by others (Kaltakci, Eryılmaz, & McDermott, 2017). Chang et al. (2007) developed a two-tier test for identification of students' misconceptions, and many other researchers used the questioning in the first tier as a classical multiple-choice question and in the second tier they utilized its reason. The developed a three-tier misconception test done by Eryilmaz (2010). In addition to the second tier, the third-tier students' confidence regarding the first two tiers was questioned. If the student chooses an incorrect choice in the first tier, then chooses an incorrect reasoning in the second tier and was sure about the responses in the first two tiers, then the student had a misconception (Kaltakci & Didis, 2007). Futhermore, Caleon and Subramaniam (2010) and Kaltakci, Eryilmaz, and McDemott (2015) had developed a four-tier diagnostic test item.

According to Hermita et al. (2017), he described various kinds of diagnostic instruments such as 1) a two-tier test does not have a composed grade to recover an influential examination, and 2) a two-tier test is not suitable to investigate learners' beginnings. The structure arrangement in the four-tier (four levels), entailed: (1) the first-tier labels about abstract questions in method of several choices; (2) the next level for the confident rating measure ("Sure" and "Not Sure"); (3) a reason related with a selection in the first tier; and (4) the second confidence rating, specifically: "Sure" and "Not Sure". The four-tier test is more accurate to diagnose students' misconceptions (Kaltakci et al., 2017). Four-tier tests can correctly evaluate students' misconceptions which are allowed of no understanding and partial understanding. Therefore, to explore student conception, we used a four-tier diagnostic instrument on the static fluid concepts.

2. Objectives

The objectives of the study aim to explore K-11 student conceptual using static fluid four tier test; scientific knowledge (SK), lack of knowledge (LK), misconceptions (M), and errors (E).

3. Materials and Methods

3.1 Research Design

The research methods used a single case study which is one type of qualitative research. A case study is used to investigate one or more establishments or groups within establishments with a view to providing related analysis and the processes involved in the phenomenon under study (Zeng, Proctor, & Salvendy, 2011). The research design used an embedded design. The case under investigation is one large case with the unit of analysis having been determined. A quantitative approach in this study is applied for analyzing the case under the study and support of the description of results. The research was finished taking data by giving the diagnostic test on static fluid concepts. This test took 50 minutes. This test was given to students who have previously studied the concepts covered in this test. Then the results were processed statistically and analyzed. Therefore, the research procedure performed is shown in Figure 1 below.
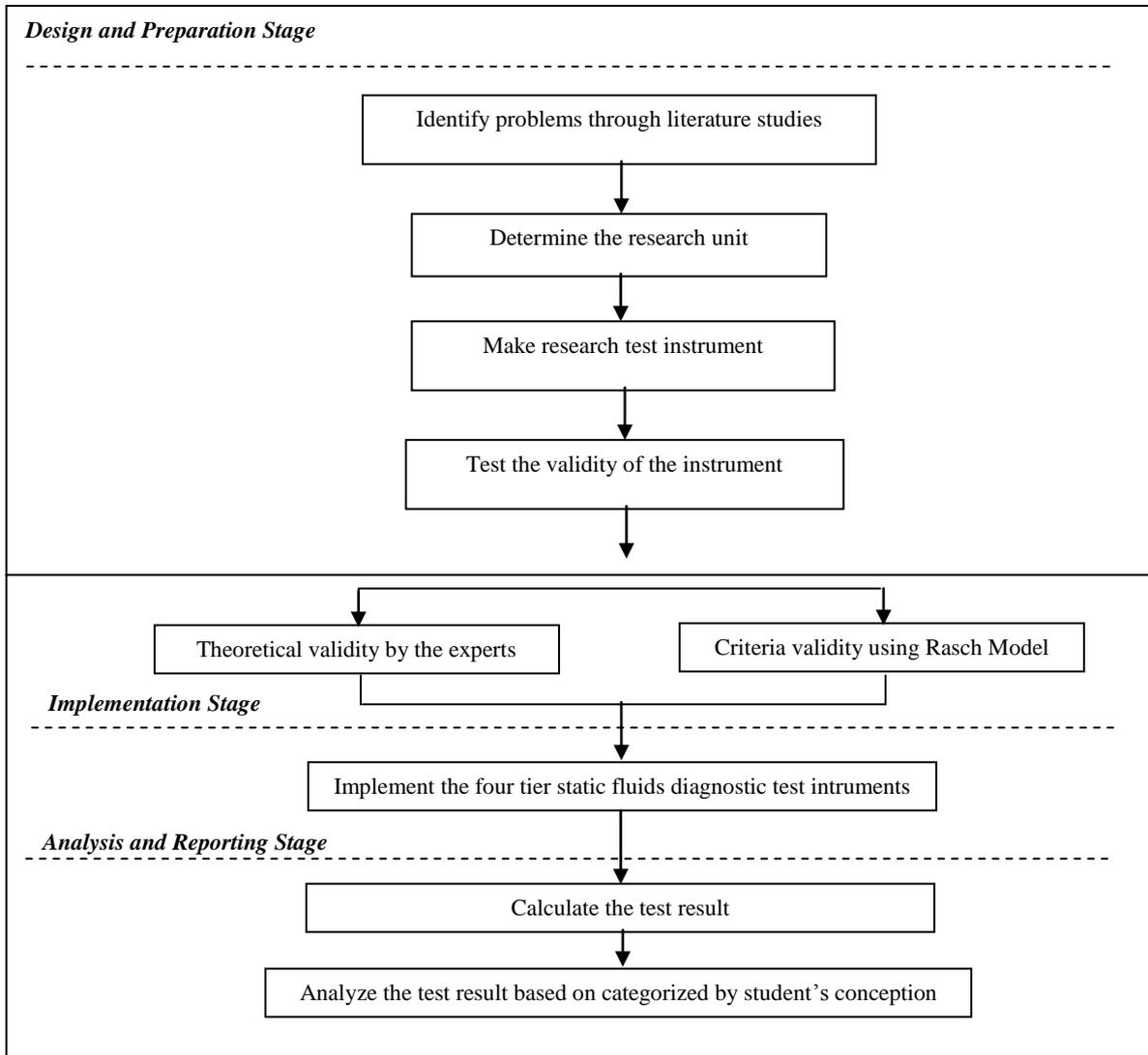
Figure 1 Research procedure

3.2   Participants

Participants in this research were 30 K-11 students, whose age was 16-17 years old. The participants were chosen with the consideration that the class had already studied static fluid concepts so that it can be seen the students' conception of static fluid concepts using prepared instruments.

3.3   Instrument

The instrument used in this research was the Four Tier Static Fluid Test (FTSF-Test). The instrument test used in this study had 12 items, covering three part of concepts: hydrostatic pressure, Pascal law, and Archimedes law. The four-tier diagnostic test items consisted of four levels, namely: the first was multiple choices, the second was confidence rating correlated to the first tier, third was a reason for completing the answer in the first tier and the fourth was confidence in rating correlated to the third tier. For analysis, this instrument we have developed the category to diagnose the students' conception. The form of a question in a four-tier format shown in Figure 2.

11.1. Beams A and B both float when put in a container filled with water. The two objects are glued together so that the two objects merge as in the following picture.

So, when a combined beam is inserted into the water, what will happen?
   A. The combined beam will sink
   B. The combined beam will float
   C. The combined beam will suspend
                    D. The combined beam will suspend then sink.

11.2. Confidence ranting:
   Are you sure about the answers to question 11.1?
      A. I am sure
      B. I am not sure

11.3. Which one below is the reason for your answer in question 11.1?
   A. The weight of a combined object increases so that the buoyant force experienced by a combined object gets smaller.
   B. The combined weight of objects increases with the combination of buoyancy forces between the two objects.
   C. The size of the combined object is greater so that the weight of the combined object will compensate for the buoyancy.
   D. The size of the combined object is greater so that the weight of the combined object cannot be balanced by its buoyant force
   E. ....
      ....

11.4. Confidence rating:
   Are you sure about the answers to question 11.3?
      A. I am sure
      B. I am not sure

Figure 2 Example of the Four Tier Static Fluid Test (FTSF-Test)

The data of students' answers on FTSF-Test were identified and categorized students conception based on Samsudin et al. (2017). The categorized data was scientific knowledge (SK), lack of knowledge (LK), misconceptions (M), and errors (E).

Table 1 The category of student conceptions through a four-tier diagnostic test (Samsudin et al., 2017)

Category	Combination of answers			
	Option (Tier I)	The First Confidence Rating Scale (Tier II)	Reasons (Tier III)	The Second Rating Scale (Tier IV)
Scientific Knowledge (SK)	Correct	Sure	Correct	Sure
Lack of Knowledge (LK)	Correct	Sure	Correct	Not Sure
	Correct	Sure	Incorrect	Not Sure
	Correct	Not Sure	Correct	Sure
	Correct	Not Sure	Correct	Not Sure
	Correct	Not Sure	Incorrect	Not Sure
	Incorrect	Sure	Correct	Not Sure
	Incorrect	Sure	Incorrect	Not Sure
	Incorrect	Not Sure	Correct	Not Sure
	Incorrect	Not Sure	Incorrect	Not Sure
Misconceptions (M)	Correct	Sure	Incorrect	Sure
	Correct	Not Sure	Incorrect	Sure
	Incorrect	Sure	Incorrect	Sure
	Incorrect	Not Sure	Incorrect	Sure
Error (E)	Incorrect	Sure	Correct	Sure
	Incorrect	Not Sure	Correct	Sure

Before implemented to the students, the validity and reliability of the FTSF-Test calculated using the Rasch model was done. The FTSF-Test had a 'fulfilled' unidimensionality for validity measure, where the index of raw variance explained by measures was above 20% (Sumintono & Widhiarso, 2014) as shown in Figure 3.

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INPUT: 30 Person  12 Item  REPORTED: 30 Person  12 Item  3 CATS  MINISTEP 3.75.0
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    Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                              -- Empirical --      Modeled
Total raw variance in observations      =    43.7 100.0%           100.0%
  Raw variance explained by measures    =    13.7  31.4%            30.9%
    Raw variance explained by persons   =     6.1  13.9%            13.7%
    Raw Variance explained by items     =     7.6  17.5%            17.2%
  Raw unexplained variance (total)      =    30.0  68.6% 100.0%     69.1%
    Unexplned variance in 1st contrast  =     5.1  11.6%  16.9%
    Unexplned variance in 2nd contrast  =     4.7  10.8%  15.7%
    Unexplned variance in 3rd contrast  =     3.9   9.0%  13.1%
    Unexplned variance in 4th contrast  =     3.5   8.0%  11.7%
    Unexplned variance in 5th contrast  =     2.9   6.7%   9.7%
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Figure 3 The result of unidimensionality (validity) using the Rasch model

The criterion reliability was done by using an alpha-Cronbach coefficient of Rasch Models. The value of the Cronbach Alpha coefficient is 0.79 (as shown in Figure 4), and designated the relations between n=30 students and 12 items. The reliability score is classified as 'good'. From the analysis of the Rasch model, it can be concluded that FTSF-Test is valid and reliable to be used.

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INPUT: 30 Person  12 Item  REPORTED: 30 Person  12 Item  3 CATS  MINISTEP 3.75.0
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     SUMMARY OF 30 MEASURED Person
--------------------------------------------------------------------------------
|          TOTAL                        MODEL       INFIT        OUTFIT   |
|          SCORE     COUNT    MEASURE    ERROR    MNSQ   ZSTD   MNSQ   ZSTD |
|------------------------------------------------------------------------------|
| MEAN      9.2      12.0       -.58      .47      .96    .0     .97    .0  |
| S.D.      4.9       .0         .94      .07      .35   1.0     .35    .9  |
| MAX.     16.0      12.0        .68      .61     2.11   2.7    2.12   2.7  |
| MIN.      3.0      12.0      -1.92      .41      .48  -1.9     .49  -1.8  |
|------------------------------------------------------------------------------|
| REAL RMSE    .50 TRUE SD    .79  SEPARATION 1.59  Person RELIABILITY  .72 |
|MODEL RMSE    .48 TRUE SD    .81  SEPARATION 1.69  Person RELIABILITY  .74 |
| S.E. OF Person MEAN = .17                                                 |
--------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .79
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Figure 4 The result of reliability using the Rasch model

4. Results and Discussion

Based on the four-tier test instrument, it can be seen the conception of students in K-11 senior high school on static fluid concepts according to the overall pattern of student answers. The students' conception categories were adopted based on Kaltakci and Didis (2007) which was categorized as scientific knowledge, lack of knowledge, errors, and misconceptions. In general, the result of the students' conceptual of static fluid concepts is shown by the percentage of student conception in each category score (as shown in Figure 5).
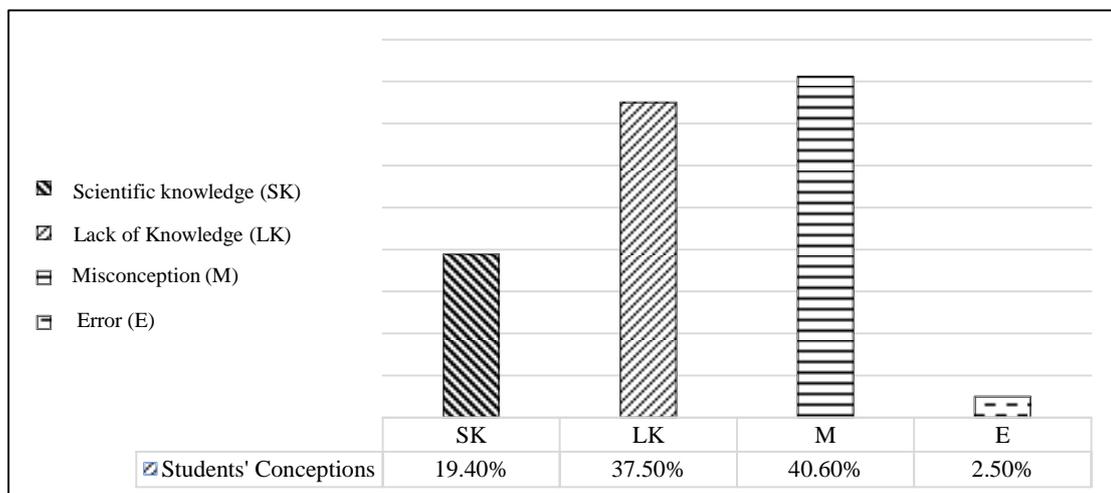

	SK	LK	M	E
Students' Conceptions	19.40%	37.50%	40.60%	2.50%

Scientific knowledge (SK)
Lack of Knowledge (LK)
Misconception (M)
Error (E)

Figure 5 The percentage of each students' conceptions

Grounded in Figure 5, it can be seen the percentage of each student's conception. The percentage in the Scientific Knowledge (SK) category is 19.4%, Lack of Knowledge (LK) is 37.5%, Misconception (M) is 40.6%, and Error (E) is 2.5%. The highest percentage is the category of Misconception (M), while the lowest percentage is the category of Error (E). This indicates that students' misconceptions in the force concept are fairly high. This is in accordance with the research of Ozkan and Selcuk (2015) which states that many students hold misconceptions in fluid concepts. Moreover, the percentage of misconceptions is higher than the other conceptions. The percentage of students' misconceptions for each item are presented in Table 2.

Table 2 The results of students' conception of each item

No Items	Scientific Knowledge (SK)		Lack of Knowledge (LK)		Misconceptions (M)		Error (E)	
	$\sum n_{SK}$	%	$\sum n_{LK}$	%	$\sum n_{M}$	%	$\sum n_{E}$	%
1	6	20.0	9	30.0	15	50.0	0	0.0
2	8	26.7	13	43.3	9	30.0	0	0.0
3	5	16.7	13	43.3	11	36.7	1	3.3
4	7	23.3	10	33.3	11	36.7	2	6.7
5	3	10.0	11	36.7	14	46.7	2	6.7
6	6	20.0	10	33.3	14	46.7	0	0.0
7	5	16.7	10	33.3	14	46.7	1	3.3
8	4	13.3	16	53.3	10	33.3	0	0.0
9	6	20.0	13	43.3	11	36.7	0	0.0
10	8	26.7	9	30.0	10	33.3	3	10.0
11	7	23.3	9	30.0	14	46.7	0	0.0
12	5	16.7	12	40.0	13	43.3	0	0.0

Based on the results of each item on Table 2, it shows that in the 12 item numbers given to students the highest student misconception was in item number 1, as half of the students' participants (n_{M1}=15) were included into the category of misconceptions. They think their experience is right so they are confident in their answers, even though the answer is wrong. It means there are experiences of students in everyday life that are in accordance with the conception of scientists and they also perceive and use concepts different from their scientific definitions (Yumusak, Maras & Sahin, 2015; Wartono, Bathlolona, & Putirulan, 2018; Prodjosantoso, Hertiana, & Irwanto, 2019).

One example of students' misconception in item number 5 is that when the same beam is inserted into two containers containing different fluids: water and oil (with a density of water greater than oil). Then it is shown that the condition of the beam in the water was "sinking", then students must answer pertaining to the conditions of the beam in the liquid oil. Students assume a thick liquid will make the object float, whereas floating or sinking an object does not depend on the viscosity of the fluid. Other misconceptions also occur as students argue that hydrostatic pressure depends on the shape of the vessel, even though the vessel's shape is not affect. Then students also argue that the magnitude of buoyancy force depends on the position of the depth of the object in the liquid, whereas buoyant forces are not influenced by the depth of the object in the liquid but rather by the volume of fluid displaced.

The second highest category of conception with the score difference being 3.1% of the highest category is a lack of knowledge (37.5%). Many students showed a lack of knowledge related to the concept of Archimedes law, especially in item number 8, 53.3% of students included in that category. In this case, some students are not sure about the answers to the questions and the reasons they gave. These findings were also found in other studies such as Taslidere and Eryilmaz (2015). According to the research of John, Molepo, and Chirwa (2016) they found that most of the wrong student answers were not followed by strong beliefs so students could not be categorized as misconceptions but did not understand the concept. Although in some conditions students correctly answered, the reasons they give were not appropriate. Then, the findings also imply that not all students' correct answers come from a strong understanding of the concept. In addition, not all incorrect student answers can be categorized as misconceptions.

Meanwhile, other categories that have the lowest percentage are in the category of scientific knowledge (19.4%) and error (2.5%). The category of scientific knowledge is indicated by the student being able to give the right answer to the questions and reasons followed by confidence, as this category is the opposite of the category of misconceptions where students have the same knowledge as the conception of scientists (Wong, Chu, & Yap, 2016; Kampourakis, 2016; Suma, Sadia, & Pujani, 2018). In item number 2 (n_{SK2}=8), it shows the highest scientific knowledge of students and the number of students who have the least misconception, students know that the magnitude of hydrostatic pressure does not depend on the size of objects in a liquid, but rather depends on the depth of an object from the surface fluid. The lowest is the

category of error, 10% of the students in item number 10 included the error category, that is indicated by students who give wrong reasons and were positive for the questions answered correctly.

5. Conclusion

Based on the results of the study that had been conducted, it is known that the conception of students can be identified based on several categories. This study obtained the conception of students in the scientific knowledge category of about 19.4%, lack of knowledge category of about 37.5%, the category of misconception of about 40.6%, and the category of error was about 2.5%. The highest average percentage was obtained by the category of misconception, and the lowest was obtained by the error category. The findings that emerged from this study suggests that the students experienced conceptual difficulties about the static fluid. Moreover, most students don't have confidence in the answers and reasons given because students don't understand the concept. In addition, the results of this study imply a four-tier diagnostic test should be used by the teacher as an evaluation tool to determine the misconceptions experienced by students. The results of this study can be a consideration for teachers in designing learning such as using a conceptual change approach. Therefore, based on this study it can be a reference for further research and teachers to prepare a learning activity that can reduce students' misconceptions.

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