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1. Preliminaries: Replying to us, multi authored papers, bibliographical details
2. Checklist for Reviewing the Typeset Proof (what to check)
3. Journal Standard Style (order of your paper and the standard style of the Journal)
4. Documenting your Corrections (how to document a request for corrections)

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The Relationship between UPSI Lecturers' Perceptions of their Teaching Practices and Students' Conceptions of Force and Motion

Nurulhuda Abd Rahman, Jaafar Jantan, Shahrul Kadri Ayop, Mohd Mustamam Abd Karim, Noor Azman Razalee, Roszairi Haron, Abu Bakar Rejab

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The Relationship between UPSI Lecturers' Perceptions of their Teaching Practices and Students' Conceptions of Force and Motion

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Abstract: This research investigated the effect of instruction on student teachers' understanding of force and motion. Lecturers' perceptions of their teaching practices during lecture session provided data on how lecture was conducted and this was then compared to students' understanding. Students' understanding was also compared to their demographic variables such as gender and academic performance. 347 students from diverse groups and 5 lecturers participated in the study. Results show that student teachers at UPSI hold strong Aristotelian beliefs about force and motion which are not in line with the currently accepted scientific beliefs. It also suggests that traditional instruction had little effect on changing the students' beliefs. In addition, lecturers perceived their teaching practices as traditional 'chalk-and-talk' where students sit passively in lecture halls with minimal interactivity. The study also found that there is no significant relationship between students' scientific beliefs and their gender or academic performance.

Keywords: Student Learning Difficulties, Physics Instruction Teacher Education, Higher Education, Teacher Perception

Introduction

ONE OF THE knowledge bases and skills that a teacher must possess is a deep understanding of the subject matter. It is assumed that students will acquire sufficient content knowledge as they go through subject specific courses throughout their attendance at a university. However, numerous research (e.g. Clement, 1982; Watts, 1983; McDermott, 1984) have shown that students and teachers alike have difficulty understanding the concept of force and motion as they are plagued with preconceptions (commonly known as misconceptions or alternative conceptions) that are usually Aristotelian beliefs rather than the accepted scientific conceptions. Teacher-centered method of teaching that is so common in schools has also been blamed for the problem which remains unresolved as the students enrolled at higher learning institutions. This study looks at the effect of instruction on students' understanding of the force and motion concept in Newtonian mechanics. Students are prospective teachers studying at Universiti Pendidikan Sultan Idris (UPSI), which is a national education university in Malaysia. They come from diverse backgrounds whilst the courses they are taking are widely varied in terms of the content including the breadth and depth of the mechanics topics taught. The study also includes students' academic performance and gender as two other factors that may influence students' understanding.

Research Context

Physics has always been taught quantitatively with too many facts, equations and numbers (Hobart, 1966; Rigden, 1987). Furthermore, the introductory physics courses have been structured to include so much content to be covered in a short period (French, 1988). A traditional didactic style of teaching then would be the most logically appropriate style to deliver such a mile-wide content within a short period of time. Using this fast-paced teaching strategy, students usually resort to memorizing facts and equations. However over-dependence on memorization is counterproductive (Whitaker, 1985) and may impede meaningful learning. Several investigators have carefully documented college physics students understanding of a variety of topics and have concluded that traditionally taught courses do little to improve students' understanding of the central concepts of physics, even if the students successfully learn problem-solving algorithms

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(Halloun and Hestenes, 1985; McDermott, 1998). In addition, the problem of misconceptions or alternative framework further complicates the learning of physics fundamentals. Misconceptions are widely perceived as conceptions that are not totally in line with the currently accepted scientific conceptions and have the characteristics of being strongly held, very hard to overcome, and impede further learning. Numerous studies (McDermott, 1984; Finegold and Gorsky, 1991) have shown that students come into a physics course not as blank slates but bring with them common sense beliefs and intuitions (i.e. misconceptions) about how the world works, which they derived from extensive personal experiences. Traditional instruction does little to resolve these misconceptions and they may be the major source of difficulty in understanding physics fundamentals.

Simultaneously, research have also established that students develop complex reasoning skills most effectively when actively engaged with the material they are studying and have found that collaborative activities are an excellent way to engage students effectively (Johnson and Johnson, 1987; Johnson, Johnson and Smith, 1991). A major study by Hake (1998) involving more than six-thousand students across the United States of America found that physics courses where students are actively involved in discussion, discovery and/or analysis of material are more effective in terms of promoting students conceptual understanding and problem-solving skills than traditionally taught courses.

Methodology

This research aims to identify lecturers' perceptions of their teaching practices during lecture session and students' understanding of force and motion and investigate the relationship between the two variables. It also aims to compare students' beliefs with their demographic variables such as gender and academic performance. It employs survey and correlational design using a questionnaire for identifying the lecturers' perception of their teaching practices and pre and post-test for determining students' level of understanding of force and motion.

The Instruments

Students' understanding of force and motion was assessed using the standardized revised Force Concept Inventory (FCI) test developed by Hestenes, Wells and Swackhamer (1992). The revised version (Halloun, Hake, Mosca and Hestenes 1995) was translated into the Malay language by one of the authors. The test can be downloaded from http://modeling.asu.edu/R&E/Research.html or alternatively from http://www3.uitm.edu.my/staff/drjj/ but is password protected to protect the integrity of the test. FCI is a multiple-choice test designed to assess students' conceptual understanding of the most basic concepts in Newtonian physics and as such does not require mathematical operations or calculations. The FCI is structured to require a forced choice between Newtonian's concepts and commonsense beliefs or misconceptions (see for example Hestenes et al 1992, Mazur 1997, Hake 1998, Savinainen and Scott 2002). Hence the inventory data can provide a picture of the status of students' conceptions and/or misconceptions of fundamentals. The test contains 30 questions related to specific concepts and laws of classical mechanics. In order to further distinguish between a lack of knowledge and a misconception, a Certainty of Response Index (CRI) is utilized in conjunction with the answers as first introduced by Hasan, Bagayoko and Kelley (1999).

The CRI is based on a six-point scale (0-5) in which 0 implies no knowledge or a total guess for the answer selected. The CRI works on the assumption that if the degree of certainty is low (CRI of 0-2) then it suggests that students are mostly guessing and thus a wrong answer represents a state of a lack of knowledge rather than a misconception. On the other hand, a high degree of certainty (CRI of 3-5) associated with a wrong answer suggests that students hold a misconception or common sense beliefs. For the purpose of this research, a CRI mode value of 3 to 5 associated with an answer where 50% or more of the students answered incorrectly indicates the presence of misconceptions. In addition, since FCI has also been claimed as the "best test currently available… to evaluate the effectiveness of instruction in introductory physics courses" (Huffman and Heller, 1995), hence, FCI results (from courses where mechanics was taught) also indicate the effectiveness of instruction received by the students.

Instructional strategies employed by lecturers in this study was done by investigating lecturers' perceptions of their teaching practices during lecture session by using the Teaching Practices Assessment Inventory (TPAI) adopted from Burry-Stock (1995a). It is one of five instruments (each addressing different aspect of science classroom teaching) which was developed based on the Expert Science Teaching Educational Evaluation Model (ESTEEM). Its main purpose is to assess the awareness level of science teachers with respect to constructivist teaching perspective. In this instrument, the lecturers were asked to give their perceptions of their own teaching practices based on the Likert scale from 1 to 5 of how often they perceived they used each behaviour during lecture sessions. There are a total of 30 items on the instrument and selected sample items are shown in Table 1.

Table 1: Sample Items from the Teaching Practices Assessment Inventory (TPAI)

Almost Never (1); Seldom (2); Sometimes (3); Often (4); Almost Always (5)

Category 1:Facilitating the learning process

- Your students are responsible for their own learning experience (you are the facilitator of the learning experience)
- Your students are actively engaged in asking questions throughout class-time.

Category 2:Context-Specific Pedagogy

- You and/or your students develop content materials.
- As student misconceptions become apparent, you facilitate student efforts to resolve them.

Category 3:Content Experiences

- Your class experiences have an appropriate balance between depth and breadth.
- You accurately present the information in your lessons.

Category 4:Content-Specific Pedagogy

- Your students have the opportunity to experience the relationship of concepts to their everyday lives.
- You allow students to establish concepts from evidence gathered during a lesson.

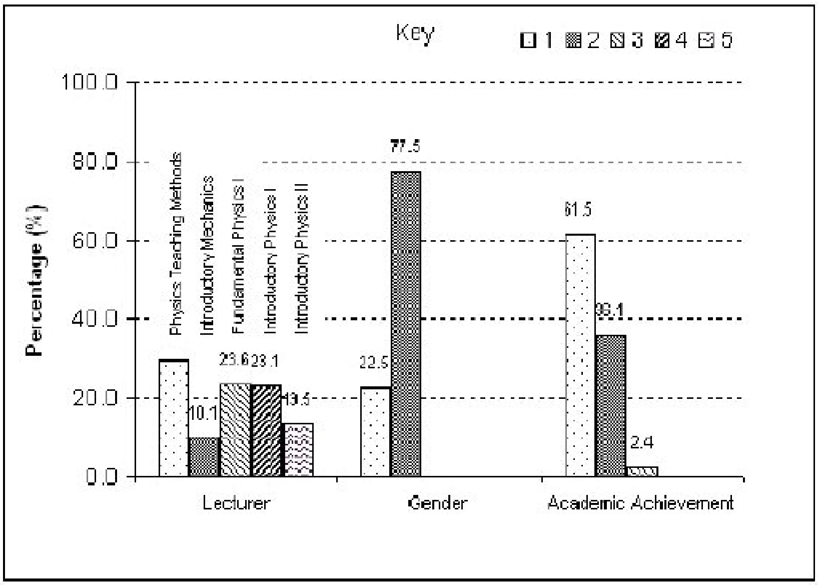
The instrument with a Cronbach alpha of 0.93 has four subscales or categories which are (1) facilitating the learning process, (2) context-specific pedagogy, (3), content experiences and (4) content-specific pedagogy. Reviews from researchers and educators in science education and field testers (Burry-Stock 1995b) supported the validity of the instrument.

The Sample

Our sample included both students and lecturers. Student participants come from a diverse group of students who are enrolled in the undergraduate science education program for the July-Nov 2005 semester at Universiti Pendidikan Sultan Idris, Malaysia, a university for producing graduate school teachers. There were 347 participants which consists of 127 semester 1 students, (majoring in Physics and taking Fundamental Physics I course), 80 semester 5 and 6 students, (minor in Physics and taking Introductory Physics I course), 35 semester 3 students, (majoring in Physics and taking Introductory Mechanics course) and 103 semester 7 students, (majoring in Physics and taking Physics Teaching Methods course). Except for students enrolled in the Physics Teaching Methods course, the rest of the students studied the topic of Newtonian Mechanics in courses they enrolled in. However, the former group of students was directly involved with the problems of misconceptions in physics (with a focus on several specific problems from the Newtonian mechanics topic) through in-class discussion and literature search. Since these students are in their final year at the university, they have taken all of the required physics courses related to mechanics.

In addition to the students, five lecturers were also involved in the study. Lecturers and one of the authors were administered the TPAI at the end of their courses.

Bar graphs in Figure 1 show the percentages of lecturers and students who participated in the study.



Key:

Lecturer: 1:A, 2: B, 3: C, 4: D, 5: E

Gender: 1: Male, 2: Female

Academic Achievement (CGPA –cumulative grade point average):

1: 3.00 to 4.00, 2: 2- 2.50 to 2.99, 3: 2.00 to 2.49

Figure 1: Percentage of Students According to Lecturers, Gender & Academic Performance

Students took the test during the first week of the semester and were proctored by their respective lecturers teaching the course. The time allotted for the FCI test is 45 minutes. In addition to the test, students were given a profile sheet in gathering information about their personal and academic background. The students were given 15 minutes to fill-in the necessary information before they began answering the multiple-choice test. At the end of the session, the students' profile and answer sheets along with the tests were collected.

Data Analysis

Profile sheets that contained answers for the FCI test were numbered and each category on the profile were coded by using the Arab numerals. The profile, the codes for the categories and the answers that a student chose for each item on the test and their respective CRI score were keyed-in into a spreadsheet template of Microsoft Excel for Microsoft Office 97 . The template was programmed to score each item on the test and provide the total score and the percentage for the test. It also calculated the mean and standard deviation for each item and the mean and standard deviation for each group of students according to their respective lecturers. In addition a quantity called the normalized gain, <g>, defined as the fraction of the maximum possible gain realized (Hake, 1998),

$$\langle g \rangle = \frac{Gain}{Maximum\ possible\ gain} = \frac{\%\ posttest\ mean\ score - \%\ pretest\ mean\ score}{100\% - \%\ pretest\ mean\ score}$$

was used to gauge the extent to which the classroom instructions were effective. Hake (2000) argued that the normalized gain is more suitable (than actual gain or average post test score) to measure course effectiveness over diverse groups of students as empirical evidence shows that the correlation of the normalized gain, <g>, with pre test scores is very low. In contrast there is a moderately negative correlation between actual gain (% post test - % pre test scores) and pre test score and also a moderate positive correlation between post test score and pre test score. Analysis on both the descriptive and inferential statistics were done by using Win SPSS , a statistical package for Windows .

For the TPAI, a profile for each lecturer is built by computing the percentage for each category. An overall percentage is computed by summing all of the category totals and dividing by 150. The more "5s" or "Almost Always" used, the higher the degree of constructivist approach was used during the lecture. Consequently the lecturer can consider him/herself an expert or constructivist lecturer. For the purpose of this research an overall percentage of above 60% (which indicates an average score of 3 for each item) is taken as an indication that the lecturer has a constructivist tendency of teaching whilst a percentage of below 60% indicates a traditional tendency. The authors of TPAI also used the following scale (Table 2) as an approximation for estimating competency levels:

Table 2: Levels of Competence

Percentages (%)	Competency Levels
85-100	Expert
70-84	Proficient
35-69	Competent
15-34	Advanced Beginner
01-14	Novice

Results and Interpretation

Student teachers score an average of 23.6% with a standard deviation of 9.26% and 29.6% with a standard deviation of 10.52% on their pre and post test respectively. Table 3 shows the distribution of the FCI scores and gain according to the respective lecturers. It also shows each lecturer's overall score on the TPAI.

Table 3: Distribution of FCI and TPAI Scores and the Respective Gains

Lecturer & Course	N	% of sample		Pre (%)	Post (%)	<g>	TPAI Score
A (Physics Teaching Methods, Sem 7 students)	103	29.7	Mean	27.25	31.20	0.054	
			sd	9.59	10.04		79.3
B (Introductory Mechanics, Sem 3 students)	35	10.1	Mean	25.24	34.38	0.122	
			sd	7.97	7.95		54.0
C (Fundamental Physics 1, Sem 1 students)	82	23.6	Mean	25.49	30.24	0.064	
			sd	9.29	11.58		49.3
D (Introductory Physics 1, Sem. 5 & 6 minor students)	80	23.1	Mean	17.83	28.62	0.131	
			sd	6.98	10.58		62.0
E (Introductory Physics 1, Sem. 5 & 6 minor students)	47	13.5	Mean	20.92	23.19	0.029	
			sd	7.41	8.16		60.0
Total	347	100.0	Mean	23.60	29.62	0.079	60.9
			sd	9.26	10.52		5.1
			Mean*	22.06	28.95		56.3
			sd*	8.68	10.67	0.088	2.9

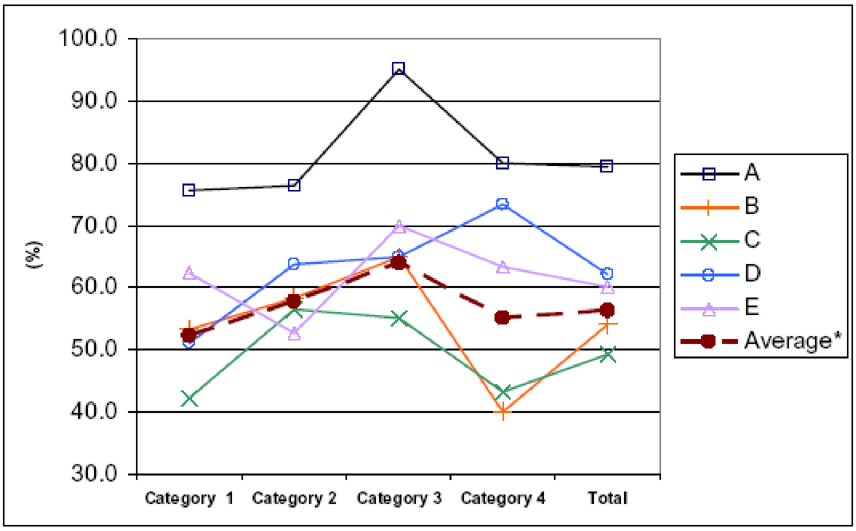
* Excluding results from lecturer A.

According to Hestenes, Wells and Swackhammer (1992), a score of 60% on the FCI is the threshold for understanding Newtonian mechanics while a score of 85% is considered as mastering Newtonian force concepts. Students who score below 60% on the FCI will find it difficult to do problem solving effectively (Hestenes and Halloun 1995). Hence, the post test mean score of only 29.6% indicates a very strong Aristotelian belief and minimal understanding regarding the Newtonian concept of force and motion. The mean score is slightly higher to the mean scores found at three other universities in Malaysia (Zainal, Zaidan, Sidek and Jaafar 2006). They are University Kebangsaan Malaysia, UKM (28.5%), Universiti Teknologi Mara, UiTM (22%), and Universiti Putra Malaysia, UPM (23%). It is comparable to high school students from 14 participating schools across the United States of America (N=1113), who scored 28% on the test (Hake, 1998). Results from a similar study by Hake show a better performance amongst college (N=597 from 16 different colleges) and university students (N=4832, from 32 different universities) with FCI scores before instruction at 39% and 44%, respectively. However, these post-test scores are well below the entry threshold of 60% and this indicates that the problem is widespread amongst students worldwide.

The average normalized gains for the courses (excluding the Physics Teaching Methods course) are <g> = 0.09 and <g>= 0.079 (including the Physics Teaching Methods Course). These gains are comparable to UKM (<g> = 0.08), but slightly higher than UiTM (<g> = 0.02) and UPM (<g> = 0.04). However, it is substantially lower than the average gains from both traditionally taught courses (<g> = 0.23) and more interactively taught courses (<g> = 0.48) from Hake's study. In fact, it is very low compared to any other studies that had been done (Savinainen and Scott 2002; Van Domelen and Van Heuvelen 2002; Crouch and Mazur 2001; Wells and Swackhamer 1995). The low pretest score is not surprising but the low normalized gain for this study and at other universities in Malaysia is just a reflection of how ineffective university physics instruction is in changing students' misconceptions on Newtonian physics. Students generally have a very strong Aristotelian belief and even after taking few courses in mechanics, their misconceptions remain unchanged.

Hake (1998) defined interactive teaching as "methods which are designed at least, in part, to promote conceptual understanding through interactive engagement of students in heads-on and hands-on activities which yield immediate feedback through discussion with peers and/or instructors". On the other hand, traditional instructional method is a "method where there is little or no use of interactive methods (teacher-student and student-content), relying primarily on passive-student lectures, recipe labs and algorithmic-problem exams". If we were to accept Huffman and Heller's (1995) claim that the gain suggests the effectiveness of instruction received by the students, then the results strongly suggest that the instructions have imparted little conceptual understanding of Newtonian mechanics.

The TPAI mean score is taken as an indicator to show if the courses were taught in a traditional way or otherwise. The TPAI mean score for the lecturers teaching mechanics course in this study is 56.3% with a standard error of 2.9, with scores ranging from 49.3% to 62%. The score suggests that the lecturers are teaching in a traditional way. This result is not surprising as lecturers were asked to reflect only upon their teaching practices during lecture sessions. The average score for category 1 (facilitating the learning process) is the lowest which further suggests that the lecturers were acting more of a "sage on the stage" rather than "a guide on the side". The result of TPAI is comparable to the result obtained from a study involving a group of forty-six nominated 'expert' teachers from schools throughout the United States who participated during the development of the TPAI and its companion instruments (Science Classroom Observation Rubric and Student Outcome Assessment Rubric) instrument. They scored a mean of 63.7% on the companion instrument (Science Classroom Observation Rubric) which contains subscales that are closely related to TPAI. Burry-Stock and Oxford (1994) concluded that the teachers "are not well-informed constructivists and they were not teaching at a particularly high conceptual level". They further conclude that the nominators' criteria of 'expertise' must have been very different from the ones used by TPAI. They further concluded that the nominators' criteria of 'expertise' must have been very different from the ones used by TPAI. In terms of the level of competency, the scores of TPAI for the 4 lecturers involved in teaching physics put themselves in the 'competent' category. According to Burry-Stock, in general a competent teacher has the ability to adapt rules and goals contextually and at the same time feel a sense of responsibility for the outcome. Figure 2 illustrates each lecturer's profile of their teaching practices.



Category 1: Facilitating the learning experience
Category 2: Context-Specific Pedagogy
Category 3: Content Experiences
Category 4: Content-Specific Pedagogy
* Average excluding lecturer A

Figure 2: Lecturers' Teaching Profile

Table 4: Distribution of FCI Scores According to Gender and Academic Performance

	N	Pre (%)	SD	Post (%)	SD	Normalised Gain
Overall	347	23.60	9.26	29.62	10.50	0.079
Gender						
Male	79	28.95	11.1	35.36	12.50	0.090
Female	268	22.03	8.01	27.92	9.23	0.076
Academic Performance (CGPA)						
3.00 - 4.00	206	22.77	9.18	29.84	10.35	0.091
2.50-2.99	121	24.66	9.20	28.84	10.10	0.055
2.00-2.49	8	22.08	4.34	28.33	8.17	0.080
Missing	12					

Table 4 shows the distribution of FCI scores based on gender and academic performance. The male students did slightly better than the female in terms of both the raw score (for pre and post tests) and the normalized gain but the difference were found to be statistically not significant at the 95% confidence limit ($p = 0.389$). This result is consistent with a series of studies investigating gender differences on FCI test by McCullough (2001, 2002, 2004). The studies consistently show that the male outperformed the female and led her to hypothesized that the FCI test may not be gender-fair. She created a different version of the FCI with daily-life and female-oriented contexts rather than school and male-oriented contexts. Results show that on average, women's gain on the new version was much greater than men's gain. She concludes that the FCI may be gender biased as the context of the test can make a difference and that it is possible to create a test that decreases the gender gap.

This study also found that the group with a higher academic performance did slightly better in the post test although the normalized gain does not show a particular trend. Even though the differences between groups are statistically significant (p = 0.048), it makes no difference because the mean score is far below the threshold of 60%.

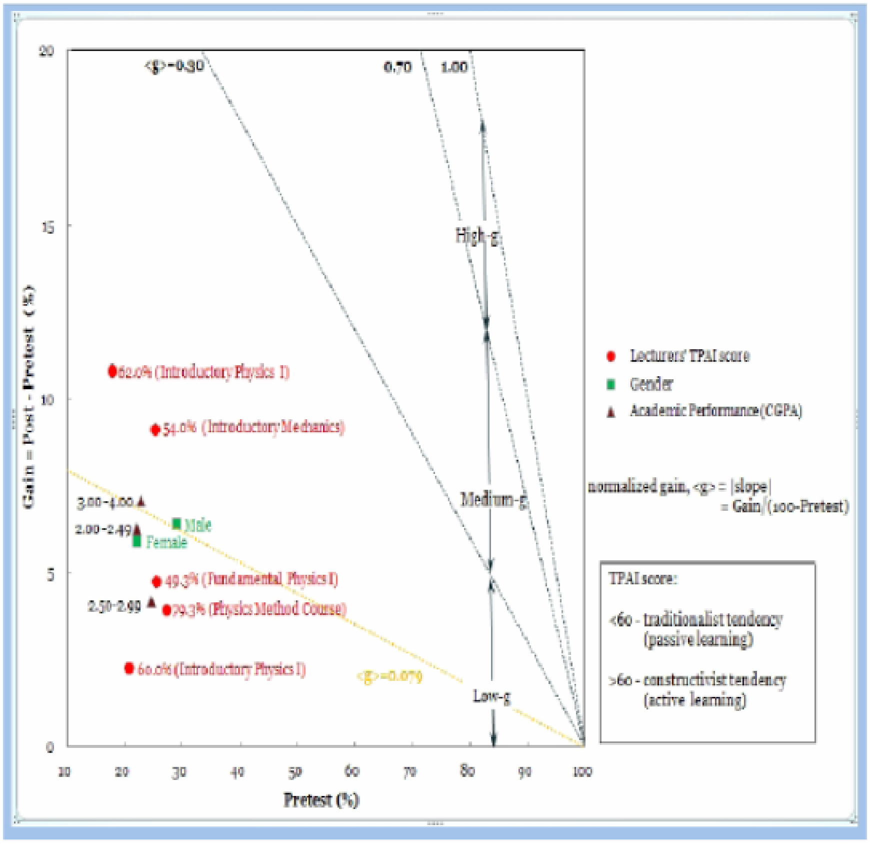


Figure 3: % Actual Gain vs. % Pretest Score

Figure 3 summarizes and illustrates students' understanding which is represented by the normalized gain, <g>, as compared to lecturers' perceived teaching styles (TPAI scores), gender and academic performance (CGPA score). It clearly shows the disappointingly low average normalized gain (<g>=0.079) obtained by students regardless of lecturers' style of teaching practices (and also types of courses), gender and academic performance.

Analysis of data from the FCI test in conjunction with the use of CRI is shown in Table 5. Items listed in the table are items where 50% or more of the students answered incorrectly but their certainty response index (CRI) is 3, 4 or 5 which indicates a high degree of confidence in their answers. In a way, it can be compared to false negatives where a Newtonian-thinker chose a non-Newtonian response except in this case it is not because of carelessness. Misconceptions identified in this research parallel findings from previously cited research (e.g. Clement, 1982; Watts, 1983; McDermott, 1984)

Table 5: Items with a High % of Incorrect Answer and a High Value of CRI

FCI item	Common Wrong Answer	Pretest (%)	PostTest (%)	Misconception Identified
1	D	51	35	More massive objects always fall faster than less massive ones.
4 15	A C	81 58	69 69	When two objects are in contact, more massive objects exert a higher force on less massive objects
10	D	45	52	Force results in velocity rather than acceleration.
13	B	59	47	An object has force that it carries with it after being given an initial push and this force reduces as the object moves against gravity Gravity near the surface of Earth increases as the object falls towards the Earth
17	A	57	67	Motion implies a force
30	E	64	69	An object has force that it carries with it after being given an initial push.

Challenges for Course Improvements

The low gain across courses should be an eye opener for lecturers to initiate a redesign of how introductory physics courses needs to be taught. There is ample evidence that physics education and cognitive science research can inform lecturers on how best to help student gain optimal understanding of physics fundamentals (Arons 1990, Mestre 1991, Hake 1992). There is also a general consensus amongst physics education researchers and educators that active-learning strategies are much more effective in promoting conceptual understanding despite some implementation problems (Hake 1998, Van Heuvelen 1991, Wells, Hestenes, Swackhamer 1995). Many research-based curriculum and instructional strategies have been developed in order to promote conceptual understanding and thus enhance problem-solving skills of the students.

Redish, in his book Teaching Physics with the Physics Suite (Redish 2002) suggested many different strategies which employed interactive learning to replace the present traditional lecture being used by the lecturers teaching mechanics courses at UPSI and at most universities in Malaysia. Large classroom classes can benefit the use of Peer Instruction/ConceptTests (Mazur 1997; Crouch and Mazur 2001) with a blend of Just-in-Time-Teaching (Novak 1999). There have been initial efforts by a few lecturers to try to implement Mazur's Peer Instruction during lecture. Unfortunately, many students are unwilling to commit time to do their pre-reading before class. They are so comfortable in their ground state and any changes to the point of requiring them to prepare before class is considered as taking up too much of their time. Employing Interactive Lecture Demonstrations (ILDs) (Sokoloff 2001) will require much financial commitment on the department and most importantly more work on the lecturer. But at present, it is encouraging to note that the department is working to secure a grant towards setting up an "interactive-engagement lecture" supported lecture hall.

The wonderful and academic Workshop Physics (Laws 1999) which enjoyed no-lecture for calculus-based physics is indeed functional at universities in America but may not be readily accepted by faculty members and the management at UPSI and universities in Malaysia as this requires a substantial change in the curriculum and other facilities. In other words, this study shall be for academic purposes and hopefully will trigger few individuals in the physics community to appreciate the worth of physics education research as means to understand the learning problems that students are indeed facing. Solving the problem cannot be done on an individual or isolated individuals in the country, but rather commitment from the management who are serious about the education reform in this country.

Nonetheless, the results of this study clearly show that students who will be future high school teachers are themselves the propagator of non-Newtonian teaching. In other words, without a deep understanding of subject matter, their teaching would be jeopardized. Hence, it is recommended that the few lecturers who are authoring this report work closely with other physics education reformers in tailoring the existing research-based instructional strategies and implement it for the introductory physics at UPSI. The good news is, at present, although the lecture is largely traditional, the use of real time microcomputer based laboratory (Thornton and Sokoloff, 1990) has already been implemented for students' laboratory experience. As this progress in the upcoming semesters, the FCI diagnostics must continue to be used to monitor students' learning (Savinainen and Scott 2000) and to provide formative assessment to the students and eventually to produce Newtonian high school teachers.

Conclusion

Results suggest that regardless of lecturers' style of teaching (although most lecturers show a traditionalist tendency), academic performance (in terms of CGPA) and gender, the gain is very small and insignificant that it does not make a difference on whether students go to class or not in order to understand meaningfully the concept of force and motion. In other words, the current teaching practices at UPSI do little in terms of promoting deep understanding and overcome misconceptions of force and motion amongst students. This is totally unacceptable since studies by Hake (1998), Wells (1995), Crouch and Mazur (2001) clearly indicate a normalized gain of more than 0.2 for the traditional method and will increase to more than 0.48 if students are actively engaged in the learning process. Hence it would be worthwhile for UPSI to begin using a more interactive style of lecture to improve on the present situation.

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