Title: PbI1@School: On Singapore Secondary One students' perception and understanding of work done and moment of force

Author(s): Munirah Shaik Kadir, James Lim, Foong See Kit, Prasanthee Rajendran and Paul Lee

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PbI1@School: On Singapore Secondary One Students’ Perception and Understanding of Work Done and Moment of Force

Munirah Shaik Kadir*
Centre for Research in Pedagogy & Practice, National Institute of Education, Nanyang Technological University, Singapore

James Lim
Chung Cheng High School (Main), Singapore

Foong See Kit
Natural Sciences and Science Education, National Institute of Education, Nanyang Technological University, Singapore

Prasanthee Rajendram
Chung Cheng High School (Main), Singapore

Paul Lee
Natural Sciences and Science Education, National Institute of Education, Nanyang Technological University, Singapore

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*Corresponding author.
Email address: munirah.sk@gmail.com

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Abstract

Studies indicate primary school students' interest and attitudes towards science decline as they progress into the secondary years. Experience shows that Singapore students are no exception. Knowing these students’ perceptions of science and understanding of science concepts should help in developing pedagogical approaches and lesson packages that will address the decline. Therefore, in our on-going study data are collected from students of six secondary one classes in a school in Singapore to learn of their views of science, reasons for liking or disliking science and their understanding of the topics in the science curriculum before and after instruction. This is done for a range of physics topics in their science syllabus. In this paper, we report the preliminary findings on the topic “Forces at Work” consisting of two sub-topics, ‘Moment of Force’ and ‘Work Done’. We group our findings into three main categories, ‘Students’ Perceptions’, ‘Students’ Preconceptions’ and ‘Students’ understanding of concepts’. Among the early findings are 1) students are confused between the two concepts of ‘Moment of Force’ and ‘Work Done’ 2) students are concerned about having to memorize a lot of information and solve many quantitative problems 3) students prefer to be given opportunities to carry out experiments as a means of verifying physics concepts to theory lessons where information is passed on to them verbally, and 4) students are good at using keywords as reasoning without actually understanding what they mean. This study surfaces key issues in understanding these young students’ learning journeys in the world of science. As such, the results from this research can guide curriculum development. We will be developing a curriculum that take into account these research results and the constraints of the school.

Keywords: secondary science, work done, moment of force, student perceptions, students’ preconceptions, students’ understanding of work done and moments
Studies indicate primary school students’ interest and attitudes towards science decline as they progress into the secondary years (Logan & Skamp, 2008). Experience shows that Singapore students are no exception. Knowing these students’ perceptions of science and understanding of science concepts should help in developing pedagogical approaches and lesson packages that will address the decline. Therefore we carry out a baseline study to find out Secondary 1 students’ current status as they embark on the secondary school science curriculum. This is done for six physics topics in their science syllabus. Data are collected from students of six secondary one classes in a school in Singapore to learn of their views of science, reasons for liking or disliking science and their understanding of the topics in the science curriculum before and after instruction.
We hope that our investigation of student understanding of these topics will contribute to the building of a research base. We hope to draw on this resource to develop a science curriculum and to adapt this curriculum to fit the constraints of traditional physics instruction. In this paper, we report the preliminary findings on the topic ‘Forces at Work’ consisting of two sub-topics, ‘Moment of Force’ and ‘Work Done’, addressing the following research questions:

1. What are the students preconceptions about Moment of Force and Work Done before instruction?

2. What are the students conceptions about Moment of Force and Work Done after instruction using the traditional teaching approach?

3. What are the students’ perceptions regarding the greatest challenges in learning about Moment of Force and Work Done before and after instruction?
Research Methods

Participants

In our on-going study, the participants are students of six secondary one classes from a school in Singapore. These classes were taught by four teachers. For the topic ‘Forces at Work’ reported here, we have analysed four classes only and the sample size is 145 students.

Material

The research instruments used for this study consist of the pre-test in Appendix 1 and post-test in Appendix 2. There are five questions in each pre-test and post-test. The pre-test involves no calculation and were based on common everyday phenomena but without the use of scientific terms like ‘work done against gravity’. The post-test has one question that requires the students to make some calculations to support their choice of answer.

The purpose of the pre-test is to (1) find out students’ enthusiasm in learning a new topic (Question 1) and whether they are able to forecast their learning difficulties even before learning the topic (Question 5), (2) find out students’ preconceptions (Questions 2 to 4) and 3) set the stage for the lessons and to motivate students to ask
more questions to satisfy their curiosity and clear their doubts. The questions expect them to support their answers with reasons so as to assess their preconceptions on the relevant scientific ideas that will be presented in the topic.

The five concepts and areas of study in the pre-test concept questions are represented in Table 1.

<table>
<thead>
<tr>
<th>Qn</th>
<th>Concepts/Areas of Study</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.1 Moment of Force:</td>
<td>Least effort is required when effort is applied furthest away from the pivot to produce the same moment.</td>
</tr>
<tr>
<td>3a</td>
<td>3a.1 Friction:</td>
<td>The smoother the surface in contact with box, the less is the friction.</td>
</tr>
<tr>
<td></td>
<td>3a.2 Force:</td>
<td>Less friction, Less force opposing motion causing the box to move further</td>
</tr>
<tr>
<td>3b</td>
<td>3b.1 Work Done:</td>
<td>Students’ interpretation and understanding of the term ‘work’ before instruction</td>
</tr>
<tr>
<td>4</td>
<td>4.1 Principle of moments:</td>
<td>Students’ Interpretation of ‘balancing’</td>
</tr>
</tbody>
</table>

Table 1. Areas of Study in Pre-Test
The purpose of the post-test is to (1) have the students evaluate their learning experience (Question 1) and to mention the challenges they encountered during their learning journey of the topic (Question 5), (2) assess students’ understanding of the concepts post-instruction (Questions 2 to 4). The post-tests are administered after the topic has been taught and the students have worked through the relevant curriculum materials prepared by the teacher.

For both tests, Question 2 is on the concept of moment of force and Question 3 is on the concept of forces and work done. For Question 4, since the students have done well in the pre-test (which is on the concept of principle of moments) in the post-test the students are assessing on the ability to distinguish between the concepts of ‘Moment of Force’ and ‘Work Done’.

The post-test has three questions consisting of several parts. Question 2b requires the students to mark out the perpendicular distance necessary for the calculation of moment needed to open the door. There are a total of 10 areas that are studied and they are presented in Table 2.
<table>
<thead>
<tr>
<th>Qn</th>
<th>Concepts / Areas of study</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>2a.1 Moment of Force:</td>
<td>Least effort is required when effort is applied at a position where perpendicular distance from pivot to effort is maximum</td>
</tr>
<tr>
<td></td>
<td>2b.1 Moment of Force:</td>
<td>Identification of perpendicular distance from effort to pivot.</td>
</tr>
<tr>
<td></td>
<td>2b.2 Moment of Force:</td>
<td>Justification that perpendicular distance is necessary for the calculation of moment</td>
</tr>
<tr>
<td>3a</td>
<td>3a.1 Work done against friction:</td>
<td>The more frictional force there is to overcome, the more the work done for the same distance moved.</td>
</tr>
<tr>
<td></td>
<td>3a.2 Students’ understanding of “Work done against Friction”</td>
<td></td>
</tr>
<tr>
<td>3b</td>
<td>3b.1 Work done:</td>
<td>Students interpretation of the term “Work Done”</td>
</tr>
<tr>
<td></td>
<td>3b.2 Conceptual change:</td>
<td>Comparing students’ understanding of the term “Work Done” before and after instruction.</td>
</tr>
<tr>
<td>3c</td>
<td>3c.1 Work Done against gravity:</td>
<td>There is no work done against gravity because the boxes are more moving perpendicular (not parallel) to the gravitational force</td>
</tr>
<tr>
<td></td>
<td>3c.2 Students’ understanding of “Work done against Gravity”</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4.1 Work done vs Moment of Force:</td>
<td>Students ability to distinguish between the two concepts</td>
</tr>
</tbody>
</table>

Table 2. Areas of Study in Post-Test
Validation of Pre-Test and Post-Test

After the pre-test and post-test were drafted by a researcher in the team, they were sent to the other team members for validation. The team consists of eight people comprising school science teachers, education researchers, curriculum officer and university professors. Team members assess the questions based on suitability of language and design, types of concepts assessed and the time available for the students to complete the tests. The tests were then improved on and sent again for review until everyone agrees on its suitability.

Procedure

The study went through the following phases:

Phase 1: Teachers’ & team validation of pre-tests and post-tests

Phase 2: Administration of pre-test to students

Phase 3: Teachers’ delivery of lessons on the topic

Phase 4: Administration of post-test to students
Phase 1:
To allow the team to become familiar with the instrument validation procedure and also to tap on the teachers’ expertise to set questions at the appropriate standard as they know their students best.

Phase 2:
The administration of the pre-test takes about 15 minutes. There is no strict adherence to time for the pre-test and students are requested to hand it in once they are ready.

Phase 3:
Teachers’ lesson delivery is based on teacher’s own pedagogical style. Field notes are taken and lesson materials kept for comparisons among four teachers’ lessons. Curriculum time for the science lessons is 3 hours per week and involves the students going though theory lessons, doing practice worksheets and carrying out some activities and experiments in the science laboratory.

Phase 4:
At the end of the topic (after several lessons have been delivered by the teacher), the post-test is administered by the teacher before he / she starts delivering lessons on a new topic. The time taken for the administration of the post-test is about 15 minutes.
Analysis

Rubrics are formulated for the pre-test and post-test based on the concepts and ideas that are reflected in the students’ answers, rather than specific answers. After validation by the research team, these rubrics are used to code the students’ answers, responses and drawings. Students’ responses and reasoning are coded and categorized in the manner as illustrated in Table 3.

<table>
<thead>
<tr>
<th>Students’ Response</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Answer</td>
<td>Coded and categorized</td>
</tr>
<tr>
<td>Wrong Answer</td>
<td>Coded and categorized</td>
</tr>
<tr>
<td>Blank</td>
<td>Ambiguous explanations &amp; Coded as ‘0’</td>
</tr>
</tbody>
</table>

Table 3. Treatment of Students’ Response and Reasoning

Coding is done by two research team members. Each class is coded by two members and any disagreement in the categories are discussed between them and shared with the research team during panel discussions to reach a consensus and final outcome. These codes are treated with simple statistics to measure students’ understanding of the concepts of ‘Moment of Force’ and ‘Work Done’ as presented in Table 1 and Table 2.
As for pre-test and post-test comparison, the students’ coded answers are further categorized and merged to highlight the main concepts that students demonstrated to have improved in and the amount of improvement made.

**Research Findings**

There is evidence from our research that some serious misconceptions about ‘Moment of Force’ and ‘Work Done’ are common among students who have had formal instruction in the relevant material. It is also becoming increasingly apparent that success in solving quantitative problems is not a reliable measure of conceptual understanding. Instructors at secondary and university levels corroborate our experience that students who can solve standard quantitative problems often cannot answer simple qualitative questions based on the same physical concepts (Arons, 1982 & Mazur, 1992). This fact suggests the presence of underlying difficulties that apparently are not adequately addressed by traditional physics instruction (McDermott & Shaffer, 1992).

The conceptual difficulties encountered by students in this topic vary in severity and frequency. Some difficulties tend to disappear
after instruction while others may persist indefinitely and interfere with the learning of more advanced material. We are also concerned with students’ perceptions as we are interested to know whether students develop a fear for the subject if they encounter more difficulties and challenges which are not addressed lesson after lesson. We have grouped our findings into two main categories, ‘Students’ perceptions’ and ‘Students’ understanding of concepts’.

Students’ pre- and post-instruction Perceptions

Students’ interest in the topic

Before instruction, 45% of the students said they think ‘Forces at Work’ will be an interesting topic, which reflects on their positive outlook of science. The most common reasons they gave were that they want to know more about the reasoning behind certain phenomena in their everyday life and mentioned positive encounters with the topic on ‘Forces’ taught in primary school.
As can be seen from Figure 1 above, for the minority of students (12%) who said “No”, most cited that they do not like studying and they find science lessons generally boring. There were a significant number of students (43%) who were careful in their response, preferring to give both sides, positive and negative opinions and thus chose the option “Maybe”. The most common reasons given are that they have no idea what the topic is about and are open to know more about the topic through the lessons. 2% said that based on past lessons, they had problems understanding the previous physics topics and were wondering whether it would be the same with this topic.
Students’ Learning Experience

![Bar chart showing percentage of students who said ‘Forces at Work’ has given them a meaningful learning experience.]

Figure 2. Post-Test Result: Percentage of students who said ‘Forces at Work’ has given them a meaningful learning experience

Based on Figure 2 above, after instruction, the majority of the students agreed that ‘Forces at Work’ has given them a meaningful learning experience. More than 60% of the students said that they have learnt something from the topic and are able to apply it to daily life. They said it made them understand some of the everyday phenomenon encountered and enjoyed the experiments that they did during the laboratory sessions. About 20% of those who said “Maybe” to the question cited that the lessons are sometimes interesting but could be complicated at times and they could not
understand it. Less than 10% chose the option “No” to indicate a non-meaningful learning experience and most said that the topic is difficult to understand and they find solving problems complicated.

Types of anticipated challenges

On the other hand, students’ perceptions on the challenges that they could face in this topic were 50-50. Half of the responses said that they are not sure of the challenges that they may face in this topic because they have not studied it yet. This is an appropriate response because it shows that they are open to new experiences without letting their past experiences hold them back.

![Students' most anticipated challenges](image)

**Figure 3.** Pre-Test Result: Students’ most anticipated challenges
However the other half of the cohort expressed their concerns. This is worrying because they were seen to have doubts about their ability to comprehend the topic even before giving themselves a chance to learn it. Their concerns, in the order of most common to less common challenges are: 1. understanding the concepts presented in this topic, 2. doing the calculations related to this topic, and 3. the memory work involved, which includes memorizing the keywords, formulae, information and definitions. 4. Others, which includes failing of tests and not scoring well for tests. Figure 3 illustrates the percentage of students with each concern.

Evaluating the students’ perceptions after instruction, students who said that they like the topic because they were able to relate it to real life went up by almost 10%. However the percentage of students who said they like the topic because of interest fell by 4%. This could mean that they do see the relation of what they are learning to real life situations but are not that interested in the learning process.
Students’ Difficulty in solving quantitative problems

If an instruction is effective in helping students understand physics concepts, we would expect the percentage of students who mentioned ‘understanding of concepts’ as their greatest challenge to drop significantly. However, the percentage only dropped by 7%. This implies that most students’ are still struggling with understanding the concepts, even after instruction.

Figure 4. Percentage of students who found solving quantitative problems a great challenge before and after instruction

On the contrary, the problem of calculations rose by 28%, with more than 50% of the students stating calculations to solve worked problems as their greatest challenge. From these results, it is clear that students found the quantitative problems encountered during
lessons for this topic even more challenging than those encountered in the previous topics. Figure 4 above illustrates the results.

*Students’ Understanding of Concepts*

An error made by the students may be a symptom of a conceptual or a reasoning difficulty or of a combination of both. It is therefore inevitable that there is some degree of ambiguity in categorizing and analyzing the students’ answers. In the analysis, each sub-topic is categorized into students’ preconceptions and conceptual understanding after instruction.

*Moment of Force*

*M1. Preconceptions of Moment*

Students are expected to have acquired the basic concepts of ‘Moment of Force’ from their primary school science curriculum. This is reflected in the results of the pre-test question on the position of the door knob, all of the students chose the correct answer. The majority (65%) of them also gave the correct reasoning, “as the door knob is furthest away from the hinge, thus the effort needed to open it will be the least”. Some characteristics
of students answers are that they used terms like “effort” and ‘fulcrum’ taught at primary level, and based their answers on what they commonly see in their everyday life. One student wrote “If opening at A is easier, then all door knobs will be placed in the middle of doors”.

Students also have expected preconceptions of the concept of balancing the see-saw as seen from the positive results in question 4 of the pre-test, with 84% of the students getting it correct. Most of them know exactly where the heavy and light boy has to sit to balance the see-saw. Their reasoning however does not reflect on their knowledge of the principle of moments. In their explanation they simply stated that the heavier boy should sit closer to the fulcrum and the lighter boy should sit further away from the fulcrum without further details. About 10% of them said that Ahmad has to be far from the fulcrum in order to be “heavier”, which showed that these students misinterpreted “Moment” to be “Force”.
M2. Conceptual Understanding of Moment after Instruction

The majority of the students (87%) know that to make it easy to open a door, minimum force is required to open it if that force is applied furthest away from the hinge. There are also some students (5%) who chose the correct answer but gave the reasoning that the moment is more at D. From this answer, we can deduce a problem of the confusion between force and moment. Some of them think that when there is more moment, doors get opened more easily. It seems difficult for them to grasp that it requires the same moment to open the same door, so it is the force applied that is different based on the perpendicular distance that the force is applied from the hinge. Some were confused between the perpendicular distance and the distance moved by the door, saying that at D, the distance moved is longer and the longer the distance moved, the less the force (6%). 2% of the students mentioned work done in their answers, showing the confusion of moment and work done. Another 10% did not explain their answers.

When we compare before and after instruction, 22% of the students improved in their understanding of the concept “minimum force is required when the perpendicular distance from the pivot is
the longest”. The figure below showed the percentage of students who understand that concept before and after instruction. As we can see from Figure 5, 65% of the students already have the understanding of the concept before instruction.

![Chart showing understanding of the concept Moment of Force](image)

**Figure 5.** Percentage of students who understand the concept of ‘Moment of Force’ before and after instruction

Post-test question 2b requires the students to draw out the perpendicular distance with the objective of testing students’ ability to identify the perpendicular distance besides just being able to mention those key words. Figure 6 shows the typical answers given by the students. The percentages of students’ responses are given in parentheses.
<table>
<thead>
<tr>
<th>Correct Answer</th>
<th>Wrong Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(50%)</td>
<td>(1%)</td>
</tr>
<tr>
<td>(1%)</td>
<td>(2%)</td>
</tr>
<tr>
<td>(2%)</td>
<td>(11%)</td>
</tr>
<tr>
<td>(1%)</td>
<td>(1%)</td>
</tr>
<tr>
<td>(3%)</td>
<td>(5%)</td>
</tr>
<tr>
<td>(1%)</td>
<td>(3%)</td>
</tr>
</tbody>
</table>

Figure 6. Sample of students’ work for Question 2b
26% of the students did not make any markings for the drawing. It is interesting to note that almost all of the students who left the drawing of ‘d’ blank gave an explanation to support their answer and most of these answers have correct keywords used in textbooks and teacher explanation, such as “It is the perpendicular distance from the line of action of force to the pivot.” This could either mean that they know which distance but are unable to express themselves in the form of drawings or they know the keywords but have no idea what the term means, thus their inability to identify and mark out the perpendicular distance in the diagram.

**Work Done**

*W1. Preconceptions of Work*

For question 3 of the pre-test, we are interested in knowing the students’ interpretation, before instruction, of the terms “same hard push” and “work”. Both terms are not in the primary school science syllabus. Students’ interpretation are assumed to be based on their common sense and understanding of the language in the layman terms. From the students’ answers, it is obvious that the majority of the students were not aware that “same hard push” means that each
of the boy has exerted the same amount of force on the box, because in their answers, they said that “Ah-Ting applied more force to get the box moving on a surface with more friction, that was why he has done more work”. Another possibility is that students could miss out reading that detail (“same hard push”) in the question. However there are students (18%) who mentioned that both brothers did the same amount of work because the force they applied to the box is the same. Only 3% of the students made reference to the “distance moved” in their reasoning.

As for the term “work” students interpreted it as “how hard someone is working” and often relate it to the amount of force exerted. Most students said that the boy who did more work is the one who is pushing the box over a rougher surface.

Almost all the students (97%) know that things pushed over a smoother surface will move further. The majority of the students also used the term “less friction” to describe the smoother surface.
W2. Conceptual Understanding of Work after Instruction

Figure 7 below shows the students’ responses for question 3a. As can be seen from the graph, 89% of the students stated that Tim has done more work against friction, which is the correct answer. From their answers it is evident that they understand the concept of work done against friction.

They stated that since gravel road is rougher (or “more rough” in their words), it creates more friction between the box and the road, hence Tim has to overcome more friction. Not many actually made reference to the data given in the question. 2% of the students either chose “Tom”, or “both of them” or did not give a response. Slightly
more than 4% of the students said that there is no work done against friction in this case because the direction of applied force is not in the same direction as the friction.

Figure 8. Percentage of students’ responses on who has done more work (Question 3b)

As illustrated in Figure 8, the question, “who has done more work”, saw 62% choosing Tim to have done more work. The reasons given here are similar to that given in 3a, with gravel road having more friction. Even though this question specifically stated that both boys exerted the same amount of force, about 35% of the students said that Tim did more work because he used more force to push the box. Out of the 26% who said both of them did the same amount of work, most gave the reasons that it was because both of them applied the same amount of force to the boxes and the boxes
moved the same distance. This shows that only some of the students are able to relate “work done” to force and distance, even after instruction.

The question of who has done more work against gravity saw about 42% saying that there is no work done against gravity. Of these, the common reason given was that the direction of motion of the box (horizontal) is not the same as the direction in which gravity is acting on, so no work is done. These students managed to apply the concept that no work is done when motion is not in the direction of force. (Note: Students are taught and expected to learn only two cases: either motion along or perpendicular to the direction of force.) As seen from Figure 9 above, 47% of the students answered

![Figure 9. Percentage of students’ responses on who has done more work against gravity (Question 3c)](image-url)
that both boys did the same amount of work against gravity because both boxes were at the same height and are of the same weight. We believe the students have remembered the formula for work done against gravity without understanding – they had not realized that the “height” in the formula refers to the “vertical distance moved by the box”.

![Understanding the concept of "Work Done"](image_url)

**Figure 10.** Percentage of students who understand the concept of “Work Done” before and after instruction

Results seem more positive for the general concept of work done, as illustrated in Figure 10. There is an improvement of 51% of students who are able to understand the concept of work done after instruction. However there is still much room for improvement because having half the cohort to not understand the concept of ‘work done’ even after instruction is a cause for concern.
Presence of Friction

F1. Preconceptions

Most students are already aware of the presence of friction, with 86% of them using the term ‘friction’ in the reasoning of their answers. 4% more students became aware of ‘friction’ after instruction.

Figure 11. Percentage of students who are able to relate the concept of friction to “Work Done” before and after instruction
F2. Conceptual Understanding after Instruction

Figure 11 illustrates students’ improvement in understanding the concept of work done against friction. After instruction, there is an improvement of 22%. This means that a total of only 24% of the students were able to grasp the concept of work done against friction. This percentage is relatively low. We can decipher that students generally understand ‘Work Done’ on its own and not in relation to work done or gravity.

Student Difficulties: Moment of Force vs Work Done

Question 4 of the post-test achieves the aim of highlighting students’ confusion between the concepts of moment of force and work done as 36% of the students agreed with Zhu, 26% do not agree with anyone, 25% agreed with Raju and 7% agreed with Abu. About 6% of the students left the answer blank. Most of the students are able to do the calculations 25 X 2 = 50, but were not sure of the units to use. It was obvious that the students were highly confused over the units, as they used newton-metre (Nm) and joule (J) interchangeably, for Case 1 and 2. Some used the same unit for both cases, others different. The reasons they gave to support their
answers were also varied, highlighting their confusions between the two concepts further. There were some students who played it safe simply by saying that Case 1 shows Moment and Case 2 shows Work Done and Moment is not Work Done, and did not comment further on the comments stated by the three boys. From the analysis of the reasoning students gave to support their answers, we concluded that 54% of them demonstrated to have confusion and disability to distinguish between the concepts of ‘Moment of Force’ and ‘Work Done’.

**Limitations of analysis**

There are various factors that can affect our comparative analysis and it is difficult to clearly determine which factor has bigger influence on the results. As such we do not aim to make any definite conclusions but rather, while highlighting possible relationships, we also raise the limitations of our analysis. They are as follows.

a) The nature of our rubrics does not really differentiate the students who know the concepts but do not know how to explain from the ones who have no idea at all about the concepts involved. Students who left their answers blank are assumed not
to know the answer. For example, we give ‘0’ for an answer that makes no sense, ‘0’ for no response and also a ‘0’ for students who wrote “I know the answer but do not know how to explain”. An interview with such students would enable us to have a greater response as to whether these students are able to verbalise their understanding better than written answers. These students could be tired from thinking of the answers after a long school day when they actually know the answer. This conclusion was based on responses made by such as “Very tired to think”.

The validation of the rubrics and coding could be improved on if there are more people verifying the coding and rubrics systems.

b) Many of the students have a poor command of the language and reasoning skills. Some of the words they chose to answer or explain certain concepts may not be what they actually mean. A dialogue session with some pictures or hands-on task could be conducted with the researcher and a pair of students to probe deeper on students’ understanding of the targeted concepts.

c) More questions in the instruments would allow us to probe deeper into students’ understanding. However students’ busy schedule and rigorous curriculum could not allow this. Having
more questions could mean students rushing through the work and not thinking through the answers and also teachers losing the curriculum time to complete the syllabus.

**Conclusions**

As the research described in this paper indicates, most students in secondary school do not develop the type of functional understanding that enables them to apply the basic concepts. We found some serious conceptual and reasoning difficulties present at the beginning of instruction that were just as prevalent at the end. Apparently, these difficulties were not successfully addressed by the standard presentation of material in the traditional secondary 1 science lesson.

To bring about a significant conceptual change, it is necessary to engage students at a sufficiently deep intellectual level. However, the traditional science lesson is a passive learning experience for many students. The criterion most often used as a measure of academic mastery is the ability to solve standard quantitative problems and answering of standard questions with appropriate keywords. In the study of ‘Forces at Work”, the attention of
students is primarily directed toward the solution of quantitative lever problems (for Moment of Force) and work done through the use of the formula Force multiplied by Distance. The type of questions that might strengthen concept development and scientific reasoning ability are generally not posed.

There is a need for instructional materials that foster the active mental participation of students in the learning process. The development of curriculum that fulfils this need should be guided by knowledge of what students know and can do, rather than by assumptions about what they should know and should be able to do ((McDermott & Shaffer, 1992).

In this paper we have illustrated how our investigation of student understanding in the limited domain of moment of force and work done has contributed to the building of a research base for curriculum development. It is our objective to use the results from this investigation to guide the development of curriculum materials that closely matches the needs and abilities of students than does traditional instruction on this topic.
Future Plans

This project aims to model the “research-development-instruction” iterative cycle by the PEG for the development of the curriculum materials and we are currently at the research phase. We are pioneering a research project called PBI1@School to assist the adoption of science by inquiry in the secondary schools in Singapore. We propose to achieve this by adapting the Physics by Inquiry (PbI) pedagogy developed by the Physics Education Group (PEG) at the University of Washington (UW) which emphasizes on conceptual understanding through an inquiry approach. As the materials by PEG are created for university courses for undergraduates or in-service teachers, our research team would modify them to suit the secondary 1 level as well as create new instructional packages for the topics that are not available, all with the intentions of addressing the learning difficulties of the students.

PEG examines student difficulties in various domains of physics and has used the results from their research to design instructional strategies that address the difficulties they discovered. We hope to do the same, focusing on the six physics topics in the secondary 1 science syllabus for a start. After coding and analysis of the results
of the pre-tests and post-tests before and after traditional classroom lessons, we would identify the topics that students encounter the greatest difficulty in and design physics by inquiry instructional packages that work towards addressing these problems. We are working to getting these ready for implementation for a new cohort of secondary 1 students in the same school.

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References


Appendix 1

Chung Cheng High School (Main)
Section: Science - Physics

Set 1 Science - Physics
Pre-Test: Chapter F2 Forces at Work

Name: ____________________________ ( ) Class: ____________________________

Gender: ____________________________ Date: ____________________________

For Question 1-4, select your answer by ticking the box □. Explain your answers.

1. I think ‘Forces at Work’ will be an interesting topic.
   □ Yes □ No □ Maybe
   Reason: ____________________________________________________________

2. Pictures A and B showed two slightly ajar doors in Choy’s home. Picture A showed her bathroom door with the knob in the middle and Picture B showed her bedroom door with the knob at the edge. Which door is easier to push open at the knob and why?
   □ A □ B □ both are equally easy
   Reason: ____________________________________________________________

3. Ah-Ting
   □ A □ B
   Reason: ____________________________________________________________

Ah-Tang
b. Who has done more work?

☐ Ah-Ting  ☐ Ah-Tang  ☐ Both brothers have done the same amount of work

Reason: ..............................................................................................................................................................................................................................................
..............................................................................................................................................................................................................................................

4.

A   B   C   D   W   X   Y   Z

Ahmad

Scotty

Ahmad and Scotty decided to get on the see saw above and try to keep it balanced. Decide which of the 4 choices below is possible. Explain your decision.

☐ Ahmad should sit at A and Scotty should sit at W.
☐ Ahmad should sit at B and Scotty should sit at Y.
☐ Ahmad should sit at C and Scotty should sit at Z.
☐ Ahmad should sit at D and Scotty should sit at X.

Reason: ..............................................................................................................................................................................................................................................
..............................................................................................................................................................................................................................................

5. In my opinion, the greatest difficulty or challenge that I will face in this topic is: ........................................................................................................

..............................................................................................................................................................................................................................................
..............................................................................................................................................................................................................................................

-End-

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Appendix 2
Chung Cheng High School (Main)
Sec 1 Science – Physics

Post-Test: Chapter F2 Forces at Work

Name: ___________________________ ( )  Class: ___________________________

Gender: ___________________________  Date: ___________________________

For Questions 1-4, select your answer by ticking the box. Explain your answers.

1. Learning Forces at Work has been a meaningful experience.
   □ Yes  □ No  □ Maybe

   Reason: _____________________________________________________________

2. __________ Picture 1 below shows a door leading to an art gallery. To swing the
   door open, a push must be applied

   door with the minimum force?
   a. At which position on the handle should you push open the
      _______  □ A  □ B  □ C  □ D

   Reason: _____________________________________________________________

3. moment of the force applied. Label your marking ‘d’.
   b. Mark out the distance necessary to calculate the

   _____________________________________________________________

   __________ hinge

   _______ Picture 1

Box B have the same weight. Box A is on gravel road and Box B is on marble floor. Tim and

Box A and Tom apply a force of 100 N on the box over the same distance of 100 cm on the surface. The frictional
b. Who has done more work?
☐ Tim ☐ Tom ☐ Both brothers have done the same amount of work.
☐ There is no work done by the brothers.

Reason: 

---

c. Who has done more work against gravity?
☐ Tim ☐ Tom ☐ Both brothers have done the same amount of work against gravity.
☐ There is no work done against gravity.

Reason: 

---

4. Case 1: Abu applies a 25 N force at a point 2.0 m away from the pivot to keep the lever horizontal. Case 2: Raju pushes a box with a 25 N force over a distance of 2.0 m.

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- Abu says, “I have done more work than Raju because it is difficult to hold the lever horizontal.”
- Raju says, “I have done more work than Abu because Abu does not look like he is doing anything at all.”
- Zhu says, “Abu and Raju have done the same amount of work. Just calculate and see.”

Who do you agree with?

☐ Abu ☐ Raju ☐ Zhu ☐ I do not agree with any of them.

Calculation and Reason:

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5. The greatest difficulty or challenge I faced in this topic is: 

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