MAURITIUS RESEARCH COUNCIL

USING RESEARCH FINDINGS (LOCAL AND INTERNATIONAL) TO IMPROVE THE TEACHING AND LEARNING OF PHYSICS AT SECONDARY LEVEL USING TECHNOLOGY

Final Report

February 2014

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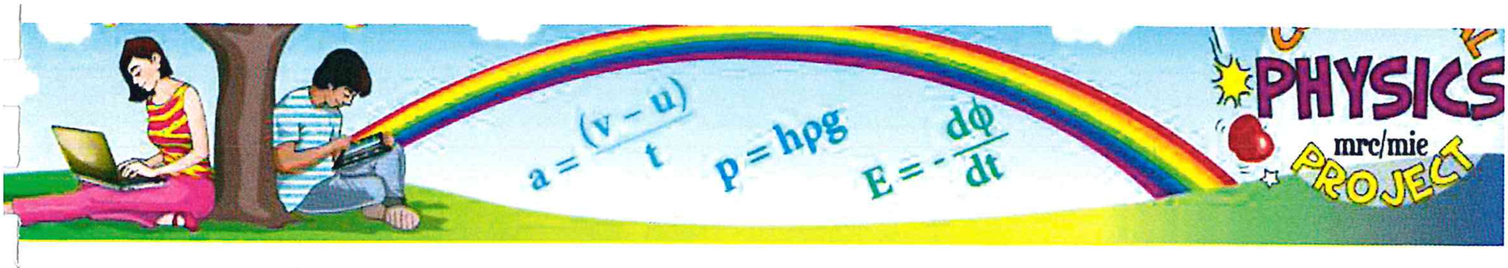

Using research findings (local and international) to improve the teaching and learning of physics at secondary level using technology

http://science.mie.mu/physics/

MRC Unsolicited Research Project

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CONTENTS

EXECUTIVE SUMMARY

This research project, the first of its kind in Mauritius, has unveiled a number of issues related to difficulties and misconceptions students have in physics at upper secondary level. In addition, misconceptions have also been detected among physics educators in certain key physics concepts. These misconceptions or alternative conceptions are deeply rooted in learners and limit the development of cognitive structures in learners. Not addressing students' misconceptions may, in the long run, impinge significantly on students' conceptual understanding, not only physics, but of other areas as well.

Misconceptions held by physics educators on certain key physics concepts have been identified during a pre-test exercise. After intervention, the post-test demonstrated a significant improvement in educators' content knowledge and pedagogical content knowledge.

Statistical analysis of findings from a case study of a purposeful sample of participants (students and one educator) about their misconceptions has provided sufficient evidence of the effect of the teacher's lack of conceptual understanding in selected physics concepts on students' understanding. The research has shown that the adoption of learner-centered strategies, in addition to engaging learners in situations of cognitive dissonance is beneficial for knowledge construction and cognitive development of the learners.

Capacity building workshops have been organized for physics educators of Mauritius and Rodrigues, involved in the pilot study.

Teaching of selected physics concepts has been undertaken by the Research Team in the pilot schools, where students have been engaged in the learning of physics in an interactive way through technology with the use of data-logging. Feedback obtained during those sessions was used to conceptualise a framework for technology integration in the teaching and learning process. This framework considers technology, not as a tool, but as a medium for effective teaching and learning. This medium incorporates three elements, namely contextual knowledge, pedagogy and technology. As per the research objectives, the development of a website (http://science.mie.mu/physics/) was undertaken. It

incorporates a platform for teachers, students and parents. Educators may use it to construct physics lessons while students are required to perform certain tasks at home with a view to acquiring (or reflecting on) prior knowledge before learning the concept at school. Parents, for their part, have the opportunity to interact with schools through the platform as a means to monitor and support the learning of their children. The web-based interactive platform incorporates a number of salient features, such as testing of prior knowledge (home and school), hands-on and minds-on activities, interactive Flash files, interactive Excel files, videos illustrating abstract concepts or guides to perform experiments, data from data-logging experiments, discussion forum, formative and summative assessment tasks, amongst others. It is the educators who have the administrative right to register students and parents on the platform, thus giving them access to the facilities in a timely manner.

To support students' meaningful knowledge construction of physics, the three stakeholders should work in collaboration to generate a common synergy.

A set of recommendations are provided with a view to bringing a paradigm shift in the teaching and learning of physics. The role that the appropriate stakeholders have to play to facilitate the integration of technology as a medium are listed.

The report also identifies the challenges inherent to the conduct of this research project. However, this research project, the first of its kind in Mauritius, very much serves to document hitches, which could account, among other causes, for the failure of some aspects of our education system.

INTRODUCTION

It is not a surprise that physics is considered one of the most difficult subjects and is feared by many students (Clement, 1982) since lower secondary level. Many of them would simply not opt for physics at the upper secondary level. Research has established that students experience considerable difficulties to develop conceptual understanding of physics concepts (e.g., Clement, 1982; Steinberg, Brown & Clement, 1990; Monaghan and Clement, 1999). Unfortunately, the mainstream secondary educational system is too examination oriented (Bah-lalya, 2006) so that students are required to learn concepts by rote (Elby, 1999; Pell, Iqbal and Sohail, 2010; Ramma, Samy and Gopee, *to appear*) to pass the examinations. There is an array of literature (e.g., Lemke, 1990; van Zee *et al.*, 2001) which emphasises considerably on the fact that rote learning restricts students' ability to display adequate cognitive strategies to perform appropriate tasks independently. What is striking is that most students have the firm conviction that rote learning will be rewarded (Elby, 1999). Elby further claims that examination questions can be successfully attempted merely by rote application of problem solving heuristics.

Research is continuously stressing on the fact that the type of instructional strategies (e.g., Roth and Roychoudhurry, 2003; Akanwa and Ovute, 2014) is a determining factor in the development of conceptual understanding. On the other hand, Zhu (2007) and Sobel (2009) emphasise that rote learning does not induce conceptual understanding in learners and limits students' ability to reason. This, therefore, severely impinges on students' self-motivation, thus affecting conceptual change (Palmer, 2005).

The paradox is that, despite the fact that there are National Curriculum Frameworks for both for primary and secondary levels, the system of education is nevertheless examination driven (Ah-Teck, 2012). This is confirmed by Seebaluck and Seegum (2012) who stress on the fact that at the primary level, enormous stress is laid on parents who have no other choice than to resort to private tuition for their children. Moreover, still at the primary level, Bah-lalya (2006) confirms that 70% of pupils sitting for the CPE examination have taken private tuition and what is arresting is that 88% of the pupils had one teacher for private tuition, while 9% had two teachers and 3% had three teachers. Unfortunately, no research has been carried out at the secondary level to investigate the relationship between examination anxiety and private tuition. Admittedly, the figures may not be significantly different to those prevalent at the primary level.

RATIONALE OF THIS RESEARCH

It has been contemplated that students studying in Mauritius (and Rodrigues) experience difficulty to articulate physics lessons at the conceptual level. Research conducted by Ramma *et al.* (in press) among a sample of students at the tertiary level from two local universities and among teachers following PGCE courses at the Mauritius Institute of Education concerning the transition from secondary to tertiary levels of education shows that rote learning of concepts is prevalent at both levels. This research study had to be conceptualised with a view to addressing a number of issues related to conceptual development in relation to teaching and learning of physics at the secondary level of education. There is ample evidence to ascertain that the teaching of physics in secondary schools in Mauritius and Rodrigues has not undergone a paradigm shift from lecture mode to the learner-centered approach.

This project has been conceptualised in a timely manner as it brings to the forefront a number of issues which are not discussed overtly, such as whether teachers hold misconceptions in physics.

Aims of the Project

This research project aims at:

- investigating by means of a literature search at national and international levels the type misconceptions students generally have in physics;
- identifying whether teachers hold misconceptions of certain physics concepts;
- identifying whether students studying physics at School Certificate or Higher School Certificate levels hold misconceptions of physics concepts; and
- developing an interactive technology-based conceptual physics lessons to address the problems related to misconceptions in physics.

The first aim will be developed under the title '**Research Findings on Misconceptions'**. In this section, an elaborate literature search will be carried out on how students' and teachers' develop misconceptions.

For the second and third aims, data on the misconceptions in physics developed by both teachers and students will be analysed and discussed. The correlation between the two groups will be highlighted.

Finally, the fourth aim undertakes to display work done in the development of an interactive website that teachers and parents may have recourse to to enable learners to develop conceptual understanding of physics.

The Local Context

It has been observed that students studying physics at secondary (lower and upper secondary) level in Mauritius and Rodrigues experience difficulty in justifying their propositions when it comes to conceptual understanding and problem solving in physics. Hestenes, Wells, and Swackhamer (1992) infer that because students have been forced to memorize bits and pieces of information in a fragmented way, the information becomes alien to them and has, therefore no meaning. Knowledge makes sense and has meaning when ideas/concepts are linked to form an integrated thought. A number of researches (Parmessur *et al.,* 2002; Ramma *et al.,* 2006; Ramma *et al.*, 2009) conducted in the local context have all emphasized the type of lessons that students should be engaged in so as to construct meaningful knowledge structures.

Prior Work

We have also observed similar types of difficulties faced by in-service and pre-service teachers during classes at the Mauritius Institute of Education. During the writing of the project proposal, a pre-test conducted among a small sample of PGCE trainees has revealed that even physics teachers do hold misconceptions about certain specific physics concepts, which, according to us, would most probably impinge on the students' understanding of the same concepts. These findings are in agreement with Clement's (2009) conclusion during his 'thought experiments' about areas of difficulties in physics among his targets who were teachers and graduate students.

RESEARCH FINDINGS ON MISCONCEPTIONS

Misconceptions in physics are views or ideas held by learners which are discordant with scientific theories (Brown and Clement, 1989; Steinberg, Brown and Clement, 1990; Vosniadou, 2002), also known as faulty theories (Dunbar, Fulgelsang and Stein, 2007). Misconceptions held by learners will certainly impede the acquisition of new knowledge and negatively impact on further understanding of concepts. A literature search is thus conducted on the misconceptions held by students and teachers in physics.

Students

Students come to the physics classrooms, not as empty slates, but with deeply rooted notions or ideas and/or naive views, which are in total contradiction with scientific principles, laws and theories. If these notions are not investigated and remedied during the teaching and learning processes in the classroom, the alternative conceptions will gradually bring learners to a state of total confusion and consequently impinge on later acquisition of concepts. It is therefore of paramount importance that teachers lay more emphasis on what students are learning rather than on what they are teaching (Redish, 1994). Unfortunately, the traditional modes of instructions leave no other opportunity for students to cognitively learn concepts but to rote learn in order to pass an examination. What is a matter of concern is that we are all aware that there is a problem, but we never dare address it. Rather, most of the time, examination is, unfortunately, referred to as the culprit, an excuse for not confronting the problem. Students who have understood scientific principles, laws and theories will be able to apply them in novel contexts and make connections within and across domains.

The traditional approach to teaching and learning physics, regrettably, limits the development of cognitive structures in students and hinders conceptual change (National Research Council, 2007). The National Research Council (2007) stresses on the fact that science should not be learnt as simple dichotomy of instructions in the form of science as content or science as process, rather students should be provided with learning opportunities within the following four strands (p. 37):

- Know, use, and interpret scientific explanations of the natural world
- Generate and evaluate scientific evidence and explanations

- Understand the nature and development of scientific knowledge
- Participate productively in scientific practices and discourse

This means that science as content and science as process should be learnt within a context in which learners can make meaning of concepts in an integrated manner.

Researches also show that students harbour naive ideas (misconceptions) which compete and coexist with the correct notions. Such interference can become a source of perpetual conflict. Conceptually-based instructions should allow students to become aware of the misconceptions and free them gradually of the misconceptions. Steinberg and Clement, (2001) argue that misconceptions are dislodged gradually and not at one go. This view is also shared by Kocakulah and Kural (2010). On the other hand, VanLehn and van de Sande, (2009) clarify that "misconceptions don't ever die, they just get beaten in so many situations by confluences that they retire" (p. 366). Moreover, Brown and Clement (1989) advocate that teaching not based on what the learners already know is deemed to fail as learning will not be meaningful. Despite that many researches are concluding that there are appreciable improvements in learning outcomes (e.g. Hake, 1998). It is, however, imperative that students are engaged in extensive practice within and across domains.

Some insights into students' misconceptions are detailed out below:

- Students have the impression that motion is the result of a force. They fail to relate force to the feature of interacting bodies; instead force is referred to as a property of an object (Halloun and Hestenes, 1985; Clement, 1982).
- Students tend to consider that for an object in motion, the direction of the force acts along the direction of the force and that a force is required to sustain motion. Constant force implies constant velocity (Halloun and Hestenes, 1985).

  Common sense beliefs of students should be investigated by teachers during the teaching/learning process. There is a need to highlight that according to Newton's Second Law of Motion, a force produces acceleration. This implies that the force is zero when a body is moving with uniform velocity.

- Students believe that the geometrical and physical properties of a body affect its free fall in vacuum and that gravity does not act in vacuum. During free fall, the speed of an object increases as the object moves closer to Earth. Gravity and weight are considered as two different forces and heavier objects fall faster. (Halloun and Hestenes, 1985).

  Here, students have the intuition that weight affects the acceleration of a body during free fall. There is confusion between weight and gravity which are the same forces.

- Students experience difficulties in differentiating between position and velocity when two objects are allowed to move side-by-side on two inclined planes and when asked whether there existed a time when the balls had the same velocity. The majority of students mentioned that it was when they were side-by-side (Trowbridge and McDermott, 1981).

  Students erroneously associate position with velocity. For them, when the balls are side-by-side, it means that velocity is same. In this situation, the distance covered by the two balls is same.

- Students believe that motion is started only when the force acting on it is big enough and when the force is big enough it causes motion rather than a change in motion (Mildenhall, 1998).

  Students, when not offered adequate guidance, tend to use different competing models to explain the same process.

- Students have the impression that the formation of a dark fringe in *Interference* is due to the combination of two dark fringes (Kocakulah and Kural, 2010).

  Students have the tendency to associate crest with brightness and trough, with darkness.

Teachers

When learner-centered materials are offered to teachers, to what extent do they engage students to construct knowledge on their own? It has been demonstrated, in the private Universe project by means of video interviews that even teachers hold misconceptions about a number of concepts, in particular the occurrence of seasons (Schneps and Sadler, 1988). These physics or science misconceptions will persist if teachers do not adopt a totally different approach to their own professional development. In the majority of cases the traditional approach is adopted, whereby the lecture method plays a predominant part in the classroom transactions (Wieman and Perkins, 2005; Schauer, Ozvoldova & Lustig, 2007). If teachers do not switch to the learner-centered strategies, it is most likely that the Socratic system of instructions will prevail and perpetuate while more and more students will shy away from science, in particular physics. Teachers have the obligation to be well versed in subject content knowledge, knowledge of learners, learning and pedagogy (Ball and McDiarmid, 1989) and as such they should be able to impart knowledge, skills and values to students not only during the teaching- learning processes but beyond, that is, during informal activities.

The very few research studies conducted in respect to teacher's knowledge emphasise that teacher's knowledge is a pre-requisite for effective teaching and that a teacher cannot explain to students about concepts if the underlying principles have not been understood (Ball, 1991a; Hill and Lubienski, 2007) by the teacher himself/herself. Teacher education institutions have the obligation to tailor appropriate training programmes, pre-service or in-service, to adequately prepare teachers for better students' output (Hill and Lubienski 2007). The authors further clarified that if schools do not address the problem, they may face the consequences when these students, on becoming teachers, return later to teach. Research shows that collaboration and discussion among peers to confront one's views is one among other the tangible ways of improving one's own understanding of concepts (e.g., Tao, 2001; Sampson and Blanchard, 2012).

THEORETICAL FRAMEWORK – TECHNOLOGY INTEGRATION

The technology-based lessons are based on three interrelated dimensions (refer to Figure 1): contextual knowledge, pedagogy and technology (Ramma *et al.* 2009). These three elements, in conjunction, lead to the construction of purposeful knowledge structures by the students. The extent to which knowledge is constructed by learners depends on the pedagogical approach the teacher adopts. Amalgams of strategies target all the students who constitute an inhomogeneous composition.

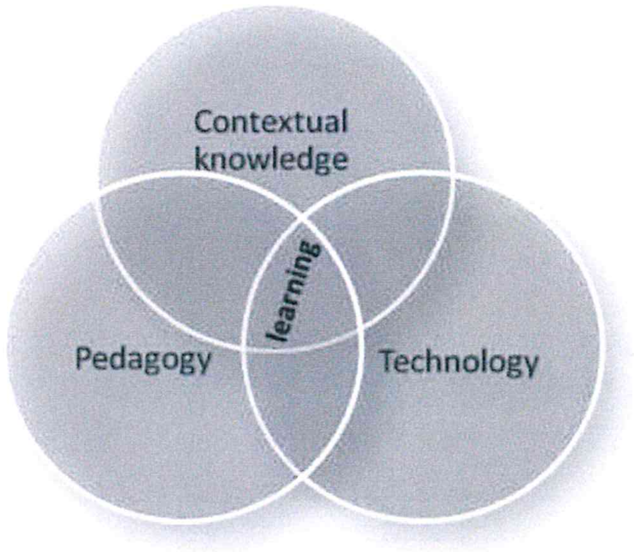


Figure 1: Technology integration

A web-site, as part of the project, has been developed to host the interactive physics lessons. The particularities of the web-site are listed below:

- Accessing the web-site (http://science.mie.mu/physics/) is possible upon registration by the School Administration.
- The users are: Rectors, Teachers, Students and Parents.
- The Rectors' role is consultative only.
- Teachers have the administrative right to register their students and the latters' parents on the platform.
- Students are registered on the platform for the whole duration of their studies at a particular level.
- Parents are provided with appropriate instructions to follow-up on the studies of their children.

The Interactive Physics Lessons

The lessons, together with the worksheets/data sheets, will be displayed on a website so that both teachers and students can have access to the designated information/lessons. Follow-up will be made by the Research Team to improve and update the lessons based on feedback received. The use of data logging will form an integral part of the conceptual lessons, which will also include elements of practical to bridge the gap with theory. Students will also have the opportunity to interact with the lessons/resource materials in a formative manner, thus giving them the opportunity to continuously test whether knowledge has been conceptually developed or not.

It is expected that this research project will enable the Research Team to drive technology-based interactive physics lessons to foster the development of conceptual understanding in learners.

The lesson on kinematics was developed as a test case for discussion with teachers during the first workshop and comprises the following features:

- **Open type questions to test the prior knowledge of students**

Students' prior knowledge (Glynn and Muth, 1994; Elby, 1999; Fugelsang and Dunbar, 2005; Ball, Thames and Phelps, 2008) should be tested and challenged with a view to identifying misconceptions. Open type questions are set to provoke critical thinking, and encourage discussion (Blosser, 2000), amongst others. Based on the responses to those questions, the teacher can decide on the starting point of a lesson and make the necessary adjustments during the course of the lesson.

- **Lesson comprising a multitude of teaching and learning strategies**

The use of multiple teaching-learning strategies is an important feature to cater for mixed ability learners. Each student has his/her own learning style and poor understanding of learning styles of students can negatively impact on the classroom dynamics (Horii, 2007; Robertson, Smellie, Wilson, and Cox, 2011; Abidin, Rezaee, Abdullah and Singh, 2011). The inclusion of a variety of teaching-learning strategies in the lessons will address the various difficulties encountered by the individual student and motivate them to develop conceptual understanding about the topic of the lesson.

Worksheets for independent and group learning

The use of worksheets has been privileged, especially after the *Physics ICT Data Logging* and *Engaging in Thinking Project* has proven its effectiveness in enabling students to challenge and revisit their existing knowledge. Moreover, worksheets offer "tremendous insight into children's understanding and development" (Carruthers and Worthington, 2006, p. 2) and their inclusion in the teaching-learning process will, undoubtedly, add value to the interactive physics lessons. Podolak and Danforth (2013) have shown that worksheets are versatile tools and are very much preferred by students and, in addition, can be used during physics lessons and beyond.

The worksheets contain graded tasks to cater for mixed-ability learners and activities with a view to engaging students in developing critical thinking.

Development of concepts through conceptual-based activities

These activities include hands-on and minds-on tasks, intentionally developed to challenge learners' pre-existing conception. Moreover, practical work is also infused in the lesson not as a stand-alone strategy but as an integral strategy in the teaching and learning process. In addition, the lessons contain real life phenomena or activities which are directly related to students' lives (National Research Council, 2012) to enable them to situate relationships between abstract and concrete (White, 1993) concepts. Data logging elements are infused in the lesson with a dual perspective: either the students are provided with empirical data (in the form of Excel spreadsheet files) from data logging experiments for discussion and consolidation of acquired knowledge, or students are allowed to collect data using data logging to develop manipulative and process skills. Excel spreadsheets are quite versatile and provide teachers with the opportunity to develop MCQ questions in an interactive way (Lewis, 2003) for independent learning of the students.

Formative and diagnostic assessment infused in the lesson

Formative assessment, contrary to summative assessment, when infused in lessons should become an integral part of the teaching-learning transaction (Shavelson *et al.,* 2008).

Formative assessment is to be understood as a process, rather than a product, whereby teachers adopt a variety of strategies (learner-centered) to decide what students already know (prior knowledge), identify gaps in current understanding, and plan future lessons to improve learning. The last part has a direct relationship with diagnostic assessment.

Lesson Concluding Remark

All lessons include a conclusion in conjunction with the learning outcomes. At times, additional challenging activities are developed to provoke students' thinking beyond the curriculum. The Discussion Forum provides the platform for such challenging discussions to take place.

METHODOLOGY

Survey

A comprehensive literature search on the various difficulties and misconceptions students encounter in physics at national and international levels was carried out. Following this survey, at least three topics have been chosen for in-depth investigation, namely **Kinematics**, **Moments**, **Light** and **Electricity**. These topics have been chosen as they are usually covered in the first year of the School Certificate and Higher School Certificate respectively.

Sample

Initially schools were grouped into four categories, namely Category 1, Category 2, Category 3 and Category 4, based on the usual grouping of secondary schools in Mauritius and in Rodrigues. Unfortunately, only three categories participated in the project as permission was not granted for one of the categories to participate in the workshops. The project Team took the decision to proceed with only the three categories (Categories 1, 2 & 4). Thus, 15 secondary schools in Mauritius and 2 secondary schools in Rodrigues within a purposeful sample participated in the project. For ethical reasons and confidentiality purposes, the names of the schools will not be disclosed in this report.

Workshops

Two workshops were conducted in the form of a capacity building exercise for 2 Educators from each of the selected schools. The discussions during the workshops helped to understand the intricacies of the classroom dynamics and also helped the Team to improve further on the lessons, that is, to consider concrete examples of real life situations in the physics lessons. For Rodrigues, only two workshops were organised and the same activities were discussed given that the sample was made up of four teachers.

First Workshop

During the first workshop organised on 6-9 December 2011 (Mauritius) and on 12-14 December 2011 (Rodrigues), the TUG-K questionnaire (Appendix 1) was administered to all the participants. Permission was sought from Professor Robert J. Beichner from North Carolina State University, USA, who kindly acceded to our request to provide us the access key to open the files. The TUG-K questionnaire consists of 26 multiple choice questions (MCQs) which capture salient aspects of graphs in the topic of kinematics (Beichner, 1994). An additional 'Explain' item has been introduced in each one of the MCQs by the Team to capture the thinking of the Educators. This amendment eventually converted the questionnaire into a three-tier type one (Treagust, 1988; Hestenes *at al.*, 1992).

Pre-Test

The TUG-K questionnaire was administered as pre-test at the start of the workshop and it was collected after one hour. No copies were given to the teachers as we intended to administer the same questionnaire at the end of the workshop. During the workshop, no reference was made to the items in the questionnaire, nor did the programme (refer to Appendix 2) mention any evaluation questionnaire. This was deliberate so as not to provide teachers the opportunity to discuss the items.

Interactions during the workshop

During the workshop, teachers were exposed to the types of misconceptions held in physics and discussions were carried out on the type of strategies that should be adopted to help learners identify the misconceptions. The use of data logging to capture data during experiments was discussed. Additionally, teachers were allowed to work in groups to come up with their own pedagogical approach. The use of Excel to plot graphs was also discussed.

Post-Test

The TUG-K questionnaire was again administered to the same teachers so as to identify any change in conceptual understanding of kinematics. The teachers had one hour to complete the questionnaire.

Second Workshop

This one-day workshop was organised on 19 April 2012 (Mauritius) with, as objectives to:

- bring to the attention of teachers involved in the project about their own misconceptions in physics, in particular, in relation to kinematics; and
- introduce teachers to the various aspects of the newly developed website.

Discussions were held to help identify one's own misconception, if any, through discussion among peers. Moreover, the lessons available on the website would allow teachers to confront their existing conceptual knowledge with a view to guiding learners to construct purposeful knowledge structures.

A second questionnaire (Appendix 3) consisting of 10 three tier MCQs based on three topics, namely force and motion, charges, and projectile motion was devised. The same questionnaire was administered to 34 students in one of the pilot secondary schools with the aim to correlate the students' responses with those of their teacher.

Teaching of Physics Concepts in Schools

Members of the Research Team developed interactive physics lessons based on the above discussions and organised teaching sessions in the selected schools at School Certificate and Higher School Certificate levels. The following concepts were taught:

- Moments (SC)
- Stability (SC)
- Light – Reflection (SC)
- Light – Refraction (SC)
- Electromagnetism (SC)
- Electricity (SC)
- Kinematics (HSC)
- Circular Motion (HSC)
- DC Circuits (HSC)

Ethical Considerations

Necessary permission was sought from the respective authorities to invite schools to participate in this research project. However, the names of schools will not be disclosed in this report for the following reasons:

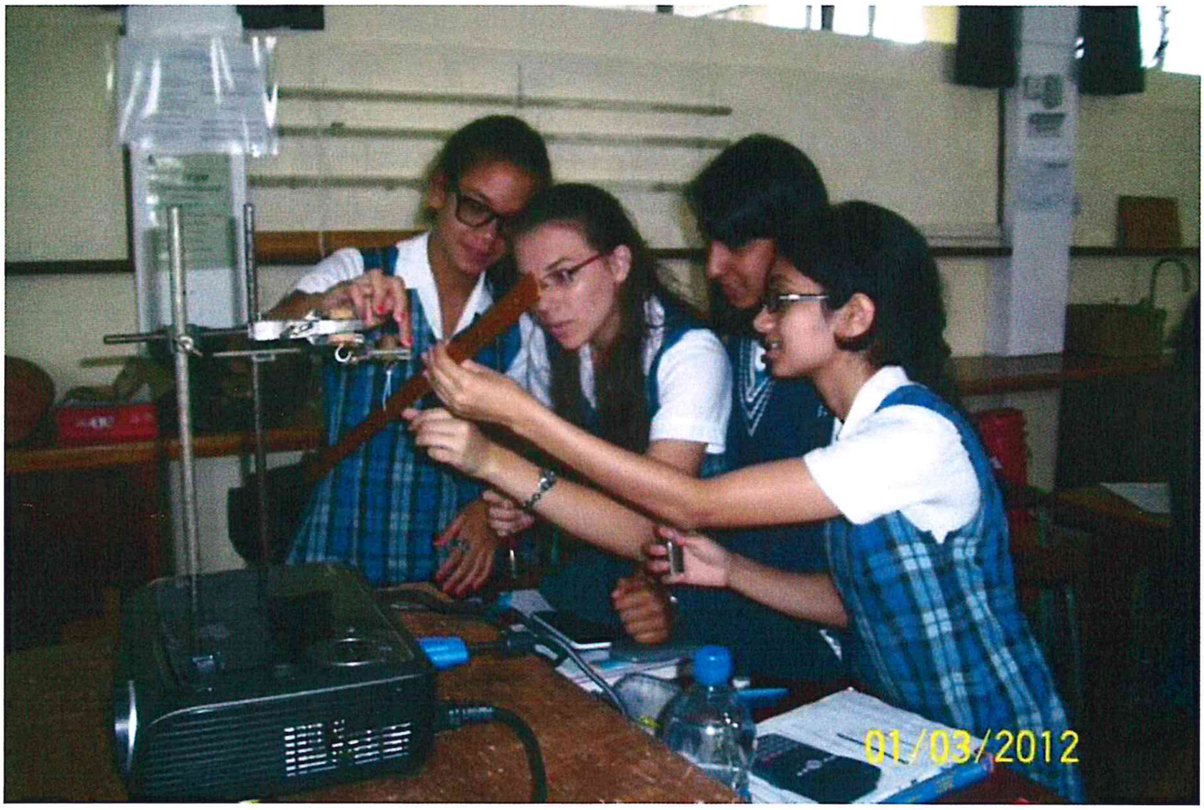
i. One of the categories (Category 3) of the schools did not grant permission to participate in the first workshop and it defeated the whole purpose to include that category in the project.

ii. There are sensitive issues related to testing of pedagogical content knowledge of teachers. The Research Team found it most appropriate not to disclose the names of schools and teachers so that the results could be communicated.

Moreover, appropriate permission was sought from the management of the different schools to teach the interactive physics concepts in the sample schools. In addition, none of the students had any objections about their picture being taken and used in the report.

TEACHING AND LEARNING IN AN INTERACTIVE WAY

The face-to-face teaching sessions organised for students at the School Certificate and Higher School Certificate levels have been very instructive as they have enabled the Research Team to collect field data which were eventually infused in our strategy to develop the online platform.



The physics lessons were taught by the two physics researchers using an interactive pedagogy and students had the opportunity to construct knowledge by working in groups and confront one another through argumentation (Osborne *et al.,* 2013). Each lesson comprised the following components:

a) Lesson plans

All lessons were carefully planned, taking into consideration findings from research about misconceptions held by teachers and students, elements of best practices from research and our own experience. The lessons were constructed to cover the three levels of abilities, namely low, average and high abilities.

b) Interactive Computer animations

A set of interactive novel computer animations related to each topic has been integrated in the lesson. The animations have been conceptualised so that they do not duplicate what is already available on the Internet.

c) Detailed worksheets

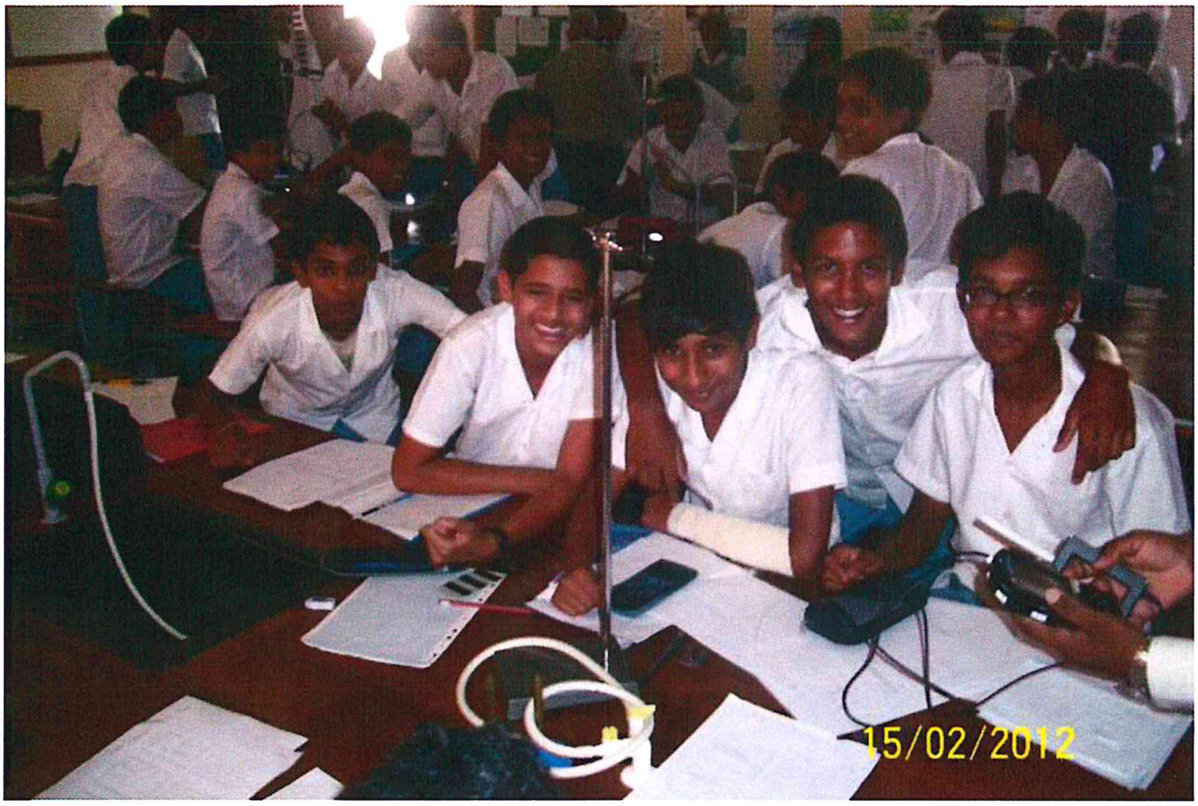
The worksheets were designed in such a way that they included written work for the students to tackle, in the form of plotting or sketching of graphs, drawing of annotated diagram to illustrate their thinking, amongst others. It was also designed in such a way that students did not need to take notes.

d) PowerPoint Presentations

The lessons were facilitated through the use of PowerPoint presentations. These included hyperlinked word documents such as notes and worksheets, graphics, interactive simulations, and graph sheets. The colourful graphics and appropriate animations schemes were used to sustain students' interest throughout the lessons.

e) Evaluation sheets

These were prepared to be administered to students after the lessons were taught. They were meant to obtain feedback from the students with a view to improving our strategies for subsequent lessons.



The teaching of the physics lessons helped the research team to conceptualise the interactive website (see Figure 2), which was one of the research objectives.

The website contains lessons, videos, simulations in interactive Flash files, worksheets, PowerPoint presentations and Multiple Choice Questions related to each lesson. Students' materials on the website are differentiated from that of teachers', as some materials support lessons and are therefore accessible to teachers only.

The lessons on the website are divided into 2 different sections - one for O-Level and the other for A-Level. A-Level students will have access to O-Level notes, whereas O-Level students will not be able to accede to A-Level materials.

It should be noted that the website has been trialled for a Form 3 lesson.

It is envisaged, in the future, to create a platform for Form 3 physics lessons.

Figure 2: The CPP website

It was agreed that each individual teacher would decide which given material would be made accessible to their students, and when. Moreover, the teachers would also decide when to provide students access to watch a particular video that would illustrate a concept. The same approach would apply to assessment questions.

On the eve of conducting any lesson, the teacher would provide access only to a particular part of the lesson, the section which would allow students to check their prior knowledge and be ready to be able to learn a new concept. Following feedback from teachers, on the website, appropriate amendments were made to improve its interactivity.

Further details about the website will be provided and discussed in the last part of this report.

DATA ANALYSIS AND DISCUSSION

Results of Pre-Test and Post-Test for the teachers

Figure 3 illustrates the general findings from the 26 teachers (including Rodrigues) who have attempted the TUG-K questionnaire (Appendix 1). Results from the pre-test (blue colour) clearly indicate that the teachers had difficulty to attempt the questions. Following intervention during the workshop, significant improvement (Wilkocson paired test, p-value = 0.0189 < 5% level of significance – see Appendix 1.1) was noted in the post-test (red colour).

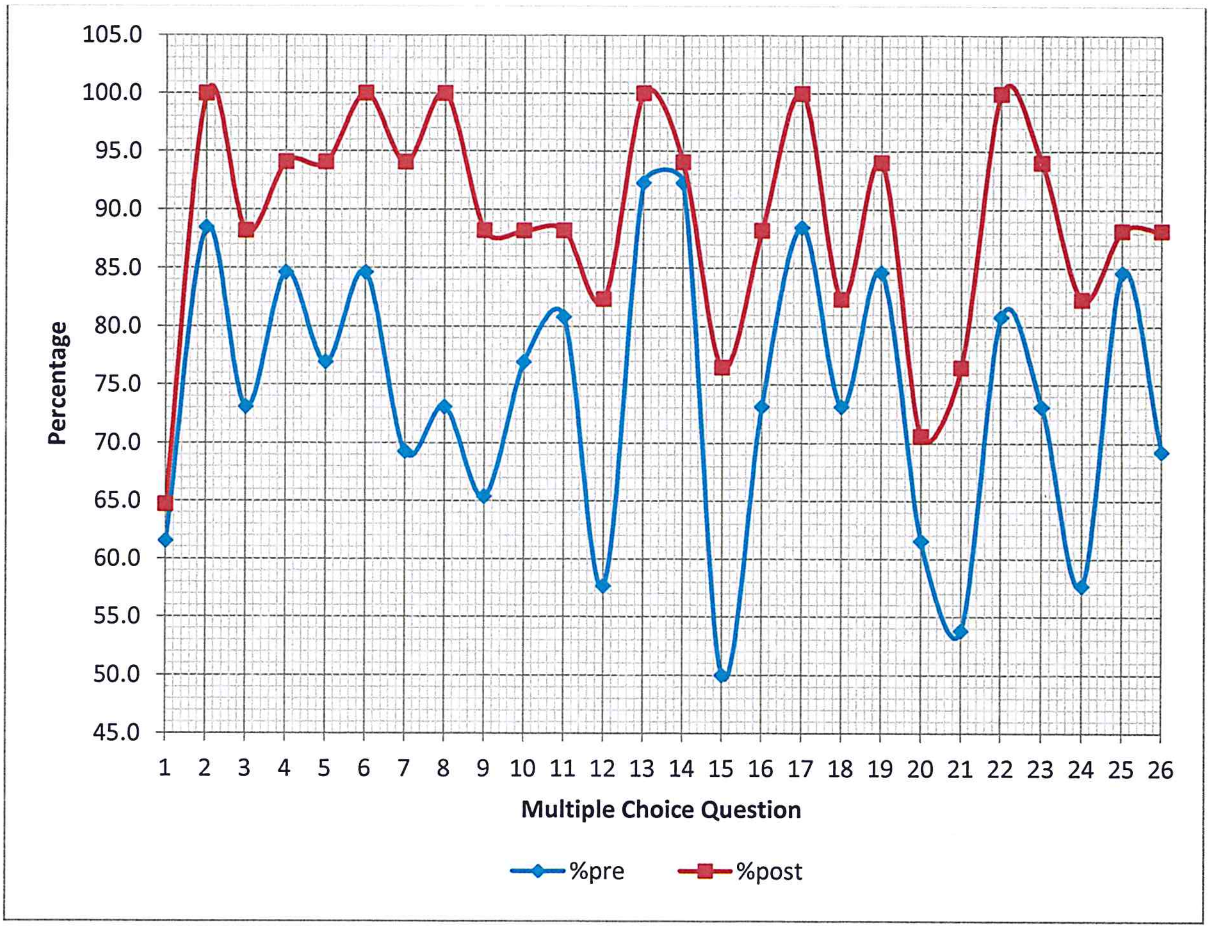


Figure 3: Results TUG-K pre- and post-tests

What is striking is that the two curves show consistency in relations to the pre-test and post-test. The results show a high degree of wrong answers among the teachers, for instance, questions 1, 7, 9, 12, 15, 20, 21 24 and 26 appear to have been very challenging, with less than 30% of the teachers who got the answers right.

Figure 4 illustrates the evolution of disparity between the pre and post-tests scores arranged in order of difficulty of question. In general a larger disparity is observed in questions that demand higher order thinking and which were wrongly attempted in the pre-test.

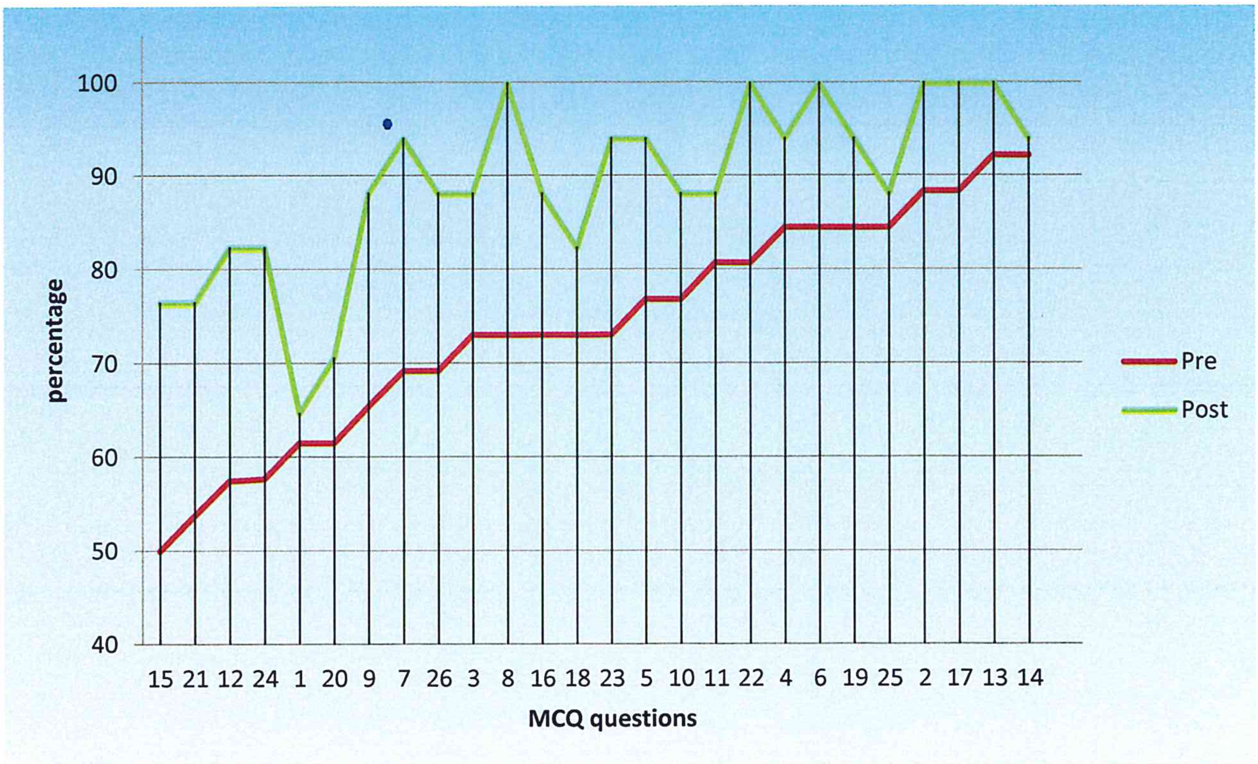


Figure 4: Teachers' results – pre & post-tests

Figure 4 shows the comparison between the performance of the teachers from a pre-workshop evaluation test and a post-workshop evaluation test, where the item numbers are ranked from the least percentage of correct responses on the pre-test (Item No. 15) to the highest (Item No. 14). While the minimum pre-test performance was 57.5 % (Item No. 15), the minimum one for the post-test was 64.7% (Item No. 1). The maximum pre-test performance was 94.3% (Item No. 14) while 100% correct responses were obtained for items No. 2, 6, 8, 13, 17 and 22 in the post-test. Table 1 summarises the performance of the teachers.

Table 1: Descriptive data

	Pre-test	*Post-test*
Mean	74.1	89.1
Median	73.1	88.2
Mode	73.1	88.2
Standard Deviation	12.0	9.5
Range	42.3	35.3
Minimum	50	64.7
Maximum	92.3	100

It can be observed, for instance, that not only have the measures of central tendency (mean, mode and median) increased, but the measures of dispersion (standard deviation, range) have decreased too. This indicates that there is less spread in the percentage of correct answers among the teachers. Teachers are more consistent in providing correct responses.

Table 2: Percentage change

	% change
Mean	21.9
Median	19.4
Mode	13.0
Standard Deviation	14.0
Range	51.0
Minimum	2.0
Maximum	53

In addition, there is a mean gain of around 22 % in teachers' correct responses from the pre-test and the post-test (see Table 2). The maximum change (53 %) was recorded for item No. 15 (from 50 % to 76.5 % correct responses) while the least change was recorded for item No. 14 (from 92.3 % to 94.1%). A strong positive correlation $(r = 0.7684)$ exists between the pre-test and post-test performances. In fact, a regression analysis (Figure 5) shows that for each unit change in the pre-test performance, there is an expected increase of about 0.6 units. The linear regression equation is given by $y = 0.608x + 44.08$ and is displayed in the scatter diagram below.

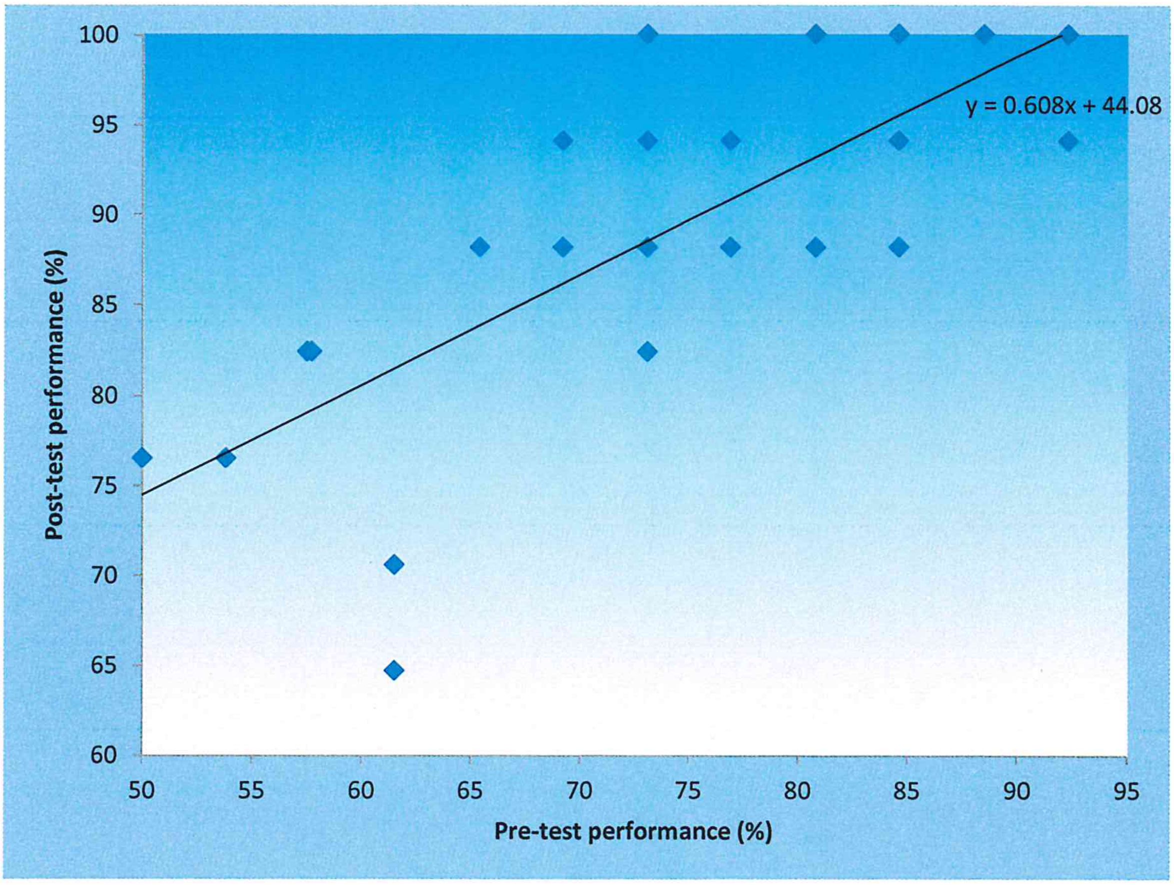


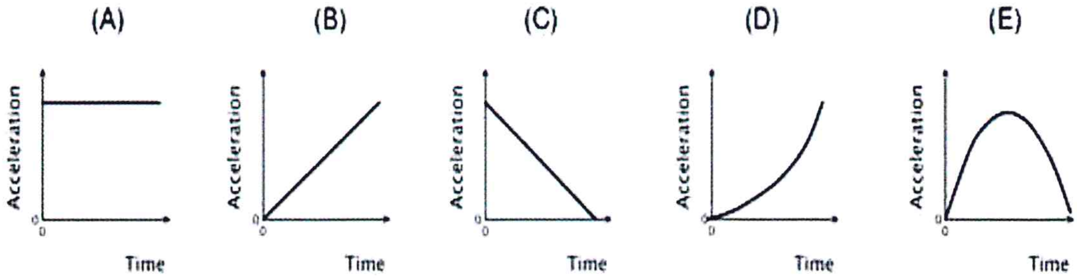
Figure 5: Linear regression

The upward trend in the regression equation indicates a positive gain in cognitive understanding among the participants from their pre-test condition to their post-test one. Based on this evidence, it can be suggested that regular professional development courses may impinged favourably on teachers' knowledge and pedagogical content knowledge.

Discussion on pre and post-tests

A brief insight into one of the 'apparently difficult' questions in the pre-test (1st workshop) is discussed herein.

1. Acceleration versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in velocity during the interval?



Give an explanation for your approach.

Figure 6: Pre-test – Question 1

Many of the teachers wrongly answered this question, with the answers varying between [D] and [E]. This novel question (Figure 6) deals with a number of salient concepts such as:

- ✓ dependent variable
- ✓ independent variable
- ✓ gradient
- ✓ area under graph
- ✓ indices
- ✓ rate – increasing
- ✓ rate – decreasing
- ✓ integration

From the explanation given, it appears that prior knowledge and critical thinking could explain why they did not successfully attempt the question. Most (i.e., 60%) of the teachers solved the question by carrying out integration and correctly made reference to the greatest area under the graph; however, in the remaining cases, the respondents made reference to the slope of the graph, which was a pointless exercise. For this question, it can be inferred that 40% of the respondents had some degree of difficulty in interpreting change in velocity from an acceleration-time graph.

To answer this question, respondents should have the basic pre-requisites, as specified above, to be able to generate the correct answer and, more so, the correct explanation(s). An answer is tagged as false positive if a wrong explanation is given for a good answer (Hake, 1998) whereas a false negative refers to a valid statement for a wrong answer (Hestenes and Halloun, 1995).

An examples of false negative and false positive are illustrated below.

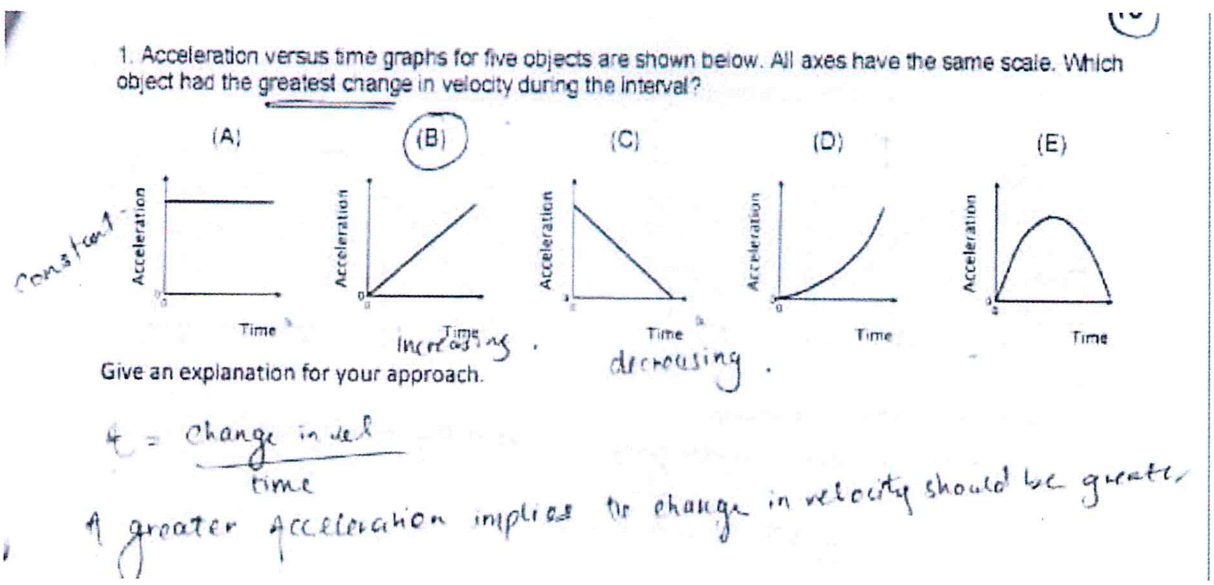


Figure 7: False negative

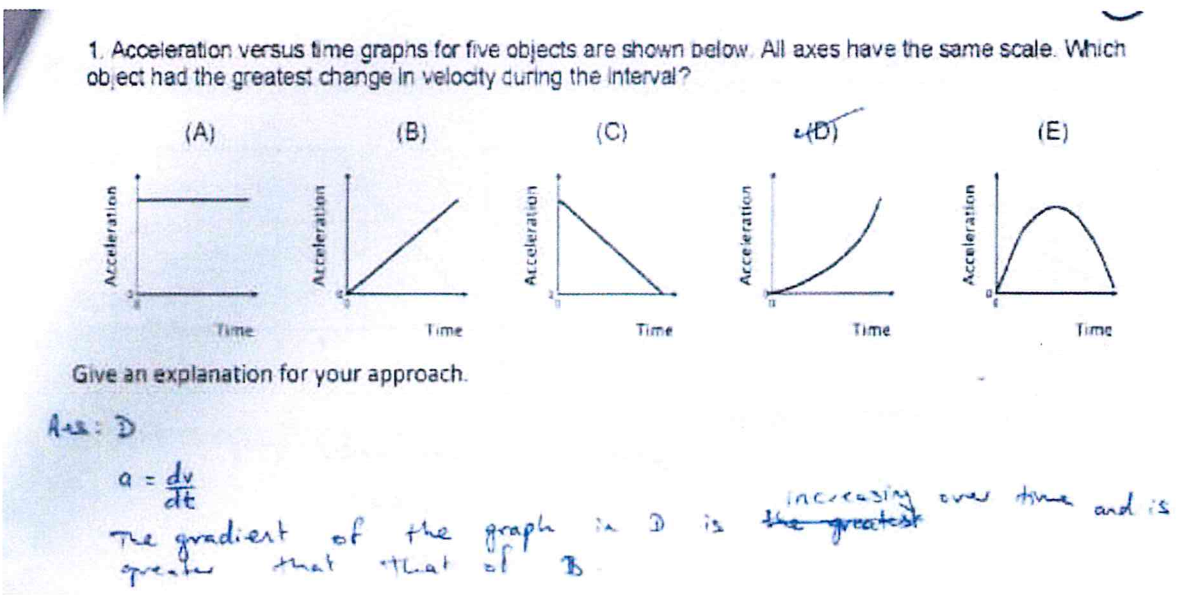


Figure 8: False negative

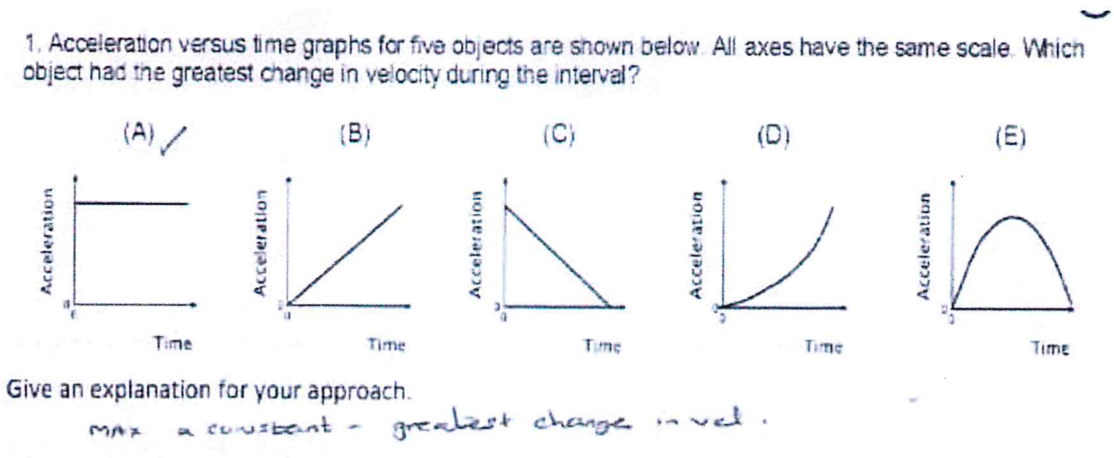


Figure 9: False positive

A teacher having a false negative tendency will not develop the content knowledge at all, not to say the conceptual understanding of the students. For example, in the above question, the teachers (see Figures 7 & 8 – False negative) used correct arguments (which is to some extent alien to the problem) but could not connect them to the correct graphical representations. The correct arguments display insufficient basics that would have enabled the teachers to make the required connections. Here, the concepts of dependent and independent variables as well as units would have added another perspective in the thinking process. Figure 9 illustrates a false positive case when the teacher obtained the correct answer using a spurious approach.

In this research study, false positive and false negative cases are considered to be sources of misconceptions.

Such a scenario can be associated with two types of problems, namely

- development of misconception in learners
- sustaining of misconceptions in the learners

The following section will illustrate the effect of teachers' misconceptions on students' understanding of physics concepts.

Teacher Effect on Students' Misconceptions

We consider one case to illustrate the influence of teachers' conceptual knowledge of physics on students. However, in the first instance, we provide a general overview of the performances of all the 29 teachers who participated in the second workshop.

Workshop 2 - General findings

In this section, we display the following results for the second questionnaire which comprised 10 items:

- teachers' responses (29 teachers who attended the 2nd workshop) showing in addition to the correct answer and justification, the false positive and true negative cases
- a selected teacher's (for convenience) response corrected with that of his students (34 in total)

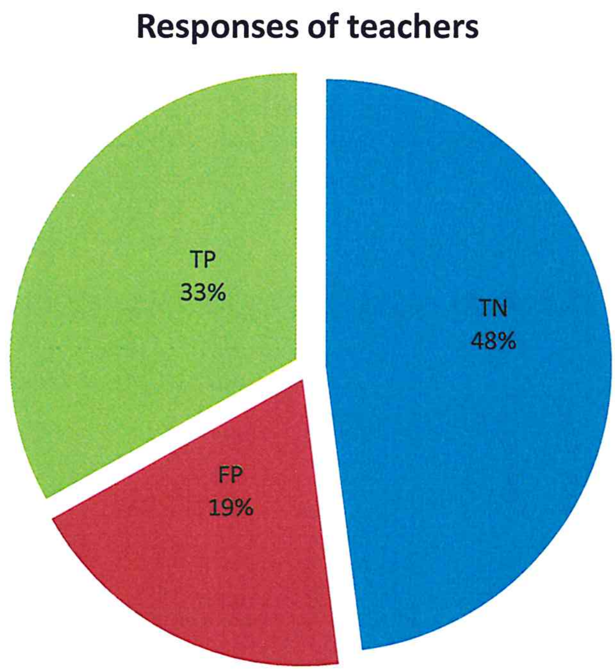


Figure 10: Teachers' performance

Figure 10 shows the overall performance of the 29 teachers who attempted the questionnaire (Appendix 3) in the second workshop. Around one third of the 290 possible answers have been identified as true positives. The majority of the responses were true negatives (48%) while 19% of the answers turned out to be false positives.

Figure 11 displays an overall representation of teachers' responses in each of the ten items categorised as true negative (TN), true positive (TP) and false positive (FP).

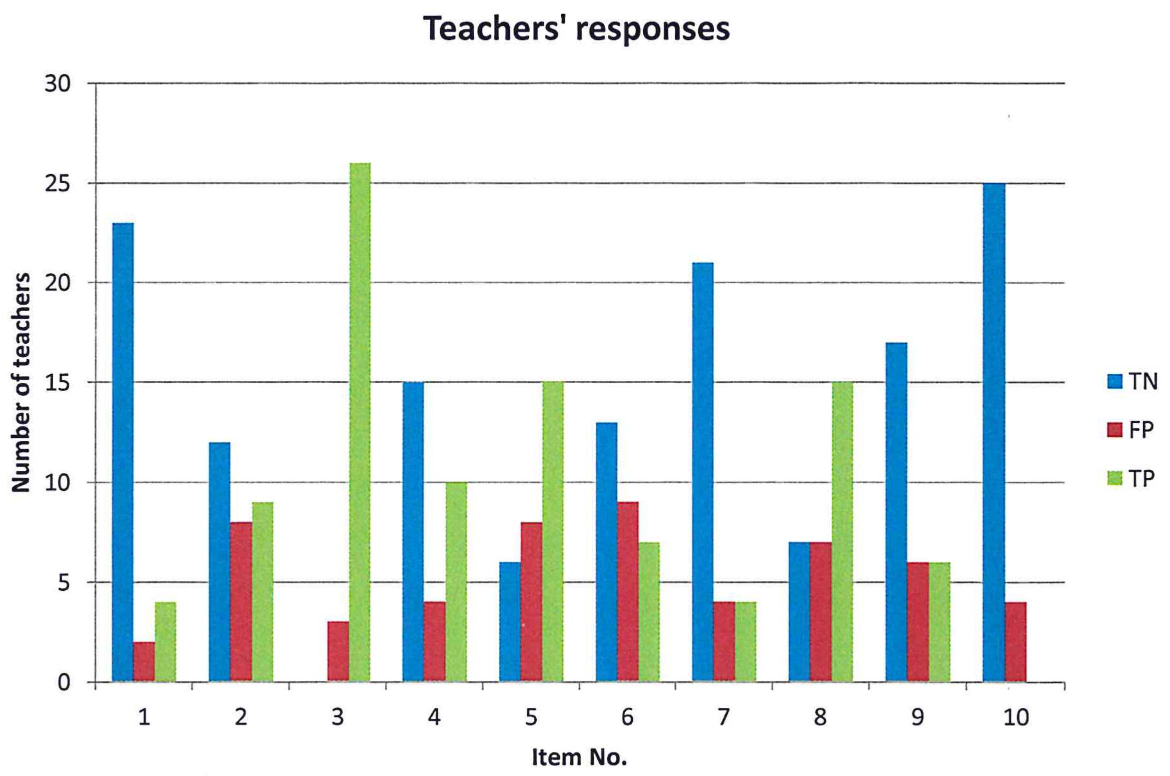


Figure 11: Teachers' responses from the 10 questions set

It should be emphasised that responses to item 3 were mostly correct answers. This was a very familiar question, however, for non-familiar items (Items No. 1, 7 and 10), which demanded substantial thinking (logical and critical), the outcomes were very poor.

Figures 12 & 13 offer some insight into the teacher's responses to items 1 and 10 respectively.

1. A force causes:

(a) Motion

(b) No change in the velocity of motion

(c) Neither (a), nor (b)

Explain: According to Newton's 1st law, every body will stay in a state of rest, [or continuous motion] unless an external force is acted upon it. So a force ~~and~~ causes motion and changes in the velocity either direction or magnitude

Figure 12: Questionnaire 2, Item 1

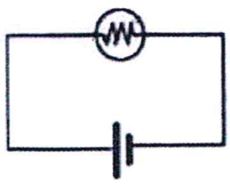
10. Is the electric field zero or non-zero inside the tungsten bulb filament?

(A) Zero because the filament is a conductor.

(B) Zero because there is a current flowing.

(C) Non-zero because the circuit is complete and a current is flowing.

(D) Non-zero because there are charges on the surface of the filament.



Explain: There is a flow of the charges.

Figure 13: Questionnaire 2 – Item 10

From the two items above, elements of misconceptions are apparent and the teacher's thinking is not rational. Though Newton's first law introduces the concept of force, it is the second that really accounts for its effect as a resultant force. Thus the 2nd law connects force and acceleration, instead of motion.

In Item 10, the teacher's response is a true negative as neither the answer is correct nor is the justification appropriate. In this case, reference should have been made to high and low potential.

Teacher-students correlation

This case study consisted of a class of 34 students. The physics teacher answered 7 out of the 10 questions correctly. However, 6 of them were false positives. Three answers were completely wrong (wrong answers, supported by incorrect justifications - see Table 3).

Table 3: Teacher's and students' data

		Number of students' responses		
Item No.	**Teacher's Response**	**TP**	**FP**	**TN**
1	TN	0	4	30
2	FP	0	6	28
3	TP	25	1	8
4	FP	2	5	27
5	FP	5	7	22
6	FP	0	10	24
7	TN	2	6	26
8	FP	4	11	19
9	FP	0	11	23
10	TN	1	5	28

TN – True Negative; FP – False Positive (misconception); TP – True Positive

Table 3 gives the distribution of the teacher's response in conjunction with the students' responses. For instance, for item 1, the teacher's answer was wrong (TN) and its implication on the students was that 30 students out of the 34 were not able to provide the correct answer (TN). In fact, from the justifications they provided there were no indication of meaningful thinking that would have oriented them towards the correct answer. The remaining 4 students gave the correct answer, but the justifications were discordant with the 'expert' view. An analysis of the implications of the teacher's responses is discussed below.

Correlation of teacher-students responses

The pie chart (Figure 14) below shows the proportion of the students' responses in conjunction with the teacher's response. 73% of correct students' responses were obtained for that particular question which was correctly answered by the teacher (Item 3). In this question, 24% of the responses from the students are associated with 'true negative', 3 % is associated with misconceptions and are referred to as 'false positive'. We believe that this misconception is well anchored into the prior knowledge of the students.

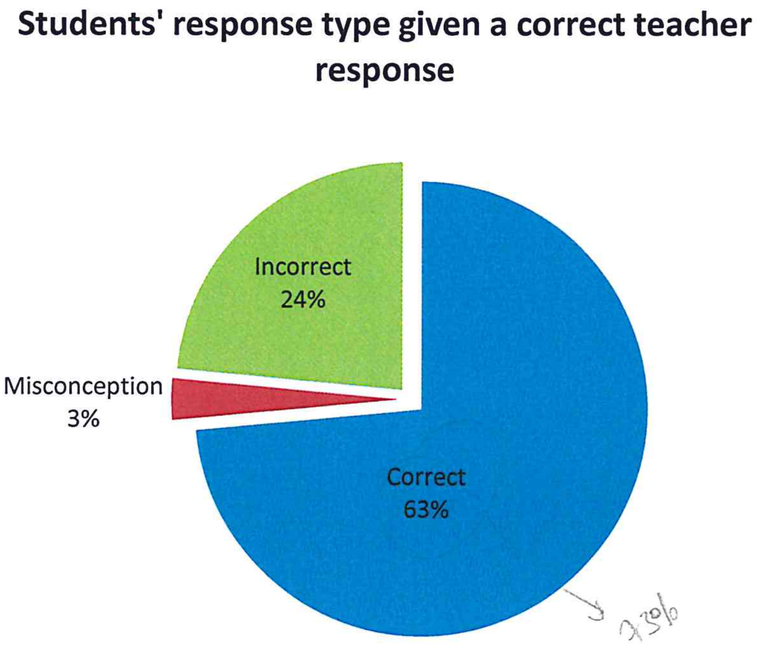


Figure 14: Students' responses from a correct teacher response

Figure 15 shows that 70% of the responses given by the students were incorrect in questions in which the teacher held misconceptions (Items 2, 4, 5, 6, 8 and 9). However, 25% of the responses from students showed misconceptions. It is most likely that the students' misconceptions have been triggered as a result of the teacher's misconceptions.

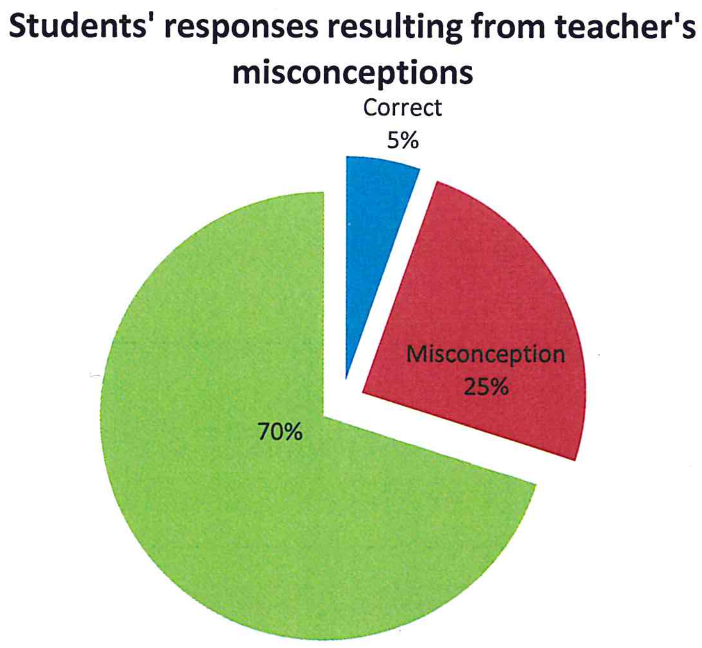
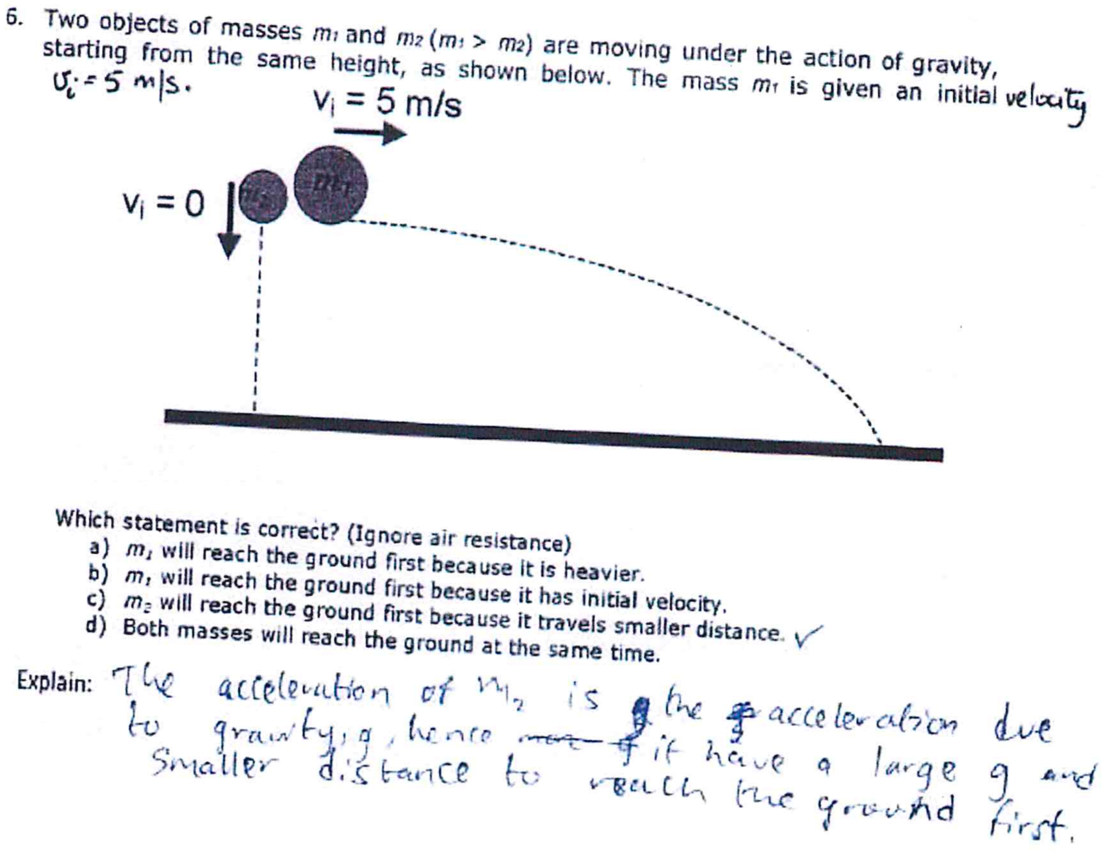


Figure 15: Students' responses

Some illustrations of the teacher's and students' misconceptions with reference to Item 6 are given below.



6. Two objects of masses m_1 and m_2 ($m_1 > m_2$) are moving under the action of gravity, starting from the same height, as shown below. The mass m_1 is given an initial velocity $v_i = 5$ m/s.

Which statement is correct? (Ignore air resistance)

a) m_1 will reach the ground first because it is heavier.
b) m_1 will reach the ground first because it has initial velocity.
c) m_2 will reach the ground first because it travels smaller distance. ✓
d) Both masses will reach the ground at the same time.

Explain: The acceleration of m_2 is the acceleration due to gravity, g, hence ~~m~~ it have a large g and smaller distance to reach the ground first.

Figure 16: A student's response

In Figure 16, the justification provided by the student clearly illustrates a particular situation of misconception acquired by the student. Though at School Certificate level, students have learnt that the acceleration of free fall is constant, this given student has certainly developed misconception in relation to acceleration of free fall as evidenced by his/her answer.

Other situations of teacher and students responses and misconceptions are illustrated below.

Teacher: Under constant acceleration, $v = u + at \Rightarrow t = \frac{v-u}{a}$. For both masses, a *are* the same and v and u are the same. u, a and v do not depend on mass.

Misconception: The argument should have been focussed at motion in two directions, the x- and y-components.

S3: m_1 has greater weight but has to travel a longer distance which will make it take longer time to reach the earth whereas m_2 has a shorter distance than m_1.

Misconception: Mass is confused with weight.

S6: As $m_1$is bigger and has a velocity of 5 m/s, the time for it to reach the ground will be the same for the mass m_2 as it is falling against gravity without a velocity and is of a smaller weight than m_1.

Misconception: Reference is wrongly made to masses. In this case, mass and velocity of one object is related proportionately to the mass and velocity of the other object.

S8: Both masses will reach the ground at the same time as the acceleration downwards is the same and they have to cover the same distance.

Misconception: Reference is wrongly made to covering the same distance, which could be vertical and horizontal.

S9: If air resistance is negligible, therefore the masses will not come into consideration. m_2 would have reached the ground first because it travelled a shorter distance but m_1 has initial velocity 5 m/s to catch up on the longer distance it has travelled.

Misconception: A wrong argument is used in relation to air resistance, mass and velocity. Again, *mass and velocity of one object is related proportionately to the mass and velocity of the other object.*

S11: Acceleration of a body in a given direction does not depend on its mass.

Misconception: The argument is flimsy as reference is made to acceleration, independent of mass. It is not clear whether reference is made to acceleration of free fall.

S12: m_2 travels a shorter distance but it has no initial velocity. m_1 is heavier but it has an initial velocity which makes it travel fast enough to reach rest position at the same time as m_1.

Misconception: Reference is wrongly made to their masses. Again mass and velocity of one object is related proportionately to the mass and velocity of the other object

S32: This is because of the acceleration due to gravity so they both will reach the ground at the same time.

Misconception: The argument about g is insufficient to claim that they both reach the ground at the same time.

The pie chart in Figure 17 shows the types of students' responses resulting from the incorrect answers of the teacher.

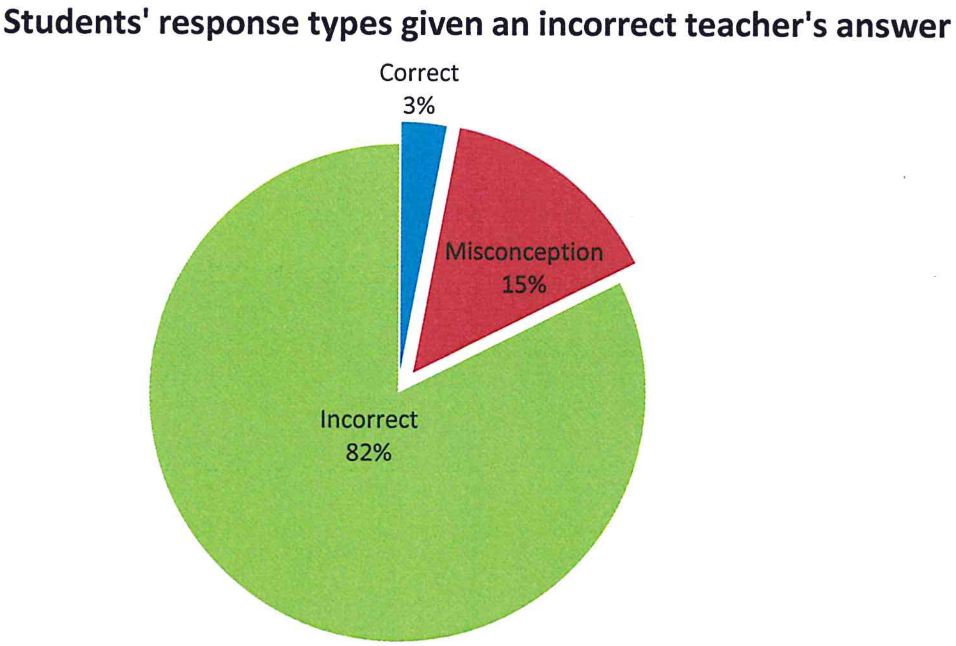


Figure 17: Students' responses and teacher's incorrect response

From Figure 17, it is observed that 82% of the answers provided by the students were incorrect. These are related to cases where the teacher also gave incorrect answers. Some misconceptions were also developed by the students.

Further analysis of Case Study (Test for independence)

A chi-square (χ^2) test at 5 % level of significance for independence confirms that the students' response is highly significantly dependent on the teacher's knowledge ($\chi^2 = 148.68, df = 4, p < 0.01$). The results of 9 follow-up post-hoc tests were carried out as shown in the Table 4. The Bonferroni correction implies the new alpha value is 0.05/9 = 0.0056.

Table 4: Test of independence

Test of independence ((H_0)	**Yates' χ^2 (df = 1)**	**p-value**	**Conclusion**
Students' correct responses v/s teacher's correct response	136.565	0	Reject (H_0)
Students' correct responses v/s teacher's misconceptions	17.09	0.00003565	Reject (H_0)
Students' correct responses v/s teacher's lack of knowledge	9.274	0.0023243	Reject (H_0)
Students' misconceptions v/s teacher's correct responses	5.434	0.01974839	Do not reject (H_0)
Students' misconceptions v/s teacher's misconceptions	7.678	0.00558981	
Students' misconceptions v/s teacher's lack of knowledge	1.655	0.19827977	Do not reject (H_0)
Students' lack of knowledge v/s teacher's correct responses	34.448	0	Reject (H_0)
Students' lack of knowledge v/s teacher's misconceptions	0.129	0.71947113	Do not reject (H_0)
Students' lack of knowledge v/s teacher's lack of knowledge	11.089	0.00086841	Reject (H_0)

For p-value < 0.05, test for independence is rejected.

Main observations:

1. Students' ability to give correct responses or not significantly depends on whether the teacher has the correct answer, or harbours misconceptions or does not know the correct answer.

2. At this point, it is not conclusive how significant teacher's misconceptions are transferred to the students. However, there is significant evidence to suggest that whether students develop misconceptions or not depends upon teacher's knowledge.

Correlation between teacher's responses and students' (Phi coefficient of association):

1. There is a strong positive correlation between teacher's incorrect answers and students' incorrect answers($\emptyset = 0.65$).
2. There is a weak but positive correlation between teacher's misconceptions and students' inability to give correct answers ($\emptyset = 0.23$).
3. There is a weak (negative) correlation between teacher's incorrect responses and students' correct answers($\emptyset = -0.18$).
4. There is a weak correlation between teachers' misconception and students' misconceptions($\emptyset = 0.16$).

THE CPP INTERACTIVE WEBSITE

One of the objectives of this research project was to develop an interactive website to help both physics teachers and students with a view to improving the teaching and learning of physics at upper secondary level.

Testing of prior knowledge

Students' Platform

In a traditional classroom, testing of prior knowledge is rarely carried out, and if it done, it is effected through the use of close-ended questions. Figure 18 illustrates a task undertaken by students at home in collaboration with parents, in the form of 'testing of prior knowledge'. At primary level, parents are very much involved in the education of their children but parental involvement fades away at the secondary level. It is not expected that parents should be knowledgeable about the content; what is required is the parents' support in the education of their children. In Figure 18, the students are expected to carry out a simple activity together with their parents on the concept of measurement (School Certificate level).

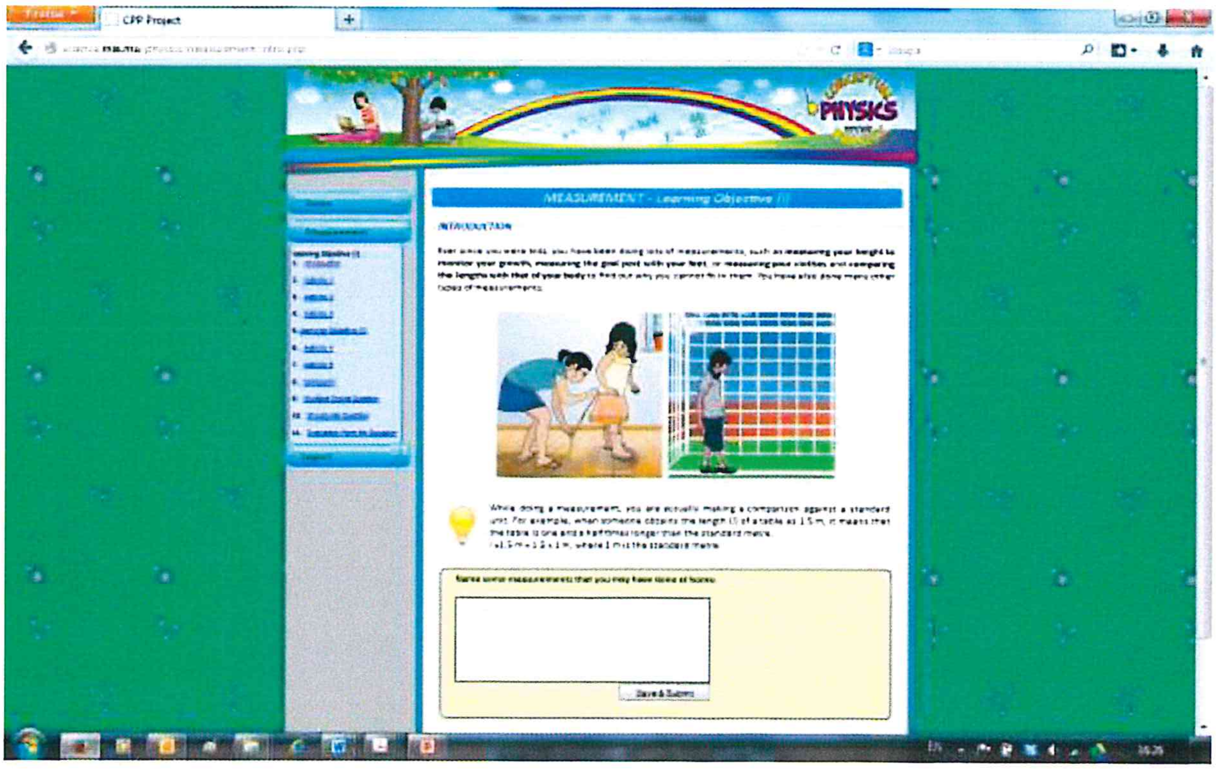


Figure 18: Home activity – Testing of prior knowledge

Such collaborative endeavour between parents and children is seen from different perspectives. Most importantly, parents' engagement in the education of their children can support the work of the teacher (Pitt, Luger, Bullen & Philips, 2013). Somehow, discussion between the parent and his/her child can put the latter in a state of cognitive dissonance, but which the teacher can make use of, in order to identify areas of misconceptions in the learners.

Students are engaged in knowledge construction, and formative assessment forms an integral part of the learning process (see Figure 19).

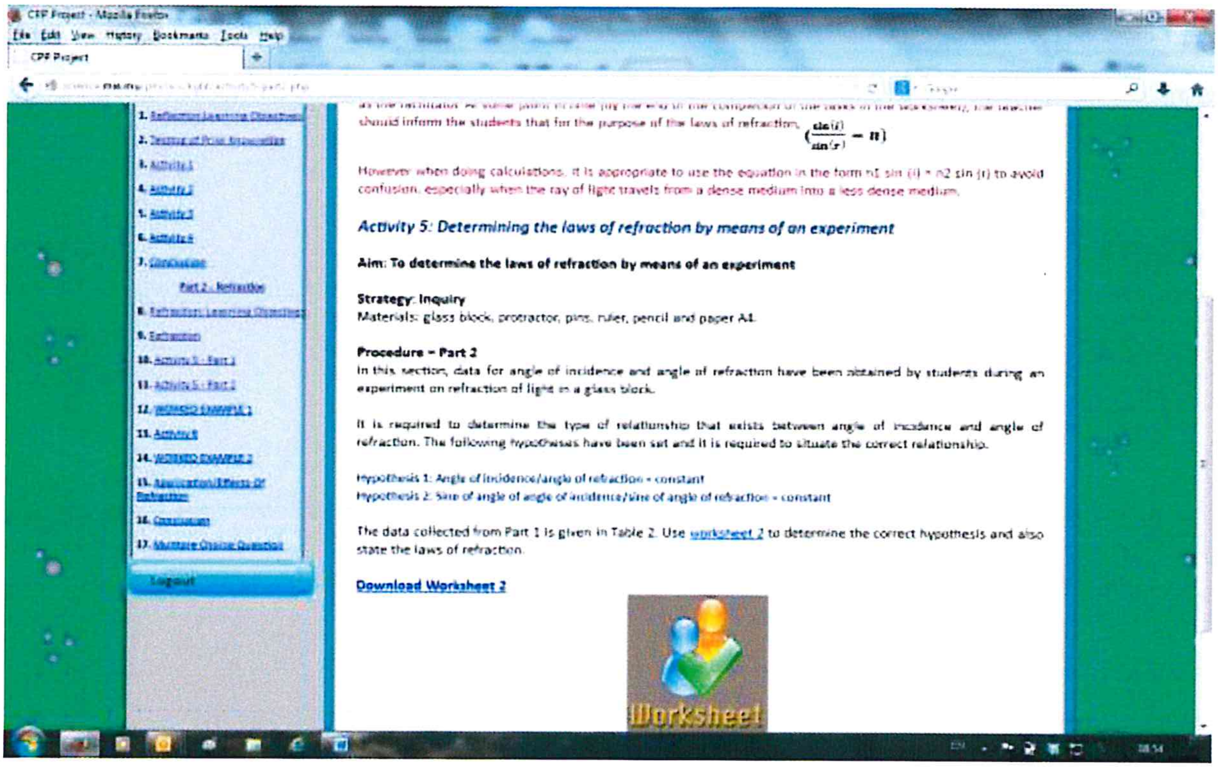


Figure 19: Formative Assessment

Figure 19 illustrates how a lesson can be conceptualised so that students can derive a particular law by being engaged in an activity and then apply the law in particular contexts. As is the practice, the laws of refraction of light (Figure 19) are first learnt through the expository method. The students rote learn the laws and then solve numerical problems. Research has shown that the teacher centered approach favours the development of misconceptions in learners.

Addressing misconceptions

In this novel approach, the learners formulate the laws of refraction of light in the first instance in an experiment while working in groups. They attempt a number of activities related to the concept and their responses are saved in the database which the teacher can use to initiate further discussions, either in class or on the discussion forum. These types of interactions help the learners to situate their misconceptions and by being engaged in this cognitive dissonance process, their misconceptions can be addressed.

It happens that when a new concept is learnt, the students have the opportunity to review earlier concepts learnt by use of the 'mouse over' – see Figure 20. As such, the students are led to maintain consistency over concepts learnt earlier, thus preventing them from developing misconceptions. In addition, interactive Flash files offer students the opportunity to challenge their pre-existing conceptions.

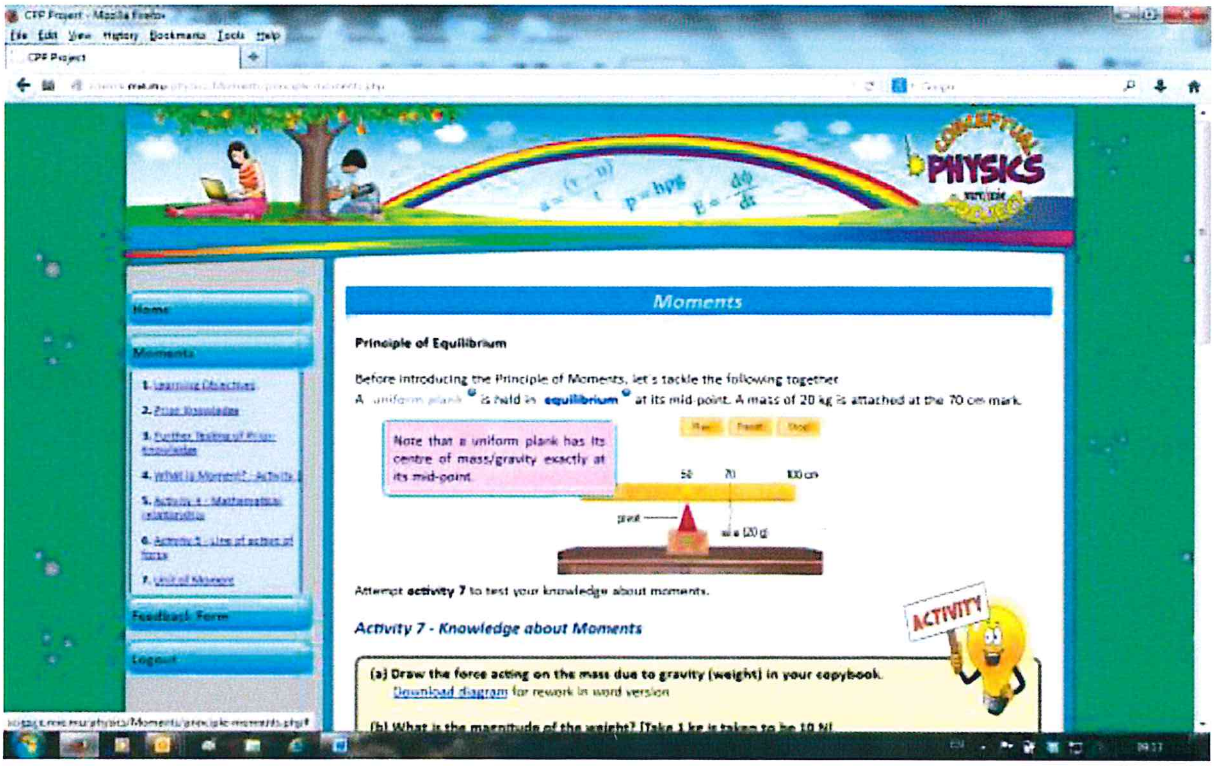


Figure 20: Mouse over

Students can attempt the MCQs and structured questions and eventually view their results at a later stage in the form of a summative assessment (refer to Figure 21). The website is designed in such a way that records of all the results are kept in a database so that teachers can use them to build formative and diagnostic assessments for future lessons and also use the information with the aim to offering appropriate support to the students.

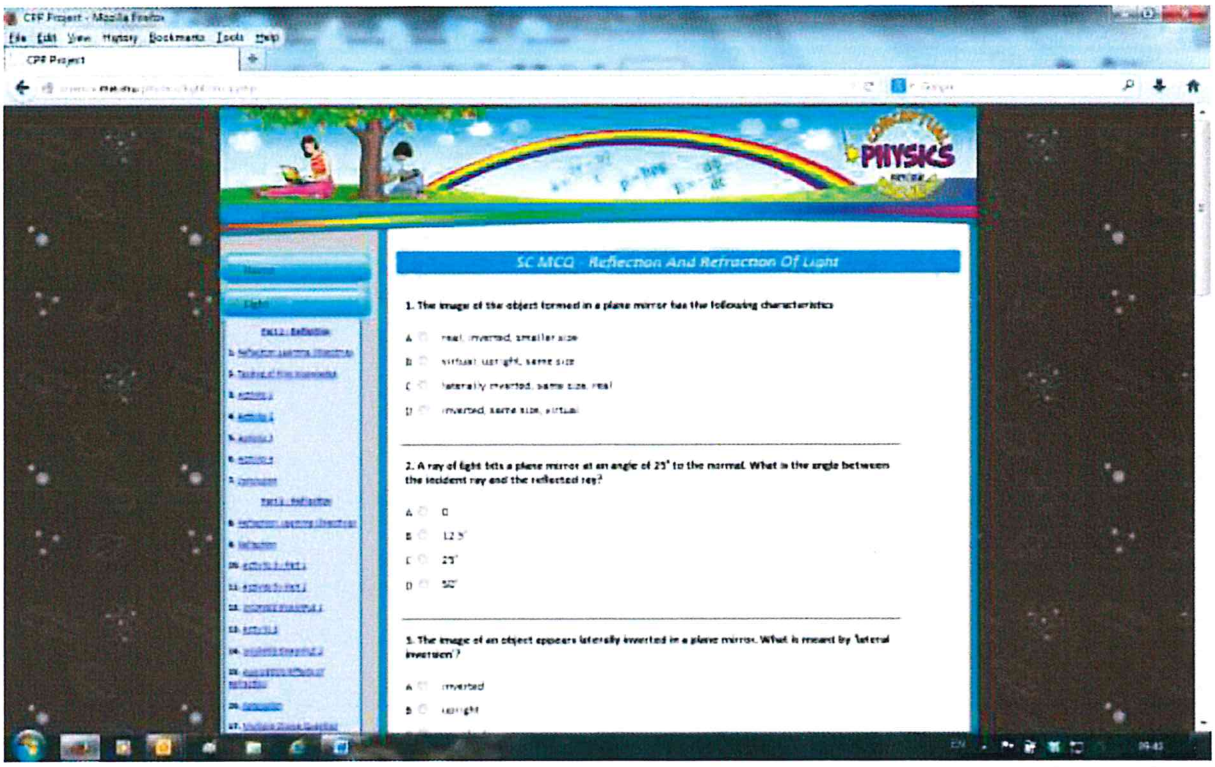


Figure 21: Multiple Choice Questions

Parents' Platform

Figures 22 & 23 showcase the platform that parents can use to interact with the teacher. All the data which have been 'saved and submitted' can be accessed by the teacher from the database. Through this means the teacher can plan his/her lessons in such a way so as to address the difficulties of the students. Parents, though having limited access, do have access to the lessons and can therefore monitor the performance of their children.

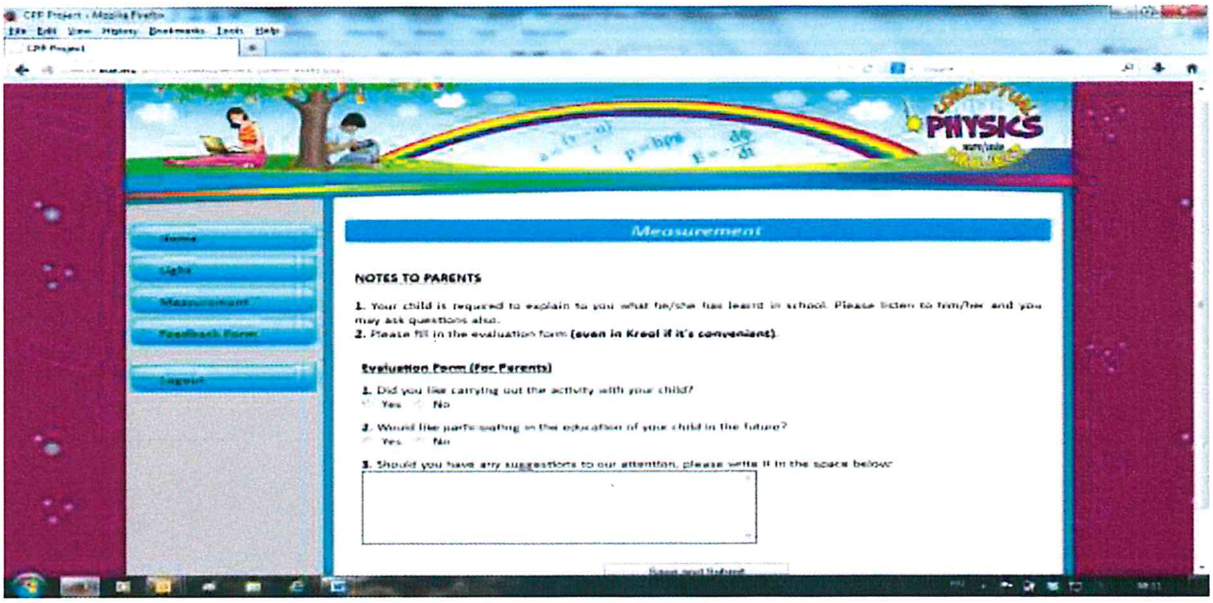


Figure 22: Platform for parents

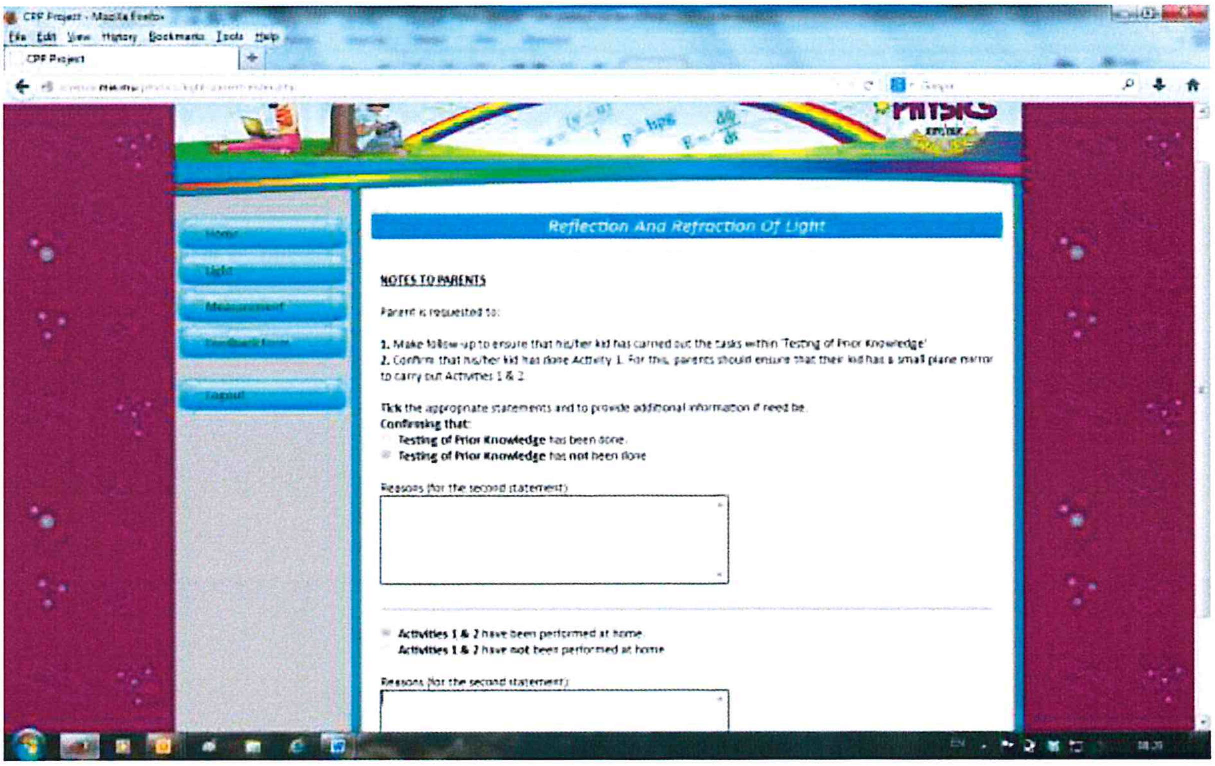


Figure 23: Notes to parents

Teachers' Platform

Teachers have the administrative right to register students and parents on the platform.

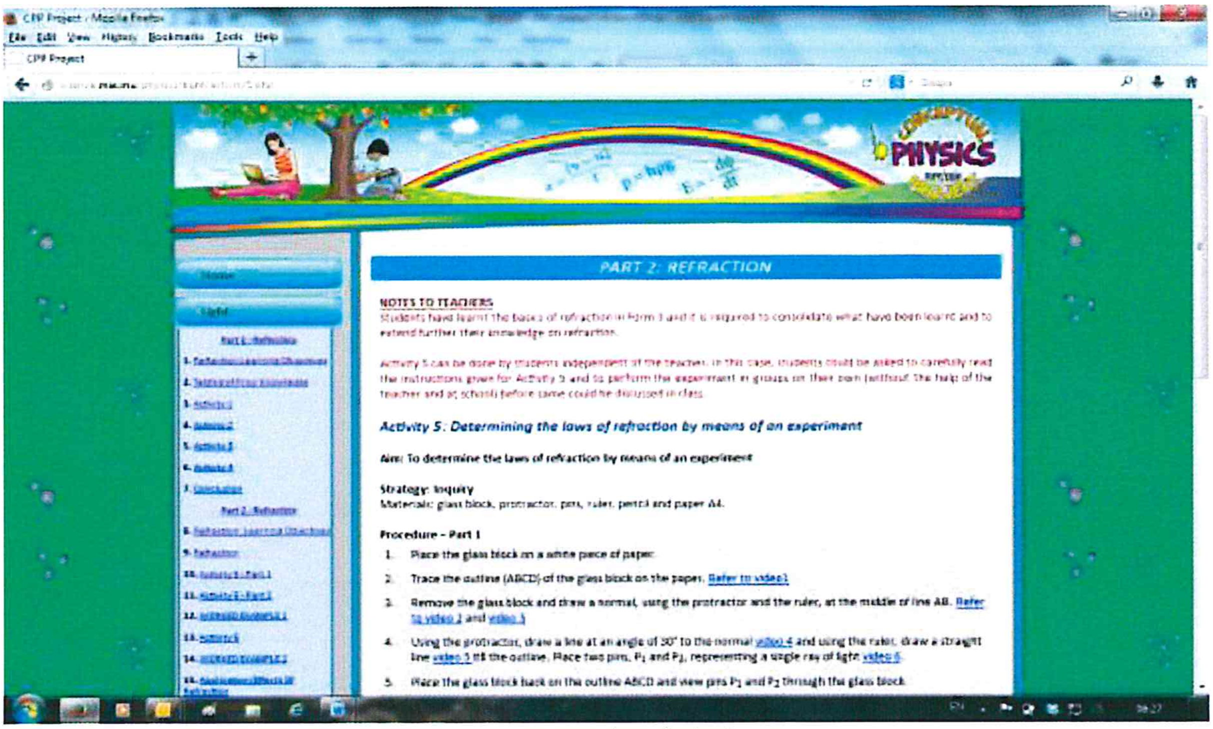


Figure 24: Teachers' platform

The Research Team, in addition to developing the physics lesson, has set instructions to teachers to guide them in the process of their teaching (see Figures 24 & 25). At the same time, teachers can create topics for the discussion forum (see Figure 26).

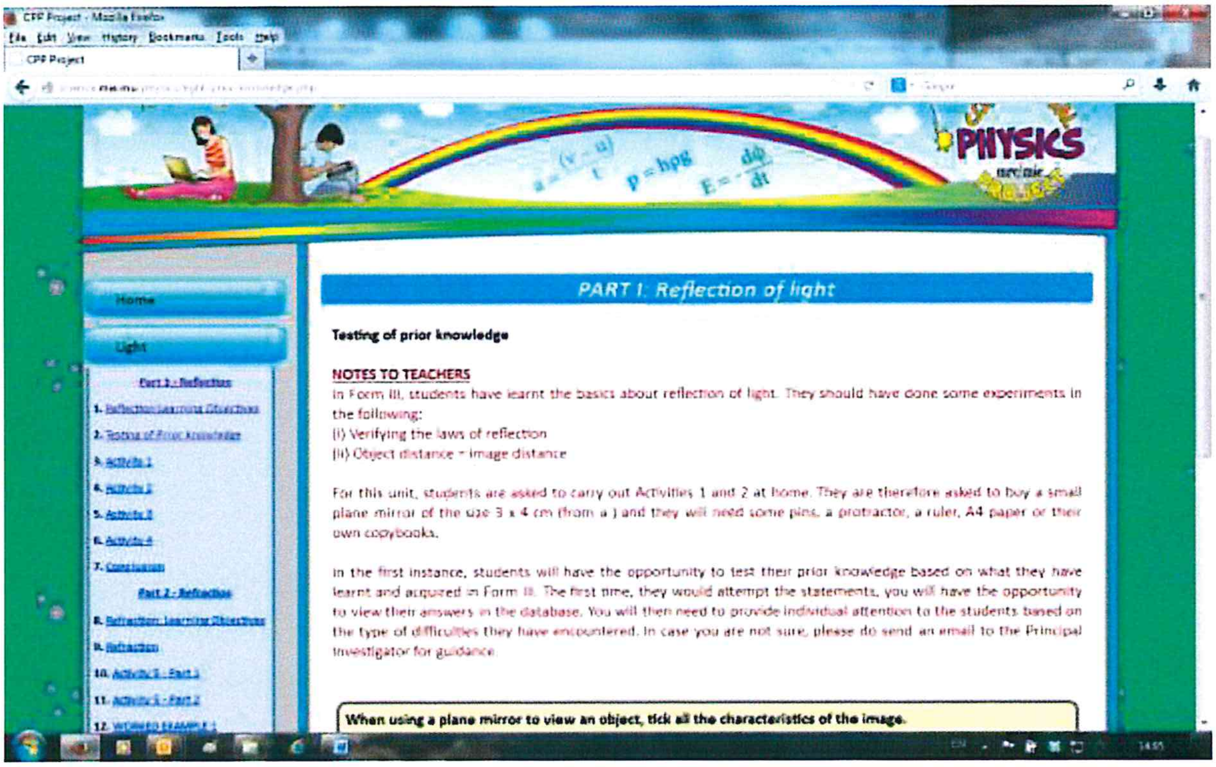


Figure 25: Teachers' platform – instructions

This discussion forum will appear on the students' platform and the latter can interact while the teacher monitors the activity.

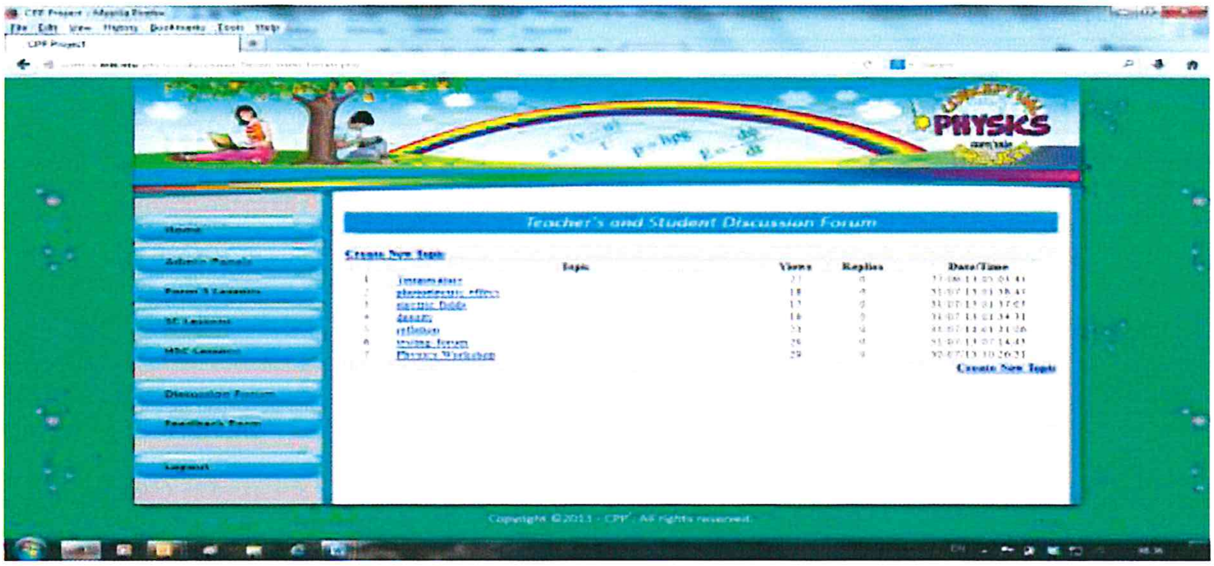


Figure 26: Discussion forum

A feedback section is available on the website, where teachers, students and parents can send their comments and suggestions to the Research Team with a view to improving the website.

Appendix 4 provides additional information on how to access the website and the various sections.

RECOMMENDATIONS

This study spanned over two years, involving physics educators, students and parents to build a synergy, thus enhancing the learning experience of the students. Ensuing the project, the following sets of recommendations are made for the successful implementation of such a novel approach:

- Physics educators should not limit themselves to a one-off pedagogical training, but should instead be engaged in continuous professional development courses spread over their entire career. The identification and dispelling of misconceptions is a lifelong process of interactions and feedback. The Mauritius Institute of Education, as the sole public teacher education institution, will have to offer such types of training on a regular basis.

- Appropriate training for the effective integration of technology in teaching and learning should form part of teacher education programmes for educators.

- Although we understand that students are preoccupied with academic performance, they should reduce reliance on rote learning and shift to a learner centered approach to knowledge construction and development of skills.

- The role of parents in the education of their children is an important aspect of the learning process. The three stakeholders (parents, students and teachers) should make an effort to embark on a collaborative venture where everyone is a winner.

- The CPP website, although contextualised for the Mauritian students, teachers and parents, is a pedagogical platform and thus a dynamic tool. To meet the changing needs of the stakeholders, the website requires continuous improvement and updating. The Mauritius Institute of Education in collaboration with its partner, the University of Technology, can facilitate this process.

- The Mauritius Institute of Education, in collaboration with the Ministry of Education and Human Resources, can provide the appropriate facilities to sustain the website in addition to developing such types of interactive physics lessons for the whole curriculum of the lower and upper secondary levels.

- A longitudinal study on conceptual understanding of physics will have to be undertaken by the Mauritius Institute of Education with the support of relevant partners to further probe into misconceptions on a larger scale, using the CPP website.

CONCLUSION

Technology has become an integral part in the teaching-learning process. However, while important investments are being made to equip schools with technology-related facilities such as interactive whiteboard, Wi-Fi, etc., little attention is being paid to (i) the use of technology as a pedagogical medium in the teaching and learning process, and (ii) the provision of adequate professional development to empower teachers to use technology for effective teaching.

The aims of this research-based project were to:

(i) identify the various misconceptions that physics teachers hold in physics at School Certificate and Higher School Certificate levels;

(ii) identify the misconceptions that students have and the eventual consequences of these misconceptions on the learning of related concepts;

(iii) carry out a literature search at the national and international levels concerning similar type of misconceptions; and

(iv) develop interactive pedagogical technology-based conceptual physics lessons to address the problem.

The research has enabled the Team to attest that physics teachers have misconceptions on certain key physics concepts. While conducting workshops for educators, a number of misconceptions (false positive cases and true negative cases) have been identified in selected physics concepts among the sample of teachers. In the first workshop, pre-test and post-test questionnaires were also administered. A significant positive impact on the teachers' subject content knowledge as well pedagogical content knowledge was noted after the workshop. From the case study of a teacher who participated in the second workshop, sufficient evidence of the influence of the teacher's lack of conceptual understanding in selected physics concepts was seen to affect students' understanding. The true negative responses (incorrect answers and wrong statements) and false positive ones often result in true negative responses from the students.

Moreover, one of our research objectives was to develop interactive technology-based conceptual physics lessons for knowledge construction by learners. The learning contents of the interactive web-based physics lessons were motivated from the literature search that we carried out at the national and international levels on the types of misconceptions teachers and students generally have in physics. An interactive aspect of the lesson was to incorporate the affective dimension, creating a platform where parents, students and parents are involved at various levels of the teaching-learning process. Home activities were proposed in such a way so that students can carry them out as prior work at home, with the support (or under the supervision) of parents. The prior works were saved in a database which could subsequently be accessed by the teacher to identify learning difficulties and misconceptions developed by students, if any. The identified difficulties and misconceptions were then taken during discussions by the teacher in the course the lessons delivery. Formative and summative assessments were also provided to engage the students in their learning. Multiple choice questions and structured questions were made available as assessment tools. The responses of the students were saved in the database for future reference for all parties concerned. Provision was also made to enable the creation of discussion forums among the three stakeholders.

LIMITATIONS

This research has been conducted with the participation of 29 physics educators from fifteen secondary schools (our convenient sample) across the Republic of Mauritius. While the findings have thrown light onto those misconceptions held by the sample teachers, which impinge on students' conceptual development (from our case study), care should be taken as to the generalisation of these findings. The sample is small, representing at most 6% of the population of physics teachers. However, the study, the first of its kind, has provided insightful data regarding teachers' and students' misconception in physics. While it is not a longitudinal study, our findings from the two year collaboration can be aligned with findings from international research.

Limited parental participation was observed for various reasons. However, the data that were obtained from a few participating parents were encouraging. We were able to identify the engagement of students at home. At times, parents were acting as collaborators and at others, they were acting as support.

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APPENDIX 1

Dear Educators,

As you are aware, we are currently working on a research project 'Conceptual Physics Project' funded by the Mauritius Research Council. This project aims at improving the teaching and learning of physics in our secondary schools.

You are kindly requested to complete this questionnaire on kinematics for 1 hour. It is important that you provide justifications (even for a straight forward answer) to all your responses.

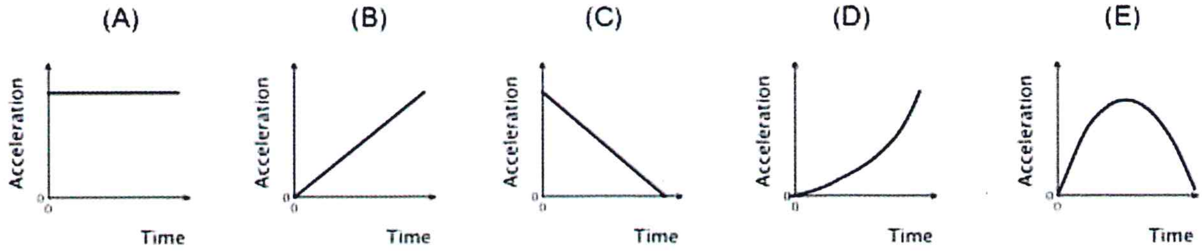
This is the first step of the capacity training workshop.

All information obtained will be dealt with in strict confidentiality.

Thanking you.

Dr Y Ramma
Principal Investigator
Mauritius Institute of Education
06 December 2011

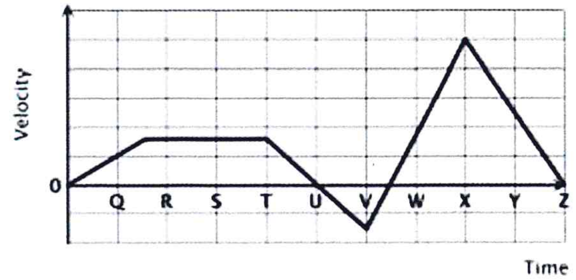
1. Acceleration versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest change in velocity during the interval?



Give an explanation for your approach.

2. The following figure shows the velocity versus time graph of an object. Which of the following options corresponds to the case when its acceleration is the most negative?

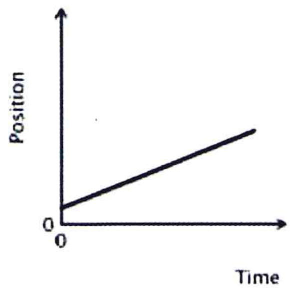
A) V to X
B) T to V
C) V
D) X
E) X to Z



Give an explanation for your approach.

3.To the right is a position versus time graph of an object´s motion. Which sentence is the best interpretation?

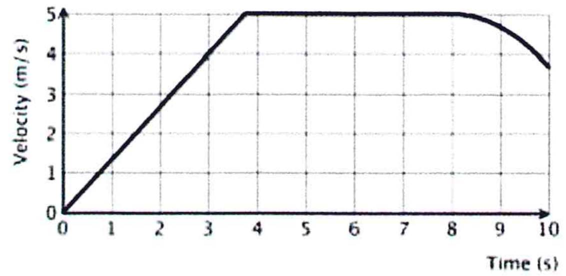
A) The object is moving with a constant, non-zero acceleration.
B) The object does not move.
C) The object is moving with a uniformly increasing velocity.
D) The object is moving at a constant velocity
E) The object is moving with a uniformly increasing acceleration.



Give an explanation for your approach.

4. An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below. How far does it move during the first three seconds of motion?

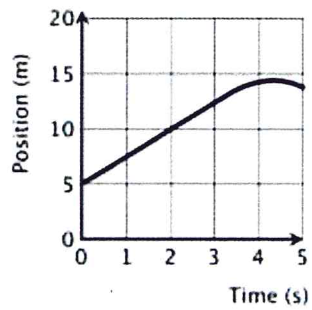
A) 0.75 m
B) 1.33 m
C) 4.0 m
D) 6.0 m
E) 12.0 m



Give an explanation for your approach.

5. The following figure shows the position versus time graph of an object. The velocity of the object at t = 2 s is:

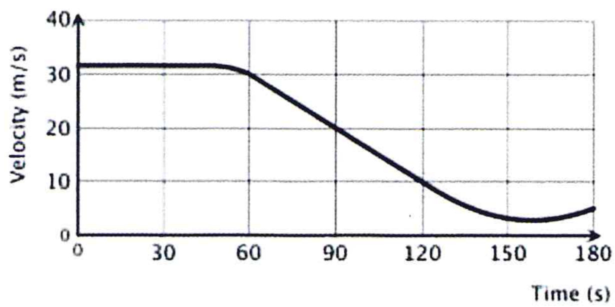
A) 0.5 m/s
B) 8.5 m/s
C) 2.5 m/s
D) 5.0 m/s
E) 10.0 m/s



Give an explanation for your approach.

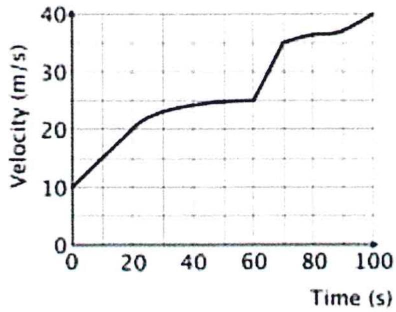
6. The graph below shows the velocity as a function of time for a car of mass 1.5×10^3 kg. What was the acceleration at t = 90 s?

A) -0.22 m/s^2
B) -0.33 m/s^2
C) -1.0 m/s^2
D) -2.0 m/s^2
E) 20 m/s^2



Give an explanation for your approach.

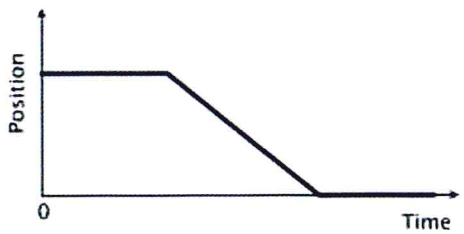
7. The graph shows the velocity as a function of time for an object that is moving in a straight line. At t = 65 s the instantaneous acceleration of the object was most nearly:



A) 1.0 m/s^2
B) 2.0 m/s^2
C) 0.46 m/s^2
D) 30 m/s^2
E) 34 m/s^2

Give an explanation for your approach.

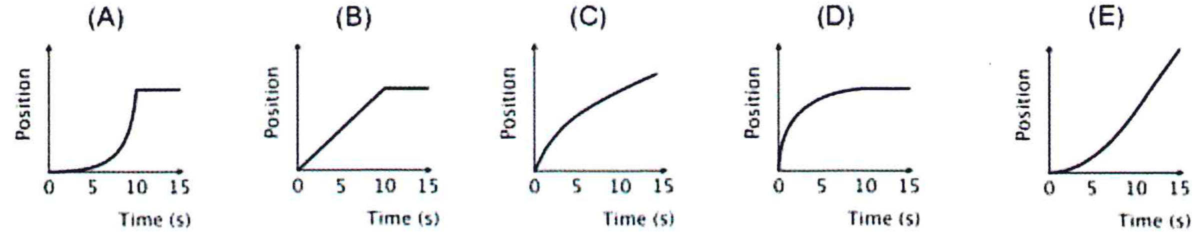
8. The following graph shows the position versus time graph of an object's motion. Which sentence is a correct interpretation?



A) The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops.
B) The object doesn't move at first. Then it rolls forward down a hill, and finally stops.
C) The object is moving at a constant velocity. Then it slows down and stops.
D) The object doesn't move at first. Then it moves backwards, and then finally stops.
E) The object moves along a flat area, moves backwards down a hill, and then it keeps moving.

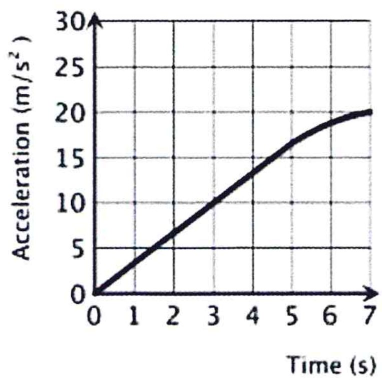
Give an explanation for your approach

9. An object starts from rest and undergoes a positive, constant acceleration for ten seconds, it then continues on with constant velocity. Which of the following graphs correctly describes this situation?



Give an explanation for your approach.

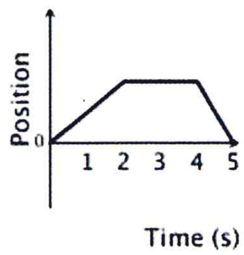
10. The following is an acceleration versus time graph of an object. If you would like to use the graph to know the object's change in velocity during the interval from $t = 0$ s to $t = 3$ s, what would you do?

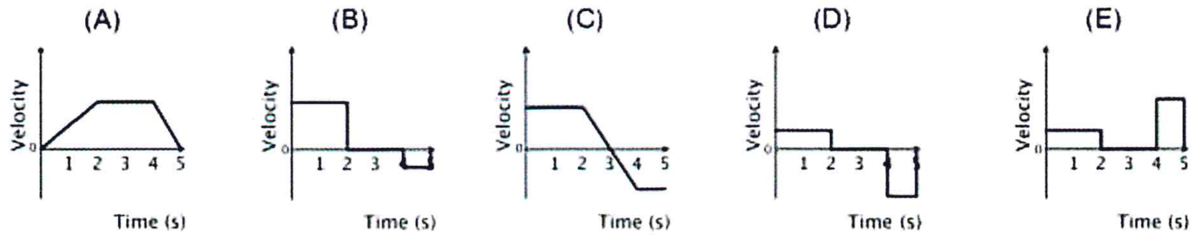


A) Find the area between that line segment and the time axis by calculating (10x3)/2.
B) Find the slope of that line segment by dividing 10 by 3.
C) Read 10 directly off the vertical axis.
D) Find the value by dividing 3 by 10.
E) Find the value by multiplying 10 by 3.

Give an explanation for your approach.

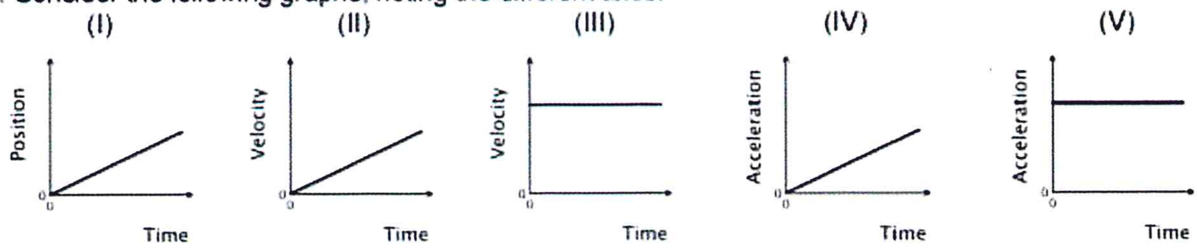
11. The figure to the right represents the position versus time of an object's motion during a 5 s time interval. Which of the following graphs of velocity versus time would best represent the object's motion during the same interval?





Give an explanation for your approach (next page).

12. Consider the following graphs, noting the different axes:



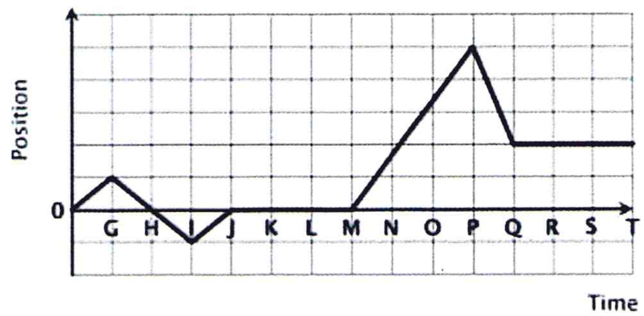
Which of these represent(s) motion at constant velocity?

A) I, II and IV
B) I and III
C) III only
D) III and V
E) I, III and V

Give an explanation for your approach.

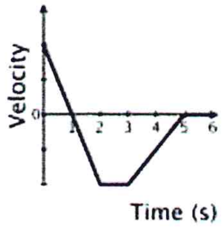
13. The graph shows the position versus time of an object moving in a straight line. Which of the following options corresponds to the case when its velocity is the most negative?

A) P to Q
B) I
C) M to P
D) G to I
E) P

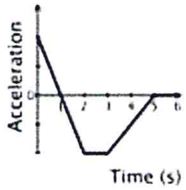


Give an explanation for your approach.

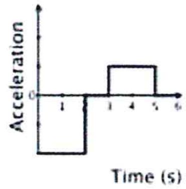
14. The figure to the right represents the velocity versus time graph of an object´s motion during a 6 s time interval. Which of the following graphs of acceleration versus time would best represent the object's motion during the same interval?



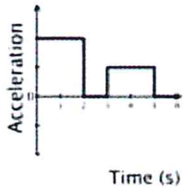
(A)



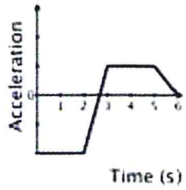
(B)



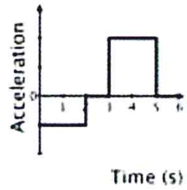
(C)



(D)

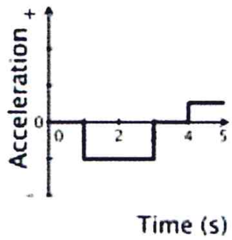


(E)

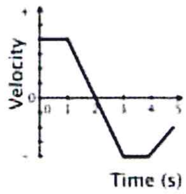


Give an explanation for your approach.

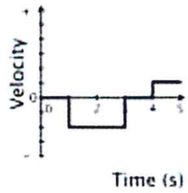
15. The graph on the right represents the acceleration of an object during a 5 s time interval. Which of the following graphs of velocity versus time would best represent the object´s motion during the same time interval?



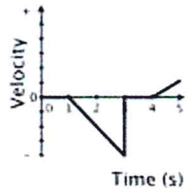
(A)



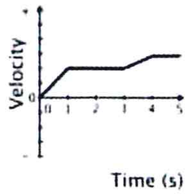
(B)



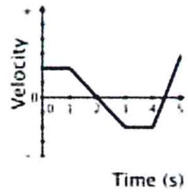
(C)



(D)



(E)



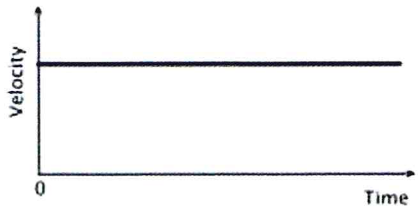
Give an explanation for your approach.

16. An object moves according to the acceleration versus time graph below. The change in velocity of the object in the first three seconds of motion was:

A) 1.5 m/s
B) 0.67 m/s
C) 2.0 m/s
D) 3.0 m/s
E) 6.0 m/s

Give an explanation for your approach.

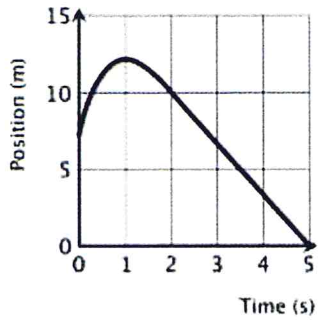
17 . The graph to the right shows the velocity of an object moving in a straight line. Which sentence is the best interpretation?



A) The object is moving with a uniformly increasing position.
B) The object's position is constant.
C) The object is moving with a uniformly increasing acceleration.
D) The object is moving with a constant, non-zero acceleration.
E) The object is moving with a uniformly increasing velocity.

Give an explanation for your approach.

18. The figure to the right shows the position as function of time for an object. The velocity of the object at t = 3 s is about:

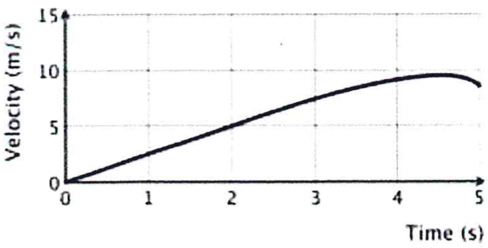


A) -3.3 m/s
B) -2.0 m/s
C) -0.67 m/s
D) -2.3 m/s
E) 7.0 m/s

Give an explanation for your approach.

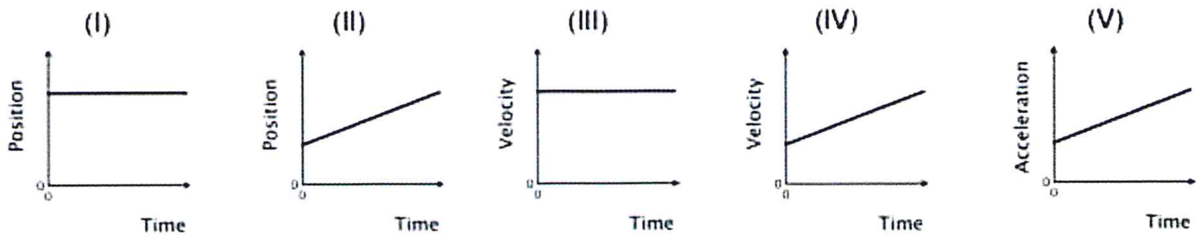
19. The graph below represents the velocity versus time graph of an object. If you wanted to know the change in position of the object during the interval from t = 0 s to t = 2 s, from the graph you would:

A) read 5 directly off the vertical axis.
B) find the area between that line segment and the time axis by calculating (5x2)/2.
C) find the slope of that line segment by dividing 5 by 2.
D) find the value of the distance by multiplying 5 by 2.
E) find the value by dividing 2 by 5.



Give an explanation for your approach.

20. Consider the following graphs, noting the different axes:

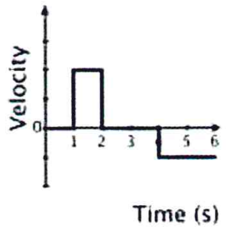


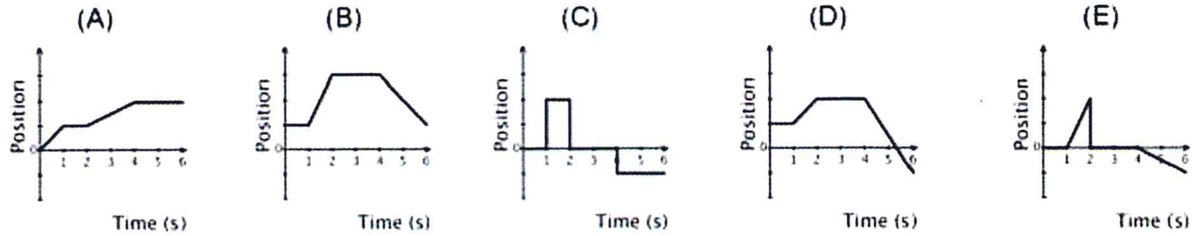
Which of these represent(s) the object's motion with an acceleration that increases uniformly?

A) II and III
B) IV and V
C) V only
D) II, IV and V
E) IV only

Give an explanation for your approach.

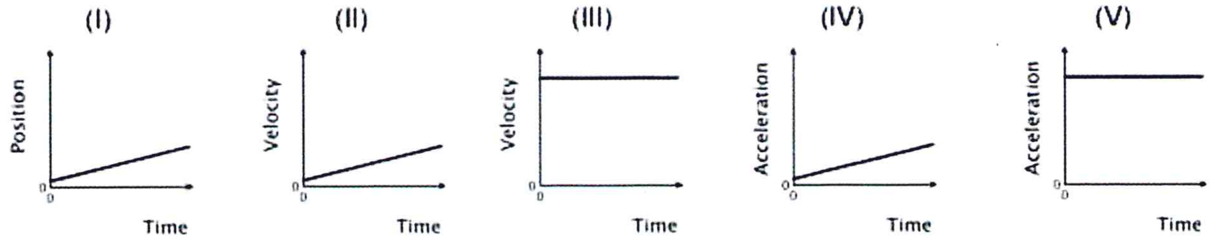
21. The graph to the right represents the velocity of an object during a 6 s time interval. Which of the following graphs of position versus time would best represent the object's motion during the same interval?





Give an explanation for your approach.

22. Consider the following graphs, noting the different axis:

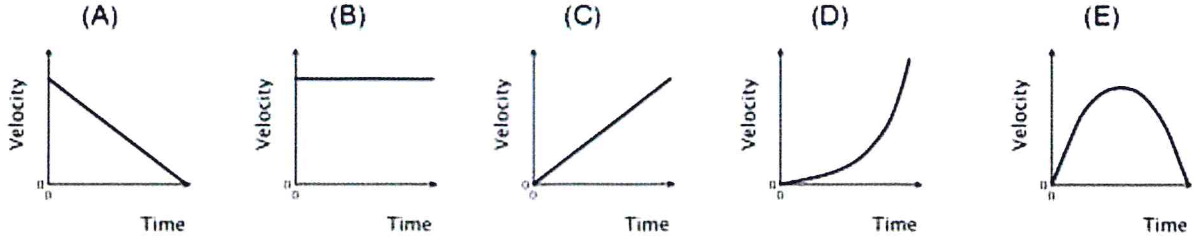


Which of these represent(s) the object´s motion with a constant, non-zero acceleration?

A) I, II and IV
B) V only
C) II and V
D) IV only
E) III and V

Give an explanation for your approach.

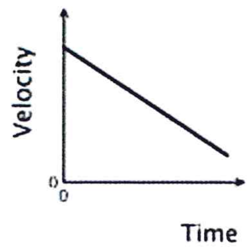
23. Velocity versus time graphs for five objects are shown below. All axes have the same scale. Which object had the greatest displacement during the interval?



Give an explanation for your approach.

24. The graph to the right represents the velocity of an object's motion. Which sentence is the best interpretation?

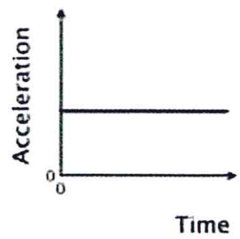
A) The object is moving with a constant acceleration.
B) The object is moving with a uniformly decreasing acceleration.
C) The object is moving with a uniformly increasing velocity.
D) The object is moving at a constant velocity.
E) The object does not move.



Give an explanation for your approach.

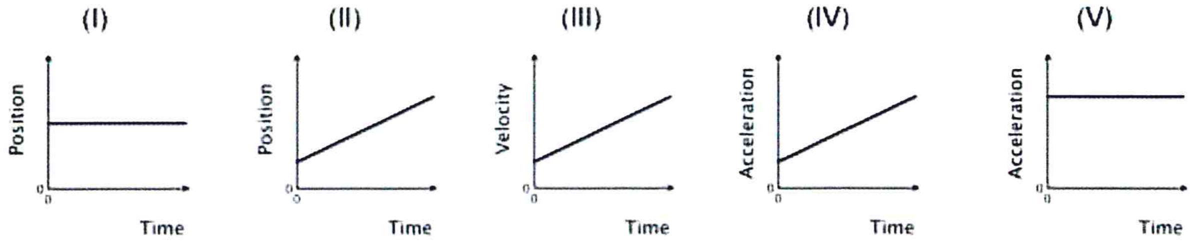
25. The graph to the right represents the acceleration as a function of time for a moving object. Which sentence is the best interpretation?

A) The object is moving with a uniformly increasing acceleration.
B) The object does not move.
C) The object is moving with a uniformly increasing velocity.
D) The object is moving at a constant velocity.
E) The object is moving with a uniformly increasing position.



Give an explanation for your approach.

26. Consider the following graphs, noting the different axis:



Which of these represent(s) the object´s motion with a uniformly increasing velocity?

A) II only
B) III and V
C) IV only
D) II, III and IV
E) III only

Give an explanation for your approach.

APPENDIX 1.1

Wilcoxon Signed Rank Test

The Wilcoxon signed test is a nonparametric test designed to evaluate the difference between two treatments or conditions where the samples are correlated. In this case, the two corrected conditions are the pre-test and post-test scores of the participants in the workshops. 17 participants filled both the pre-test and post-test questionnaires, out of which 3 paired values were identical, that is, the difference score was zero. These three cases were discarded from the analysis as per the test procedure so that the sample size, N, was reduced to 14.

The hypothesis of the test is as follows:

Null hypothesis (H_0): The medians of the two samples are identical.

Alternative hypothesis (H_1): The median of the pre-test is less than the median of the post-test.

Result Details

Test statistics: Sum of positive ranks (T_+) = 19

At 5% level of significance, the critical value for $N = 14$ is $T_{0.05} = 25$.

The p-value = 0.0183 < 0.05.

Decision rule: Reject H_0 because $T_+ < T_{0.05}$ $(19 < 25)$.

Conclusion: There is sufficient evidence at 5% level of significance to support the claim that the median score in the pre-test is less than the median score in the post-test.

APPENDIX 2

MRC Funded Research

Using research findings (local and international) to improve the teaching and learning of physics at secondary level using technology

Team Members

Dr Yashwant Ramma (MIE-Principal Investigator)

Mohun Cyparsade (MIE)

Ajit Gopee (University of Technology)

Ajeev Bholoa (MIE)

Swalehah Beebeejaun-Roojee (MIE)

Priya Ramroop (MIE)

Indranee Ramdin (Research Assistant)

Capacity Building Workshop

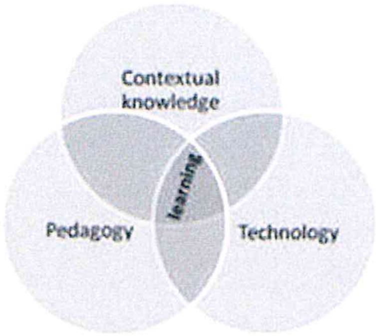
Aims of the Project

- identify the misconceptions that students have and the eventual consequences of these misconceptions on the learning of related concepts
- carry out a literature search at the national and international levels concerning similar type of misconceptions
- develop interactive pedagogical technology-based conceptual physics lessons to address the problem.

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

The Paradigm



Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

The Workshop - schedule

Day 1

- Administering of Questionnaire
- Introducing a conceptual physics lesson (Lesson 1)
- Discussion
- Hands on
- Discussion

Day 2

- Introducing the use of Excel/ Flash in interactive physics (Lesson 2)
- Discussion
- Development of worksheets in Word
- Discussion

Day 3

- Using data logging in interactive physics (Lesson 3)
- Discussion
- Collecting data during hands-on
- Using collected data to construct lessons
- Discussion

Day 4

- General Discussion
- The way forward

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Questionnaire

- It is required to complete the questionnaire which consists of 26 multiple questions.

- Justifications also should be provided alongside the answers.

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Prior Knowledge of Learners

- Why to consider it? How important is it?

- How to accommodate learners' prior knowledge in one's lesson?

You and your dog go for a walk on the football pitch. On the way, your dog runs in a haphazard way and makes many side trips to chase other dogs. When you both finally arrive on the football ground, do you and your dog have the same displacement?

Conceptual Physics Project - MRC/MIE

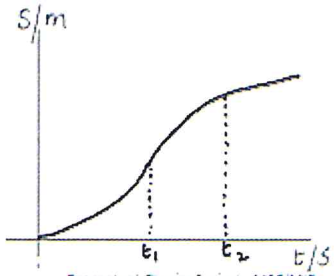
Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Relating one type of a graph to another [position (distance/displacement), velocity, acceleration]



Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Matching descriptive information with related features of a graph

Two bodies A & B situated at 100 m start moving towards each other with speeds v_1 and v_2. They meet at time t.

(i) Illustrate the motion of A & B on a graph.

(ii) Write down the equations of motion.

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- The meaning of the area under a graph

How do you determine the required information from a graph?

Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Representing continuous motion with a line or curve

When do we represent motion with a line?

When do we represent motion with a curve?

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

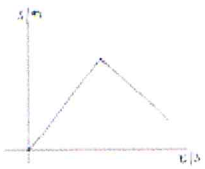
Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Differentiating between the shape of a graph and the path of the motion

Does this graph illustrate uphill and downhill motion?



Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Negative velocity, constant acceleration

If an object is moving with high speed, what can be said about its acceleration?

If the acceleration is positive (negative), is the object speeding up (slowing down)?

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Prior Knowledge of Learners

Students have difficulty with:

- Negative acceleration and deceleration

Is there a difference between negative acceleration and deceleration?

Conceptual Physics Project - MRC/MIE

Capacity Building Workshop

Day 1

Teaching conceptually

Preparation which entails the following:

- researching
- discussion
- hands-on/minds-on
- assessment for learning

Conceptual Physics Project - MRC/MIE

APPENDIX 3

Dear Students,

We are actually conducting a research study on misconceptions in physics among educators. We will very much appreciate if you could honestly answer the questions set below so that we could build a pedagogical approach to helping physics educators. All responses will be treated confidentially.

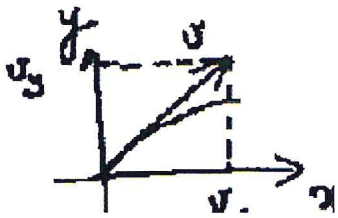
Thank You.

Dr Y Ramma, Mr M Cyparsade
04 March 2011

1. A force causes:
   (a) Motion
   (b) No change in the velocity of motion
   (c) Neither (a), nor (b)

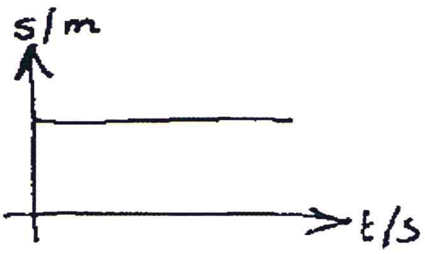
   Explain:

2. During a projectile motion, a body has x-component of velocity as: $v_x= v\cos\theta$. Draw the relationship between v_x/ms^{-1} and t/s.



Answer:

3. What can you say about the behaviour of the body from the following graphical relationship?



Answer:

Explain:

4. Which law introduces the concept of force?

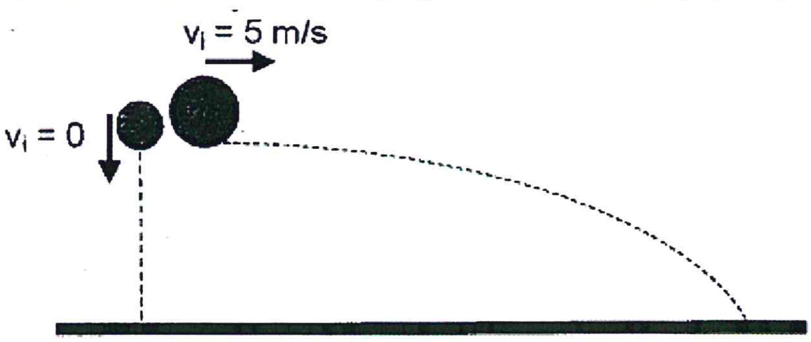
(a) Newton's 1st law of motion
(b) Newton's 2nd law of motion
(c) Newton's 3rd law of motion

Explain:

5. Two blocks each of mass *m*, move along the x-axis as shown below.
 If at some instant t, $v_2 > v_1$ then,
a) $a_2 > a_1$
b) $a_1 > a_2$
c) we cannot determine which block has the larger acceleration

Explain:

6. Two objects of masses m_1 and m_2 ($m_1 > m_2$) are moving under the action of gravity, starting from the same height, as shown below. The mass m_1 is given an initial velocity v_i = 5m/s.



Which statement is correct? (Ignore air resistance)

a) m_1 will reach the ground first because it is heavier.
b) m_1 will reach the ground first because it has initial velocity.
c) m_2 will reach the ground first because it travels smaller distance.
d) Both masses will reach the ground at the same time.

Explain:

7. Moon stays in orbit because
   (a) The gravitational force on it is balanced by the centrifugal force acting on it.
   (b) The gravitational force on it is balanced by the gravitational force of the Earth.
   (c) The gravitational force on it is balanced by the centripetal force acting on it.

   Explain:

8. Are charges used up in a light bulb, being converted to light?

   (A) Yes, charges moving through the filament produce "friction" which heats up the filament and produces light.

   (B) Yes, charges are emitted.

   (C) No, charge is conserved. It is simply converted to another form such as heat and light.

   (D) No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

   Explain:

9. Why do lights in your home come on almost instantaneously?

   (A) Charges are already in the wire. When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.

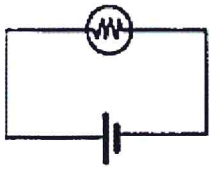
   (B) Charges store energy. When the circuit is completed, the energy is released.

   (C) Charges in the wire travel very fast.

   (D) The circuits in a home are wired in parallel. Thus, a current is already flowing.

   Explain:

10. Is the electric field zero or non-zero inside the tungsten bulb filament?



(A) Zero because the filament is a conductor.

(B) Zero because there is a current flowing.

(C) Non-zero because the circuit is complete and a current is flowing.

(D) Non-zero because there are charges on the surface of the filament.

Explain:

APPENDIX 4

ACCESS TO THE CONCEPTUAL PHYSICS WEBSITE

The research project funded by the Mauritius Research Council in collaboration with the Mauritius Institute of Education, entitled: **Using research findings (local and international) to improve the teaching and learning of physics at secondary level using technology**, also known as '**Conceptual Physics Project**', aims at developing a research-based mind-set among teachers and students with the view to improving the quality of teaching and learning of physics in secondary schools of the Republic of Mauritius. The project undertakes to identify the various misconceptions that students hold in physics at School Certificate and Higher School Certificate levels and to propose appropriate remedial actions to address them.

Access the platform at: http://science.mie.mu/physics/

The website caters for three different categories of users; namely:

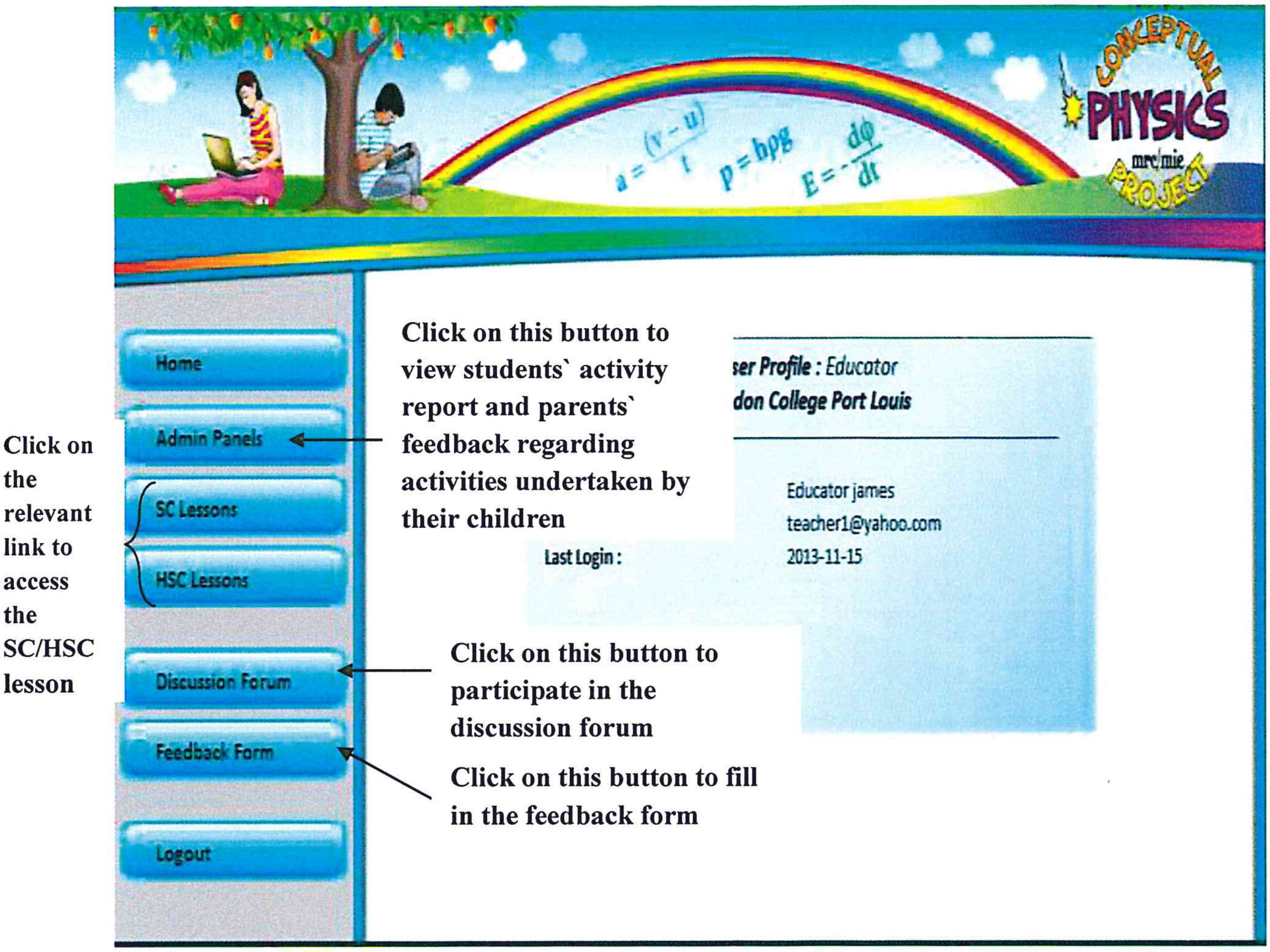
- Teacher

- Student
- Parent

Users are required to log in by feeding in their email address and password. Once you logged on the system, you will have an individual account.

The account that follows provides a description of the website used by the teacher. It also highlights the arguments on the effectiveness of the website from the teacher perspectives through the lenses of teaching and learning theories.

Below is the screen shot which appears once you logged in as a teacher.



Details pertaining to the user, here the teacher will appear in the middle of the interface. These include the name of the college where the teacher works, the name of the teacher, class and login status.

On the left, the teacher will be provided with links to:

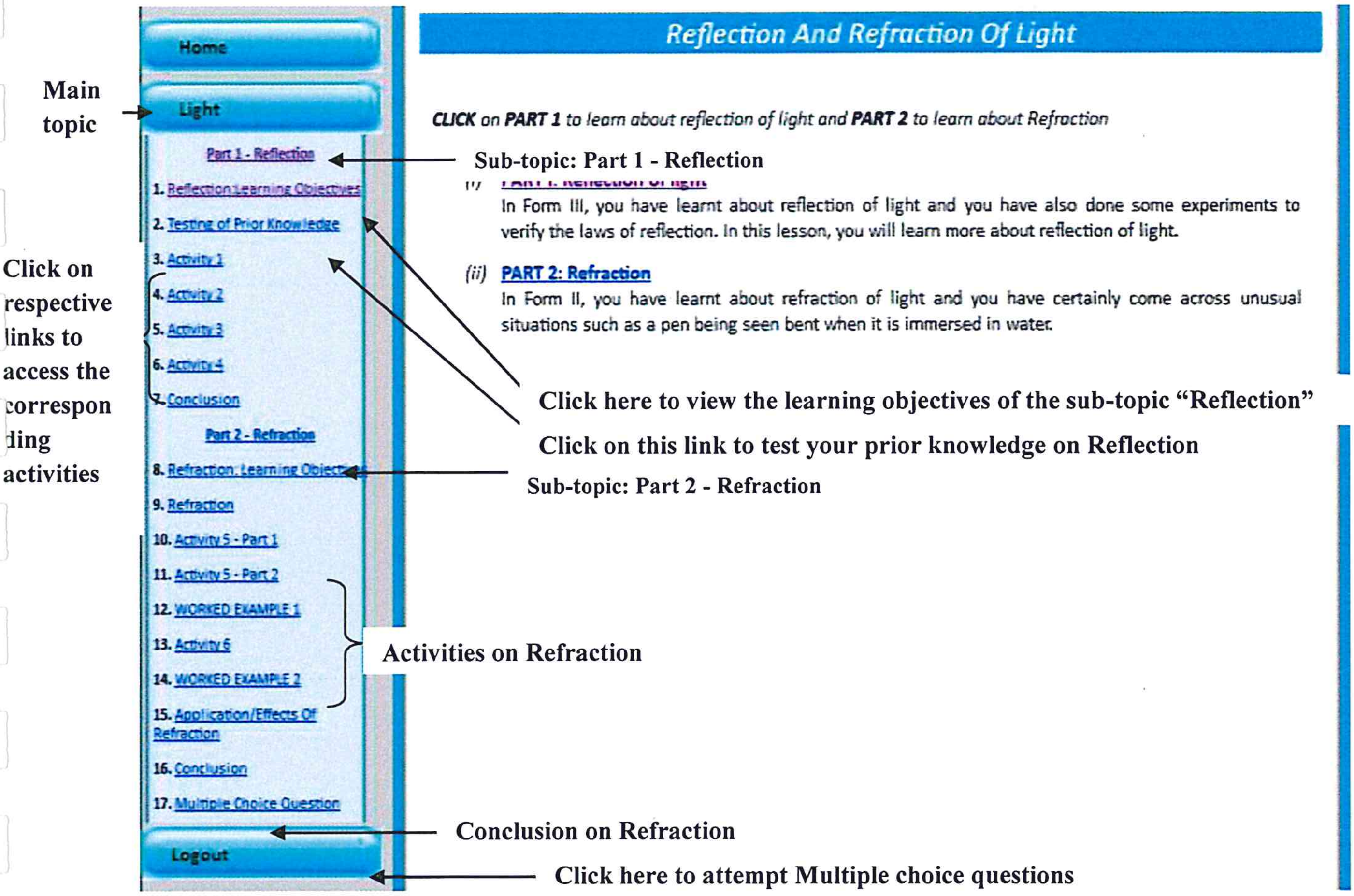
1. S.C and H.S.C topics, (together with administrative privilege of monitoring student activities)

2. The admin button where teacher can monitor:

   - student activities; and
   - view parents` feedback

4. Teachers' access to the discussion forum
5. The feedback allows teachers to provide his views on students work.

The topic 'light' (reflection and refraction) for SC level is available and fully implemented on the CPP website, upon the request of educators who participated in the project. This topic is used as a showcase to understand the pedagogical implications as well as how the CPP website can help in identifying and addressing the issues linked to misconceptions in Physics.



The main SC topic 'light' is divided into two sub-categories: "reflection" and "refraction" respectively. Under each sub topic, there are hyperlinks to the learning objectives, testing of prior knowledge of the topic, activities and conclusion which the user can access by clicking on the relevant link as depicted in the above snapshot. Links to access and download worksheets and other materials are also provided. Links for the multiple choice questions are provided and the progress of students can be monitored through a progress log by assessing 'student activities' under the 'Admin Panel' category.

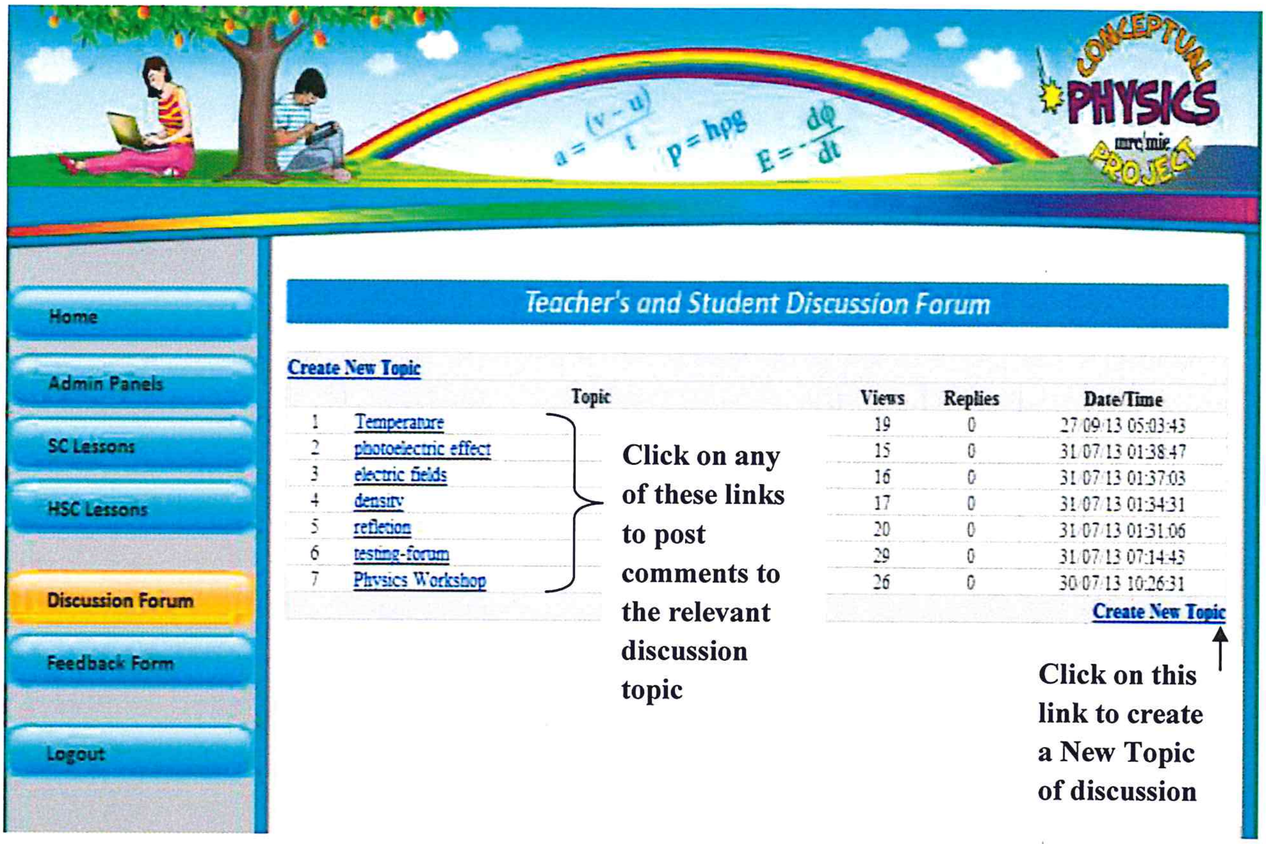
The use of the CPP website allows teachers to identify the different abilities of students and give individual feedback which take much lesser time than in traditional class.

The Role of the teacher

There is a paradigm shift in the teacher's role. Instead of prompting answers from pupils now teachers have to challenge the students to defend their evidence and arguments. The aim here will be to make pupils become critical of their own and others evidence. This will be one of the ways how misconceptions can be addressed. Through the CPP website the role of the teacher will be that of a facilitator, allowing learners to construct purposeful knowledge structures.

The website will act as check post pointing out errors and asking for alternative suggestions and clarifications. This will hopefully give rise to a culture of reflecting, arguing, sharing and construction of knowledge. Using the CPP website must be seen as one where the teacher and learners collaborate in the Zone of Proximal Development to foster deep and life-long learning.

The snapshot below depicts the interface for the Teacher`s and Student Discussion Forum.



- Teachers can create a new topic of discussion by clicking on the "Create New Topic" link as depicted by the snapshot above.

- Teachers can also post their comments to any discussion topic by clicking on the relevant link.

The discussion forum provides the space for learning to occur in a social context. Participations in discussion can clarify meanings as pupils search for shared understanding.' Knowing' becomes a mental production while knowledge will be continuously reconstructed.

Discussion motivates learners to take active part in the lessons and contribute their own ideas and meanings. Here the teacher should monitor the discussion and provide cues and prompts so that pupils feel involved and engaged in the search of meanings. Providing a focal problem to explore rather than 'filling the pot' can dramatically change students' attitude towards the subject.

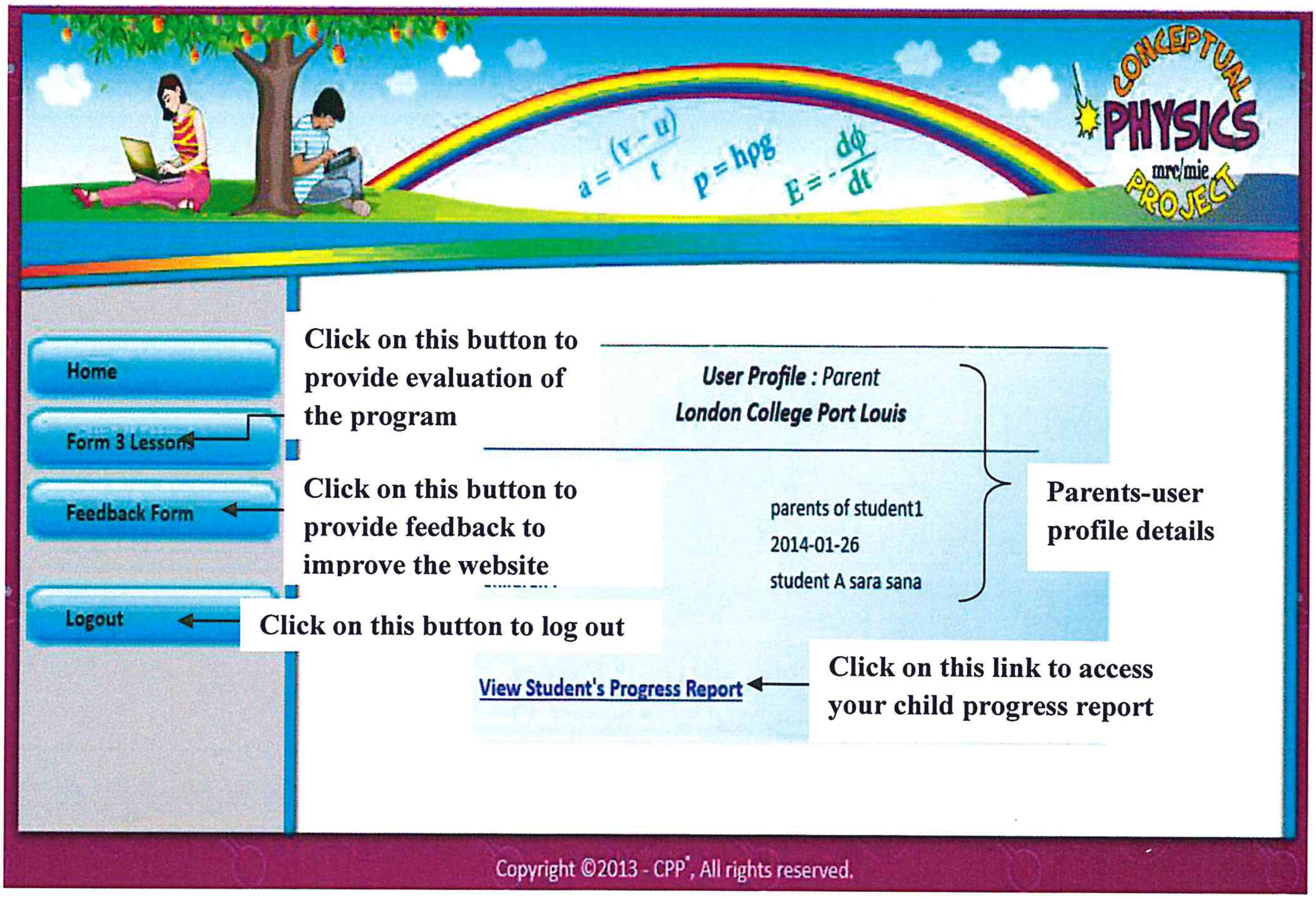
Parental Contribution

Research shows that parental involvement in children's learning is a key factor in promoting children's academic achievements, as well as their overall behaviour and attendance. For this purpose, the CPP website has made provision for a parental corner, with the following facilities:

- Provide parents user profile details (Name of parents and name of child);
- Parents can access and view the Progress Report of their respective child (for MCQs); and
- Feedback form to send suggestion to improve the website to the admin.

NOTE: Parents must send feedback on each activity that their kid has attempted for proper follow-up actions to be taken.

The snapshot below depicts the interface for parents with the features mentioned above:



$a = \frac{(v - u)}{t}$
$p = h\rho g$
$E = -\frac{d\phi}{dt}$
CONCEPTUAL
PHYSICS
mrc/mie
PROJECT
Home
Form 3 Lessons
Feedback Form
Logout
Click on this button to provide evaluation of the program
Click on this button to provide feedback to improve the website
Click on this button to log out
User Profile : Parent
London College Port Louis
parents of student1
2014-01-26
student A sara sana
Parents-user profile details
View Student's Progress Report
Click on this link to access your child progress report
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