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Level of Conceptual Understanding Among Secondary Students on Topic of Forces and Motion Using Half-Length Force Concept Inventory (HFCI)

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Abstract: This study aimed to identify the level of understanding of secondary school students on the topic of forces and motion as a whole as well as based on different genders. A total of 73 students from one of International School was selected as respondent. This survey study used the Half-Length Force Concept Inventory (HFCI) model. Data were analyzed using the IBM Statistical Package for Social Science (SPSS) Statistics version 26. The study found that the level of understanding of secondary school students on forces and motion topic was at low level. The misconception found in the aspect of force motion related to Newtonian concept of force. There was a significant difference in term of level of conceptual level of understanding in forces and motion topic between male and female students (M = 43.88, p =.001) which is less than .05. Results showed that the students having low level of conceptual understanding in forces and motion topic. This also will give some insights to teacher at secondary level towards identifying weakness among students on topic of forces and motion as well as improving method of approach in teaching and learning to students.

Keywords: forces and motion, half-length force concept inventory, conceptual understanding

1.0 Introduction

Education is the key fundamental of high skills and knowledgeable human capital. In the perspective of education, conceptual understanding is necessary for any student to master any science field especially physics. The biggest challenge in mastery the conceptual understanding in physics is when students' encountered discrepancy or incompatibility in applying the concept. As reported by Abdul Rahman and Zakaria (1994), students have difficulty to understand and applying physics theory that they have learned. Before students learn any new concept in physics, they have already experienced the concept or phenomena in their daily life. Students tend to believe in their logical thinking and ideas which they thought to be the explanation to what they have experienced. However, that thought is not verified and it is not necessarily correct and be the

explanation to what they belief (Nurul Fatihah, 2013). This kind of belief then become a discrepancy among students to understand a new physics concept that will be introduced.

Physics is commonly known as the fundamental science as it studies the natural phenomena of the world around us. However, physics is perceived as a difficult subject and it always come with students' alternative conceptions and difficulties which is contradict with physics concepts. Henceforth, students have difficulty in understanding some important topics in physics such as mechanics, electricity, magnetism, thermodynamics, wave, and optics (McDermott and Redish, 1999).

Forces is one of the most fundamental concepts in physics. Topic of forces plays a very important role in understanding a concept of motion and how energy can be transferred. Conceptual understanding of forces is also a prerequisite to various engineering field. Despite the importance of topic of forces and motion in physics and engineering, many students at secondary level and higher facing difficulty in understanding this concept (Muhammad Erfan and Tursina Ratu, 2018; Alias and Ibrahim, 2015). Study on physics education identified many conceptual misunderstandings related to topics in physics and most of them are Newtonian Physics which include forces and motion (McDermott and Redish, 1999).

Conceptual understanding is permanent and difficult to be corrected once it is built into the mental structure (Holton, 2001). Therefore, this study discussed diagnostics on the level of understanding and misconceptions in the topic of force and motion among secondary school students. This step is very important to ensure that students have a strong level of conceptual understanding in the topic of force and motion before moving to a higher education level. This study used an appropriate instrument suitable to physics syllabus for secondary school students to identify their conceptual understandings and misconceptions.

To perform analysis on misconception among students on topic of forces and motion, this study employed the method developed by Han et al. (2015) known as Half-Length Force Concept Inventory (HFCI). This method is developed via collaboration research done between few universities in the United States and China. The questions developed in this method is related to the concept of forces and motion. The HFCI provide a solution to a number of issues with inventory testing (Han et al., 2015).

The Half-Length Force Concept Inventory (HFCI) is one instrument used to test the conceptual understanding. HFCI is not just a test instead it assesses students' grasp the concept of Newtonian physics (Han et al., 2015). HFCI is an important instrument to assess level of conceptual understanding in topic of forces and motion among students at introductory physics education level. It is a derivative from FCI and an improved version of FCI which was first introduce in 1980s. As reported by Halloun and Hestenes (1985), the result of their studies which began in early 1980s on the belief among students where:

a) Their first experience belief is dominant where usually only small part of their belief will have paradigm change after teaching and learning physics.

b) Most of their belief related to motion generally do not match with Newtonian concept.

HFCI is a test of intelligence; it is the test to probe conceptual understanding among students. It consists of 14 multiple-choice items covering concepts of kinematics, Newton's law of motion and variety of type of forces. All the dimension concepts of the items are as follows:

No	Concepts	Dimension Concepts
1	Kinematics	a) Velocity results from rate of change of position b) Acceleration results from rate of change of velocity c) Constant acceleration entails parabolic orbit changing speed d) Vector addition
2	First Law	a) With canceling force b) With force i) Velocity direction constant ii) At constant speed
3	Second Law	a) Impulsive force b) Constant force implies constant acceleration
4	Third Law	a) Impulsive force b) For continuous forces
5	Superposition Principle	a) Vector sum b) Canceling forces
6	Type of force	a) Normal, impulsive, friction, air resistance, gravitational

Lately, the involvement of women in physics subjects at the university level is unsatisfactory (Ivie and Tesfaye, 2012). Female students like to study medicine or subjects related to biology compared to physics and engineering (Reid and Skryabina, 2003; Thomas, 1990). Female students also did not show interest and positive attitude in studying physics in high school. This problem is not only at the secondary level, but also at the college level (Perkins-Gough, 2006).

Based on these problems, this study investigated the level of conceptual understanding for secondary school students in general and based on gender. This study also explored the misconception in conceptual understanding that arises among secondary school students in the topic of forces and motion. This study will identify percentage of students which able to answer the questions correctly which then reflect their level of understanding of the topic. In addition, this study can serve as a guideline for students to improve their conceptual understanding and correct their misconception in the future.

Hallon and Hestenes (1985) stated that students' who scores 85 percent and above have a firm understanding and mastered Newtonian physics. They classified those students as "Newtonian Thinkers". Students which score 60 percent and below as having weak understanding of Newtonian physics. As stated in the study, most of the results obtain showed lack of understanding in Newtonian physics especially concept of forces and motion. On the other hand, the conceptual misunderstanding is obvious. Factor which could leads toward conceptual misunderstanding is gender. To investigate conceptual misunderstanding in topic of forces and motion between gender on first semester students in university, it showed there is no significant difference in percentage of their score (McCullough and Meltzer, 2001). Female students showed slightly higher percentage in several items than male students, but overall percentage between male and female students are almost similar and it did not give any effect on their grades. This give an insight to instructor or lecturer on students' background on physics concept.

Another study done by Seth Sulaiman and Lew Fee Ngoo (2008) to investigate the level of conceptual understanding in forces and motion topic among male and female students. The result showed mean percentage scored by male students is higher compared to female students. It also stated that the overall conceptual understanding on forces and motion topic is unsatisfactory. There was also a study conducted in Malaysia to evaluate conceptual misunderstanding among physics pre-services teachers on topic of forces and motion. The studies reported that conceptual misunderstanding also occur among prospective teachers which some of their ideas contrary to what is accepted by Newtonian Physics suggested by Nabilah et al. (2013). Besides, many studies conducted in other institution in Malaysia also shows similar trend in conceptual misunderstanding.

As reported by Nieminen et. al., (2012), male students significantly outperformed female in pre-test scientific reasoning. However, conceptual misunderstanding among gender after learning topic of forces and motion is not significant. It also stated that FCI is not a gender biased test. Same goes to HFCI as it is a derivative from FCI. This indicates the gender difference in learning was related to students' abilities of understanding and learning the concept itself. HFCI has been validated and certified as a measure of the coherent of students' understanding of forces concept and motion. Data from many studies provide evidence that HFCI can be used to evaluate students' conceptual coherence especially on contextual coherence of concept of forces and motion.

2.0 Methodology

2.1 Research design

This study use survey study design and it is classified as one type of study under descriptive research. According to Creswell and Creswell (2009), survey study design is a procedure in quantitative research in which the researcher conducts a survey.

2.2 Population and Sample

Total number of secondary students is 136 students. The population involved in this study only the students taking physics subject. This study involved 73 physics students as respondents to generalize the finding to the population of 90 physics students at a secondary school.

2.3 Instruments

Based on the research objective to find out the level of understanding among the secondary school students on forces and motion topic, this study use the latest version (version 1) of Half-length Force Concept Inventory (HFCI). It is half-length version of Force Concept Inventory (FCI) developed by Hestenes, Wells and Swackhamer (1992). This concept inventory is in English language. Researcher is available during the session if there is a need to translate any English term to Malay term verbally to eliminate language factor in answering the question correctly. Every test or inventory is protected so that its integrity is well preserved.

This inventory contains two equivalent section, section A and section B of 14 multiple-choice questions. It is derived from original FCI questions which covered the same concepts and have similar assessment characteristics. HFCI divided FCI questions into two half-length test; each section contains a different subset from the original version of FCI. This two half-length test is practical in terms of lesser administration time, lesser time taken for the test to be done and in eliminating possible test-retest effects (Han et al., 2015).

2.4 Data Analysis

Data from students will be analyzed by using SPSS V26.0 and Microsoft Excel from Microsoft Office 2010. Normality of data is tested for all collected data. Normality test of the data used in this study is Kolmogorov Smirnov.

a) General objective for this study was analyzed by using descriptive statistic. This study reported students' mean, standard deviation, maximum and minimum score in answering HFCI.

b) For the first specific objective, researcher will use parametric test which is independent t-test to investigate the significant difference on the level of conceptual understanding between secondary male and female student on force and motion topic. Normality of the data tested using Kolmogorov-Smirnov for both male and female students' score. It showed that the distribution of the data is normally distributed and it obeyed assumption in using independent t-test.
c) For the second specific objective, researcher analyzed based on percentage score for correct and wrong answer. Low HFCI percentage score for correct answer (less than 20%) or high HFCI percentage score for wrong answer (more than 50%) indicates misconception in understanding force and motion topic.

3.0 Results and Discussion

The normality test on score for male and female students was performed quantitatively using Kolmogorov-Smirnov. The result in Table 1 shown significant value p = .093 and p = .144 for male and female respectively. Significant value and result of the study shown the value of p is more than .05 for both male and female students. Thus, the data is normally distributed.

Table 1: Normality test result for score of male and female students

	Gender	Kolmogorov-Smirnov		
		Statistic	df	Sig.
Score	Male	.126	42	.093
	Female	.137	31	.144

Based on Table 2 mean level of conceptual understanding among secondary school students on the topic of forces and motion is 37.87%. Overall average male and female students score is in low level of conceptual understanding.

Table 2: Mean score (percentage) of overall students

	Descriptive Statistics		
	N	Mean	Std. Deviation
Score	73	37.87	15.46

Based on Table 3, most of the students score between low to moderate level of understanding which are 43.8% (32 students) and 37.0% (27 students) respectively. There is no student score above 80 percent for this test. Even though this test is conducted to upper level of secondary students, level of conceptual understanding on force and motion topic is considered low. This result is supported by Ahmad Tarmimi Ismail and Shahrul Kadri Ayop (2016). They reported most of secondary students were having low conceptual understanding on force and motion topic and there are no students having high level of conceptual understanding. This result generally portrayed level of conceptual understanding in forces and motion topic is problematic.

Table 3: Students' score in HFCI

Level of Understanding	Frequency	Percentage (%)
Very Low	7	9.6
Low	32	43.8
Moderate	27	37.0
Good	7	9.6
Total	73	100.0

Based on Table 4, independent t-test showed the result on conceptual understanding on force and motion topic based on gender. There is a significant difference in score for males (M = 43.88, SD = 14.85) and females (M = 29.72, SD = 12.38; t (73) = 4.31, p = .001, two-tailed). The p value is lesser than .05 showed that there was a significant difference in mean score of the dependent variable for the two groups (i.e. male and female) (Julie Pallant, 2011). In this case the dependent variable is score to indicate the level of conceptual understanding on force and motion topic. This result was contradicted with Ahmad Tarmimi Ismail and Shahrul Kadri Ayop (2016). They reported there was no significant difference in conceptual understanding in forces and motion topic between male and female students.

Table 4: The difference on conceptual understanding based on gender

Gender	N	Mean	Std. Deviation	t	Sig. (2-tailed)
Male	42	43.88	14.85	4.313	.001
Female	31	29.72	12.38		

Below is the analysis of common misconceptions among high school students on the topic of forces and motion. Low HFCI percentage score for correct answer (less than 20%) or high HFCI percentage score for wrong answer (more than 50%) indicates misconception in understanding force and motion topic. Based on Table 5, questions that involve in misconception were question number 3 and 11.

Question	Percentage					Correct answer
	A	B	C	D	E	
1	17.9	20.5	8.2	49.3	4.1	A
2	42.4	4.1	0.0	8.2	45.3	E
3	1.3	13.6	30.4	0.0	54.7	C
4	13.6	74.1	5.4	2.7	4.2	B
5	6.8	26.2	10.9	20.5	35.6	B
6	2.7	21.9	20.5	12.3	42.6	E
7	16.4	48.2	2.7	27.3	5.4	B
8	19.1	36.9	16.4	20.5	6.8	B
9	49.4	4.1	30.1	4.1	12.3	A
10	6.8	10.9	31.7	30.1	20.5	C
11	24.4	23.2	9.5	27.3	15.6	E
12	39.7	16.4	6.8	37.1	0.0	D
13	9.5	6.8	24.6	37.2	21.9	D
14	5.4	35.6	10.9	21.9	26.2	E

Question 3 in HFCI tested on force motion concept. There are 30.4% of students answered correctly with choice of answer C and 69.6% of students answered wrongly. Highest percentage of wrong answer for question 3 is 54.7% with choice of answer E. Misconception aspect assesses in this question is related to Newton's First law. It is being confirmed by students' statement post answering the HFCI. The students were discussing about this question in class mentioned that if there is a motion, there is a force acting on it. It showed this misconception is related to Newton's First law.

Question 11 in HFCI tested on force and motion concept as well. There are 15.6% of students answered correctly with choice of answer E and 84.4% of students answered wrongly. The students have to be able to relate it with Newton's Second law which stated F = ma. Force is directly proportional to acceleration means constant force implies constant acceleration. When the woman applied double force, the acceleration will be doubled and speed will increase at that instant.

Based on these two questions, it showed students tend to use their common sense when answering the questions. The misconception was force exerted on the object will remain even after it moves and speed will double if the force exerted on the object is doubled. It was aligned with study done by Driver et al. (1994) stated students' misconception on forces and motion can be divided into some mains ideas. The ideas were if there is a motion, there is a force acting, moving object has a force within it which keeps it going and speed is proportional to the force applied on the object.

4.0 Conclusion

Based on study and discussion, it is found that mean level of conceptual understanding is 37.87% which is low. From the data analysis, minimum score recorded was 7.18% and maximum score was 71.43%. There are 32 students or 43.8% of overall respondents score is categorized at low

level. This result is aligned with study done by Ahmad Tarmimi Ismail and Shahrul Kadri Ayop (2016) reported that level of conceptual understanding on force and motion among secondary school student is at low level. This study also shows that there is a significant difference between score of male and female student. HFCI test is relevant to be used to test level of conceptual understanding among secondary students as it assesses the overall grasp of Newtonian concept of force.

Through HFCI test, level of conceptual understanding can be studied and research objective was achieved. In addition, it shows that low level of conceptual understanding occurs among students especially in the topic of force motion and application of force concept in solving problem. Overall, level of conceptual understanding among secondary school students which located at urban area on topic forces and motion was found to be at low level and it shows confusion of concept of forces and motion still occur in quite a significant manner.

Through action research, teachers able to improve the weakness in teaching topic of forces and motion and enhance level of conceptual understanding among students. Therefore, it is encouraging that teachers will improve their quality of teaching as well as their approach in teaching topic of forces and motion via various method. This effort can also be supported by lecturer or researcher in university by introducing more effective method or approach in teaching topic of forces and motion.

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