PE - 15

PERFORMANCE OF DIPLOMA OF SCIENCE STUDENTS AT UPSI IN FORCE CONCEPT INVENTORY

Nur Solehah Rahim and **Shahrul Kadri Ayop***

Department of Physics, Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris (UPSI), Malaysia

Abstract

This study surveys understanding of force and motion concept among students taking Diploma of Science in UPSI. Their understanding were measured by Force Concept Inventory (FCI). Students understanding were compared with national level and to their demographic variables such as gender and academic background in Physics. 134 students and 2 lecturers participated in this study. t-test was used to analyze the difference of student conceptual knowledge with students demographic variables which is gender and student academic background in high school Physics. Results show that the UPSI's normalized gain is comparable to the national level. The level of students' conceptual knowledge according to the demographic variables are found significant, minima and hold strong Aristotelian beliefs about force and motion.

Key words: Force Concept Inventory, FCI

INTRODUCTION

The Malaysian science curriculum comprises three core science subjects and four elective science subjects. The core subjects are science at primary school level, science at lower secondary level and science at upper secondary level. Elective science subjects such as Biology, Chemistry, Physics and Additional Science are offered at the upper secondary level. Students specifically studied physics subjects since Form 4; however, the students' weaknesses in physics are a problem. Students often claimed physics is a difficult subject to learn compared Chemistry and Biology (Clement, 1993).

One of the branches of physics is the study of the concept of force and motion. According to Taber (1998), students' misconceptions seriously focused on the topic of energy as well as force and motion. Topic of force and motion is one of the topics that offered at UPSI in several courses for physics and sciences students. To enhance students' understanding of force, Ibrahim Halloun has developed questions that related to the force concept and eventually known as the Force Concepts Inventory (FCI). It was found that most students are too weak to understanding the basic concepts and very important for students to learn the concept properly before they pursue other physics knowledge.

FCI was introduce in 1992 by Hestenes, Wells & Swackhamer as a successor to and replacement for the Mechanics Diagnostic Test (Scott and Schumayer, 2012) and can be use as a diagnostic test in each academic level from foundation to the university level. It was constructs with the aim to explore the extent of students' understanding of the basic concepts of force and motion (Noridah, 2005).

FCI requires a force choice between Newtonian concepts and common sense alternatives. All the concepts in **Table 1** are essential to the Newtonian Force Concept. The table is best interprets as a decomposition of the force concept into six conceptual dimensions (Hestenes, Wells, & Swackhamer, 1992). It consists of 30 multiple-choice items covering concepts as kinematics, Newton First law, Newton Second Law, Newton Third Law, Superposition Principle and kinds of force.

Studies related student's preconceptions and misconception about physics education still do not so prominent and widespread in Malaysia. This causes the educators especially physics teachers or lecturers cannot know specifically student's preconceptions about the basic concepts of force and motion (Noridah, 2005).

Studies at the National University of Malaysia showed that there are many misconceptions on topics Force and Motion (Kamilah, 2007). Researcher found that the students was lack of scientific knowledge and influenced by the belief system that is not consistent with science concepts. The Force Concept Inventory, therefore, is not a test of intelligence; it is a probe of belief systems (Hestenes, Wells & Swackhamer, 1992).

Based on these problems, the researcher wants to investigate the conceptual knowledge of UPSI's students in force and motion. This study will identify understanding difficulties faced by students. In addition, through this research, we also know the different values of gain that could be obtain and compare with other local universities in determining the students' changing conception in understand the concept of force and motion. Therefore, this study can serve as a guideline for the benefits of lecturers and students to increase their understanding and correct their misconception in the future.

The objectives of the study are (i) to compare the FCI for students taking Diploma of Science at UPSI with national level and (ii) to find the connection between FCI performance and student's gender and student's SPM grade among students taking Diploma of Science at UPSI. SPM stands for Sijil Pelajaran Malaysia (Malaysia Education Certificate) which is taken by Malaysia student after 13 years of compulsory education.

Furthermore, this study can assist lecturers in evaluate the effectiveness of the teaching system they were using. The researcher hopes through this study, UPSI Physics lecturers can also identify what aspect that needs to be focus in terms of teaching readiness in order to improve the level of conceptual physics knowledge among the students. In addition, it is hope that through this study, the Faculty of Science and Mathematics, UPSI can identify the strength and weaknesses in the offered Science Programs.

RESEARCH METHOD

Data Collection

We collected data from 134 respondents taking the Diploma in Science at UPSI who registered Basic Physics 1 (SFU 1013) courses. This course provides knowledge on the general principle of physics. Students will be exposed to the basic problem solving based on algebra and trigonometry skills. The discussed topics are including scientific method, kinematics and dynamics, work, energy and power, rotational and gravitational motion, solids and liquids.

The respondents are distributed into 8 groups, namely A, B, C, D, E, and F. Two lecturers conducted these groups, Lecturer A (A, B, C, D) and Lecturer B (E, F, G, H). Some samples in group A and B are rejected because their data are not complete. All of the fifteen data are rejected, because they did not take pre-test. Distributions of all students are as shown in **Table 1**.

Table 1 Sample Distribution

Lecturer	**A**				**B**				**Total**
Group	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**149**
Number of Respondents	21	34	13	18	15	12	17	19	
Rejected Respondents	13	2	-	-	-	-	-	-	**15**
Accepted Respondents	**8**	**32**	**13**	**18**	**15**	**12**	**17**	**19**	**134**

Force Concept Inventory

Force Concept Inventory has high validity and reliability. In 1995, the FCI updated and has become a generic instrument used worldwide in universities and schools (Scott and Schumayer, 2012). FCI is also probably the most widely used instrument for evaluating the effectiveness of instruction in physics education research (Hestenes & Halloun, 1995). It has gone through a lengthy process of validation and its reliability has been well established (Nieminen *et. al.,* 2012).

Since FCI first published, it used in many physics courses throughout the world as a standard instrument for the assessment of student conceptual understanding of basic mechanics. Over the time, FCI has acquired a status of a standardised instrument for measurement of student conceptual understanding on mechanics. This resulted in a wide use of the test, first in the USA and then in many other countries throughout the world (Maja Planinic *et. al.,* 2010).

Since Hake's study, FCI has influenced the development of innovative pedagogies and has played a key role in facilitating acceptance by mainstream physics members. Although FCI has been given more than one hundred thousand times at several hundred institutions worldwide, little data exits on its reliability. However, Lasry *et. al.*, (2011) reported in their findings that high Kuder-Richardson reliability coefficient values (KR-20 > 0.8), and show that FCI has a high internal consistency reliability. They also stated the high test-retest reliability shows that FCI total score is a precise metric.

Research Procedure

Pre-test is administered in the first week of the semester and students were not allowed to refer any reference book and proctored by their respective lecturers teaching the course. At the end of the session, the students' profile and answer sheets along with the tests were collected. The same procedure repeated for the post-test in the last week of the semester.

By taking the pre-test, students may be sensitised to certain topics and then pay closer attention to these topics when they come up in the class. On the other hand, the pre-test is taken very early in the semester and students have no idea that they will ever see the same test again. However, Henderson (2002) reported there are no statistically significant differences in post-test scores between the groups of students who did and did not take the pre-test. Thus, taking a pre-test does not appear to bias post-test results.

Data analysis

Data from students' answer sheet were keyed in into a spreadsheet of Microsoft Excel for Microsoft Office 2007, transferred to the form of graphs, and schedule to the see the difference on respondents' answers. t-test in SPSS 17.0 programme was used to analyse the difference of student conceptual knowledge with students demographic variables which is gender and student academic background in Physics.

RESULT AND DISCUSSION

Scores obtained by the students divided into three categories of knowledge level based on the score range as determined by Halloun and Hestenes (1985). 100% respondent fall in the category <59% which indicates "very strong Aristotelian, minimal understanding Newtonian" in both pre- and post-test.

Respondents mean scores are 21.22% with a standard deviation of 2.11 and 25.87% with a standard deviation of 2.78 on their pre-and post-test respectively as shown in **Table 2**. From these, normalized gain of 0.059 is found using pre-defined $\langle g \rangle$ (Hake, 1999). The average normalised gain has become reasonably well established in the physics/astronomy literature (almost from nine literatures) as a sensible method of analyzing pre-and post-test results, even though most education researchers have never heard of it Hake also operationally define the categories of normalised gain $\langle g \rangle$.

From **Table 3** UPSI indicate the highest mean score and normalised gain. However, it is not much different with UKM mean score and normalised gain. Differently from the other two local universities, UPSI mean score is slightly higher to the mean scores found at Universiti Teknologi MARA, UiTM ($\langle g \rangle = 0.02$), and Universiti Putra Malaysia, UPM ($\langle g \rangle = 0.04$). Except for this study which get data from Diploma students, data by other researcher were collected on Bachelor degree students. Bachelor students have exposed to the Physics culture more often compare to the diploma students who just entered university after high school. However, all data are consistent showing "low-g" level.

The low pre-test score is not surprising but the low normalised gain for this study is just a reflection of how ineffective university physics instruction in changing students' misconceptions on Newtonian physics (Abd Rahman *et. al.*, 2007). Students generally have a very strong Aristotelian belief and shows they will have difficulties to follow Physics courses at the next level. This result strongly suggests that the instructions have delivered little conceptual understanding of Newtonian mechanics. It was found that the normalised gain for UPSI's students is comparable with other local universities even though it is still far below the 60%

threshold.

Table 2 Distribution of FCI Scores and Normalised Gain

	N	Pre (%)	SD	Post (%)	SD	Normalised gain $\langle g \rangle$
Overall	134	21.22	2.11	25.87	2.78	0.059

Table 3 Comparisons of Mean Scores and Normalised Gain at National Level

University	Post-test Mean score (%)	Normalised gain $\langle g \rangle$
UKM*	28.5	0.08
UiTM*	22	0.02
UPM*	23	0.04
UPSI**	29.6	0.088
UPSI***	25.87	0.059

*reported by Zainal *et. al.*, (2006) **reported by Abd Rahman et. al. (2007) ***this study

Table 4 Distribution of Respondents in Groups by SPM Physics Grade

Group of Respondents	SPM Physics Grade	Number of Respondents (%)
G1	A+, A, A-	19
G2	B+, B, B-	50
G3	C+, C, C-	26
G4	D	5

Table 5 Distribution of FCI Scores According to Overall, Gender, Lecturer and Students Academic Background in Physics

	N	Pre (%)	SD	Post (%)	SD	Normalised gain $\langle g \rangle$
Overall	134	21.22	2.11	25.87	2.78	0.059
Gender						
Male	34	23.53	2.06	30.39	2.55	0.089
Female	100	20.43	2.05	24.33	2.70	0.049
Lecturer						
A	71	20.80	1.95	24.04	2.28	0.041
B	63	21.69	2.28	27.94	3.14	0.079
Students Group						
G1	26	22.56	1.93	30.64	3.44	0.104
G2	67	21.00	2.30	24.78	2.31	0.048
G3	35	20.10	1.93	25.14	2.84	0.063
G4	6	24.44	0.75	21.67	1.61	0.037

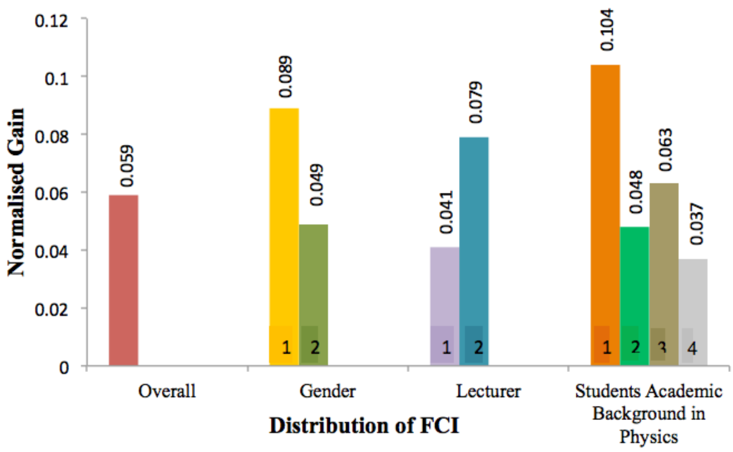
Table 5 shows the distribution of FCI scores based on gender. The male students did better than the female in terms of both the raw score (for pre-and post-tests) and the normalised gain. This result is consistent with Abd Rahman *et. al.*, (2007) and McCullough (2004). Normalised gain in this study for male is 0.09 and 0.05 for female and was found statistically significant ($p < 0.05$). However, both results are still in the "low-g".

In order to find the normalised gain across the student academic background in Physics, researcher sort all the data gained into several groups of respondents. Respondents were sort by their SPM Physics grade. G1 for A+, A, and A- and G2 for B+, B, and B- and G3 for C+, C, and C- and G4 for D as tabulated in **Table 4**.

This study also found that the group with a highest academic background in Physics who is respondent in G1 did better in the post-test although the overall normalised gain for each group does not show a particular trend and were found significant ($p < .05$)(see **Table 5**). The result is consistent with Abd Rahman *et. al.*,(2007) and Kamilah.

However, the respondent in G3 ($\langle g \rangle = 0.06$) showed better normalised gain compare to the G2 respondent ($\langle g \rangle = 0.05$) (see **Table 5**). Based on respondents' academic background in Physics, G2 suppose to get better post-test compare to G3. It may be because G3 were the unlearn respondents and G2 were the relearn respondents. Researcher assumed G2 respondents answered the test based on their wrong prior knowledge which is difficult to change while G3, the unlearn respondents were answered the test based on their new knowledge. As mentioned before, students' ideas are stable and resistant to change. That is probably why G2 is lower than G3.

Table 5 is translated into graphical form in **Figure 1**. We can see that male perform better than female, group by lecturer B performs better than lecturer A and good academic background in G1 performs better.All of these finding are statistically significant ($p < .05$)



Key:
Gender: 1: Male, 2: Female
Lecturer: 1: Lecturer A, 2: Lecturer B
Students Academic Background in Physics: 1: G1, 2: G2, 3: G3, 4: G4

Figure 1 Normalised Gain of Students vs. Distribution of FCI According to Overall, Gender, Lecturer and Students Academic Background in Physics

CONCLUSION AND SUGGESTION

The study on 134 respondents using FCI at UPSI and found the following result:

a) Respondents' normalised gain was in the "low-g" category where their normalised gain is below 0.3 ($\langle g \rangle < 0.3$). Respondents have a very strong Aristotelian belief and minimal understanding of force concept because their means score 25.87% is far below 60% score range as determined by Halloun and Hestenes (1995). However, this result when compare to the national level.
b) In comparing the FCI for two different groups of lecturer, researcher found Lecturer's B students ($\langle g \rangle = 0.08$) did better than the Lecturer's A students ($\langle g \rangle = 0.04$). Both group did not show a lot of different in their pre-test score, but their post-test shows a lot of different and thus affected their normalised gain.

c) Male students did better than female in terms of both the raw score (for pre-and post-tests) and the normalised gain. Female post-test mean score (24.33%) is slightly better than male pre-test (23.53%) but too low compare to the male post-test (30.39%). Normalised gain for male is ($\langle g \rangle = 0.09$) and ($\langle g \rangle = 0.05$) for female.

d) The group with a highest academic background in Physics who is respondent in G1 did better in the post-test and yet get the highest normalised gain ($\langle g \rangle = 0.10$). G2 ($\langle g \rangle = 0.05$) got lower normalised gain compare to G3 ($\langle g \rangle = 0.06$). However, G4 shows unexpected score means. G4 got the highest pre-test and the lowest post-test.

The FCI pre-and post-test scores indicated that the tests used in this study helps to identify potential low gainers or a poor indicator of university FCI gain (Hake, 2002). Some improvement strategies or possible intervention for potential low-g's are:

a) Urge students with low diagnostic physics scores to brush up. Some may need tutoring.

b) Urge students to exert extra effort, for instances, attend help sessions, join study groups, seek help from classmates and instructors.

c) Interview students with low score of the tests to uncover serious cognitive or affective problems.

d) Perform demonstration to visualized abstract concept (Kadri, 2011).

REFERENCES

Abd Rahman, N., Jantan, J., Ayop, S. K., Abd Karim, M. M., Razalee, N. A., Haron, R. & Rejab, A. B. (2007). The relationship between UPSI lecturers' perceptions of their teaching practices and students' conceptions of force and motion. *The International Journal of Learning,* Vol. 14.

Clement, J. (1993). “Using bridging analogies and anchoring intuitions to deal with student. Preconception in physics”. *Journal of Research in Science Teaching,* 30(10) 1241-1257.

Hake, R. R. (2002). Relationship of individual student normalized learning gains in mechanics with gender, high-school physics, and pretest scores on mathematics and spatial visualization. *Physics Education Research Conference (PERC2002).*

Henderson, C. (2002). Common concerns about the Force Concept Inventory. *The Physics Teacher,* 40, 542-547.

Hestenes, D. & Halloun, I. (1985). The initial knowledge state of college physics students. *American Journal Physics* 53 (11) 1043-1048.

Hestenes, D. & Halloun, I. (1995). Interpreting the force concept inventory: A response to Huffman and Heller. *The Physics Teacher,* 33, 502-506.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher,* 30, 141-158.

Kadri, S., Jaafar, R., Adli, W. Z., & Nazihah, A. (2013). Physics demonstration of sound waves using Visual Analyser. *Latin-American Journal of Physics Education*, *7*(1).

Kamilah Osman. (2007). Mengkaji tahap pengetahuan konseptual fizik bakal guru Universiti Pendidikan Sultan Idris. Unpublished Degree of Education Thesis, Tg Malim: Universiti Pendidikan Sultan Idris.

Lasry, N., Rosenfield, S., Dedic, H., Dahan, A., & Reshef, O. (2011). The puzzling reliability of the Force Concept Inventory. *American Journal Physics*, 79 (9) 909-912.

McCullough, L. (2004). Gender, context and Physics assessment. *Journal of International Women's Studies. Special Issue: Women in Science*, 5(4) 20-30.

Nieminen, P., Savinainen, A., & Viiri, J. (2012). Gender differences in learning of the force concept, representational consistency, and scientific reasoning. *Online First publication in International Journal of Science and Mathematics Education.*

Noridah Bachok. (2005), Prakonsepsi Pelajar Semester Akhir Major Fizik Upsi Terhadap Konsep Asas Daya Dan Gerakan : Satu Tinjauan Awal. Unpublished Degree of Education Thesis, Tg Malim: Universiti Pendidikan Sultan Idris.

Planinic, M., Ivanjek, L., & Susac, A. (2010). Rasch model based analysis of the Force Concept Inventory. Physical Review Special Topics - Physics Education Research 6, (010103) 1-11.

Scott, T. F., Schumayer, D., & Gray A. R. (2012). Exploratory factor analysis of a Force Concept Inventory data set. *Physical Review Special Topics - Physics Education Research*, 8, (020105) 1-10

Taber, K.S. (1998). An alternative conceptual framework from Chemistry education. *International Journal of Science Education*, 20(5) 597-608.

Zainal Abidin Sulaiman, Zaidan Abd Wahab, Sidek Abd Aziz & Jaafar Jantan. (2006). Probing students' understanding of forces. Paper presented at the national Physics Conferences 2006 (PERFIK 2006).