Investigating the common core constructs in students' acquisition of logico-mathematical concepts in physics at HSC level.

V K P Parmessur, P.I.
Dr Y Ramma, MIE
Dr H Bessoondyal, MIE
Dr A Ramdinny, MIE

Mauritius Institute of Education

Core-constructs

This research study aimed at:

Addressing a fundamental problem linked with the integration of mathematics and physics knowledge in students' acquisition of logico-mathematical concepts.

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The objectives of the study were to:

- Determine the state of physics teaching with respect to conceptual difficulty in understanding of abstract concepts,
- Investigate the degree of awareness of logico-mathematical concepts in physics from the teachers' and students' perspectives,
- Investigate and address students' logical problem solving skills with emphasis on integration.

Core-constructs

The traditional approach to teaching.

- The depositor-depository approach [Freire, 1972]
- The Chalk & Talk approach

Core-constructs

The traditional Approach

- Learners are passive recipient of knowledge.
- Memorizing is an important factor in the acquisition of knowledge
- It is assumed that learners will develop understanding by themselves
- Summative assessment is a deciding factor

Core-constructs

Branson *et al.* (1998) reveal that:

Physics courses have not been designed to introduce students to the physics community as it really is, to show how physics links with human culture, or to reveal how new ideas in science develop (p. 25)

Core-constructs

It a known fact that physics is considered as one of the most difficult subject in the school curriculum.

Core-constructs

"Every teacher claims that physics is a difficult subject and this makes it harder to us. Physics is too a vast subject and not all the subject matter is discussed in class + there is too much spoon-feeding and during the exams-we cannot deal with difficult numbers as we cannot think for ourselves. Teachers are too much syllabus-oriented."

(statement made by a physics student; Ramma, 2001)

Core-constructs

Students who learn concepts by rote do not develop cognitive structures and they inevitably produce alternative conception (misconception) in order to explain an event or a physical phenomenon. The gradual building up of misconceptions leads to a mismatch between conceptually correct and incorrect items which inevitably may create a state of confusion in the mind of the learner.

Core-constructs

An example:

A car starts its motion with initial velocity ***u*** and attains velocity ***v*** during time ***t***. What is its average velocity?

$$\langle \text{average velocity} \rangle = \frac{v - u}{t}$$

?

Rote learning

Misconception

Core-constructs

In order to understand physics it is necessary that students:

- develop a qualitative understanding of physical phenomena on Earth and in the Universe,
- develop analytical skills with a view to quantifying the qualitative understanding,
- be able to support acquired knowledge with corresponding facts.
- develop a critical mind and problem solving skills.

Core-constructs

Mathematics is a language which is formed in the human mind whereas physics is the fundamental study of nature.

Mathematics forms the basis of physics.

Core-constructs

Mathematics is a necessary but not sufficient condition for students, taking part in the Higher School Certificate level of the Cambridge UCLES examination, to obtain good results in physics.

[Ramma and Bessoondyal, 2001)]

Core constructs

Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice.

(Shulman, 1986, p. 9)

Core-constructs

"The students do not have sufficient mathematical skills for the physics/engineering courses" and that " those students who do cope with the mathematics course are still unable to apply it in context" (Gill, 1999, p.82).

It is really an issue of concern when students claim that there is "no apparent relationship between the two subjects either at A-level or at university" (Gill, 1999, p. 85).

Core-constructs

Methodology

- Research Design (mixture of qualitative and quantitative)
- Critical Analysis of the 'A' physics curriculum
- Critical Analysis of the Mathematics (Form I – VI) and Additional Mathematics (Form IV-V)
- Testing of prior knowledge and development of questionnaire
- Observation of physics lessons
- Development of lessons based on an integrated approach involving core constructs
- Implementation of the new methodology
- Evaluation of the lessons through questionnaires

Core-constructs

The Sample & Access

Twelve colleges were selected with at least one college per zone (inclusive of two colleges in Rodrigues).

(6 States Colleges, 6 Private colleges coded as C1- c12)

Access to schools were obtained as per the normal procedures pertaining to ethics.

Core-constructs

Analysis of the Maths & Physics curricula

The two curricula (Form I – VI) have been thoroughly analyzed with a view to determining:

(i) The degree of interrelationship between the two subjects,

(ii) The extent to which the relationship exists.

Core-constructs

Consider an example:

$$v^2 = u^2 + 2as$$ Physics

$$y^2 = a^2 + 2bx$$ Math

Core-constructs

Consider another example:

$$\text{Work done} = \vec{F} \bullet \vec{S} = \left|\vec{F}\right|\left|\vec{S}\right|\cos\theta$$

$$\text{Moment} = \vec{F} x \vec{S} = \left|\vec{F}\right|\left|\vec{S}\right|\sin\theta$$

Core-constructs

Categorization of concepts in terms of level of difficulty

Concepts	Low level	High level
Mass	✓	
Weight	✓	
Force		✓
Pressure		✓
Acceleration of free fall	✓	
Terminal velocity		✓
Projectile motion		✓
Momentum		✓
Conservation of momentum		✓
Newton's Law of Gravitation		✓
Potential at a point		✓
Kinetic energy	✓	

Core-constructs

We are using the term 'core constructs' to describe the process of coherence and association related to the process of schematic learning.

Core-constructs

Testing of Prior knowledge

The main objectives of setting question based on prior knowledge to participants were to determine:

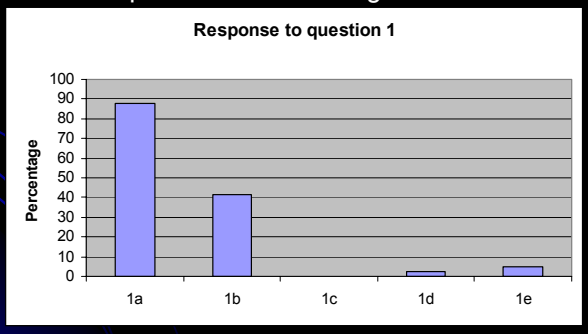
- Whether there is evidence of basic conceptual understanding of physics at least up to School Certificate (S.C) level
- Whether there is evidence of adequacy in understanding basic knowledge of mathematical reasoning

Core-constructs

Question No 1: Measurement of length

In this question, five answers have been provided where there are two right answers. Answer 'C' is the distracter as students may associate the term "measuring the length" with "calculating the thickness".

Our assumption is that: students usually do not pay attention to the aspect of comparison when making a measurement.

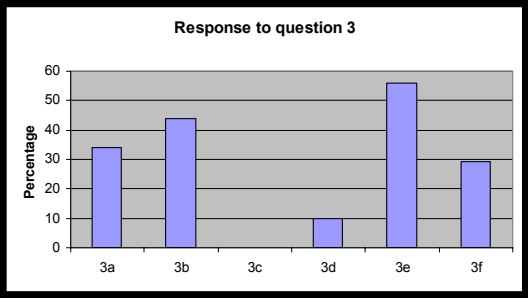


Core-constructs

Question No 3: Free fall motion

In this question, six answers are provided with two correct one.

When an object is in a state of free fall, it is important to note that acceleration of free fall is constant, provided the fall is close to the earth surface. The question makes mention to neglect air resistance so that students may link their knowledge of terminal velocity where net force is zero with a situation when net force is not equal to zero.



Core-constructs

Question 12: *Frictional force*

12. Frictional force is a force that opposes motion. Figure 4 shows a car moving from left to right. In which direction does frictional force acts?

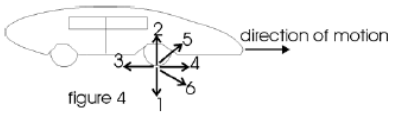
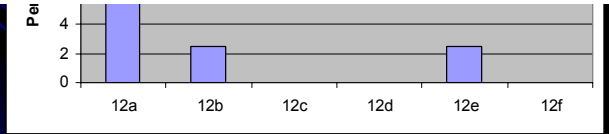


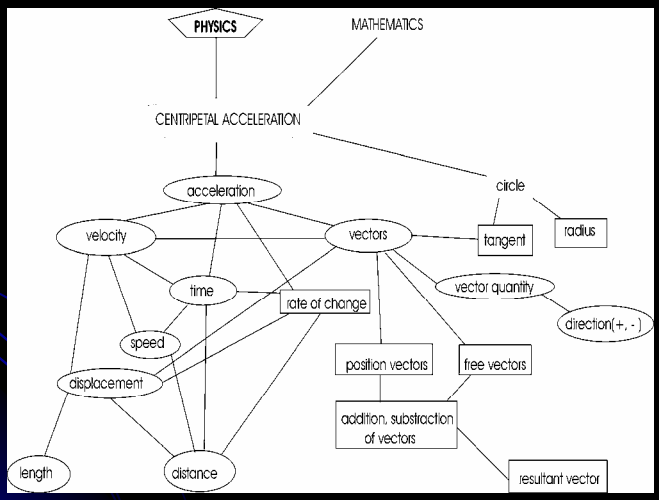
figure 4

	A	1
	B	2
	C	3
	D	4
	E	5
	F	6



Core-constructs

Identifying core constructs



Core-constructs

Observation (5 schools)

The observation schedule is based partly on Bloom's Taxonomy. The schedule comprises of the following:

- **Aims of the lesson,**
- **Learning outcomes,**
- **Adequate planning of the lesson,**
- **Pre-requisites (testing of),**
- **Methodology,**
  - **Good introduction**
  - **Systematic development of lesson,**
  - **Good questioning techniques based on:**
    - **Knowledge**
    - **Comprehension**
    - **Application**
    - **Analysis**
    - **Synthesis**
    - **Evaluation**
  - **Response time**
  - **Linkages with mathematics (teacher's perspectives)**
  - **Linkage with mathematics (student's perspectives)**
- **Conclusion.**

Core-constructs

Unstructured Interview

Some of the key questions are:

- Do your pupils face difficulties in the learning of physics?
- What kind of problems?
- Why do they encounter these problems?
- How do you help them to solve these problems, if any?
- Do you make use of other subjects to help your pupils understand physics better?
- If yes, which subject(s)?

Core-constructs

Teachers' Questionnaires

The questionnaire comprised of statements:

- of general nature,
- related to types of questions set by the students,
- referring to whether students are aware of underlying mathematical concepts involved in physics,
- about problems students face in studying physics at 'A' level,
- concerning interdepartmental collaboration.

Core-constructs

Teachers' Questionnaires

Outcomes

Data from the teachers' questionnaires reveal that there is basically no problem in the teaching-learning process and that teachers are fully aware of the problems that students encounter. According to the teachers, students are given due attention in the learning process and linkages between mathematics are made by the physics teacher.

Core-constructs

Teachers' Questionnaires

Our Comments

Most of the answers provided by the teachers do not match our observations and the feedback obtained from students

Core-constructs

Observation

Sample of the classroom 'interaction'

Core-constructs

Unstructured Interview - Teachers

From the unstructured interviews, the teachers claimed that:

- *they are aware that students encounter mathematical difficulties during physics lessons,*
- *they take into account the mathematical problems during the development of the physics lessons,*
- *students encounter difficulties in physics due to their inability to understand concepts that have already been explained (prior knowledge),*
- *they make in-depth analysis of integration or differentiation during physics lessons,*
- *they ask lots of questions to students,*
- *they find language not to be problem in the teaching of physics, but at times they have to resort to Creole.*

Core-constructs

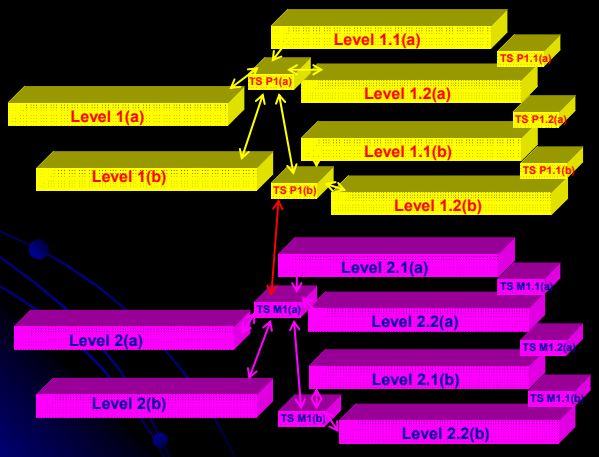
Developing a Thinking Paradigm

A Model of thinking was developed with a view to:

- analysing and challenging pre-existing knowledge of students,
- investigating conceptual difficulties of students,
- determining the level of thinking and understanding in physics and mathematics,
- enabling the students to develop core constructs.

Core-constructs

Developing a Thinking Paradigm



Core-constructs

Adopting an assessment framework

The Comprehensive Interactive Process Model

- Conceptual process evaluation (CPE)
- Procedural process evaluation (PPE)
- Analytical process evaluation (APE)
- Experiential process evaluation (EPE)
- Conclusive process evaluation (CoPE)
- Summary process evaluation (SPE)

Parmessur et al. (2003)

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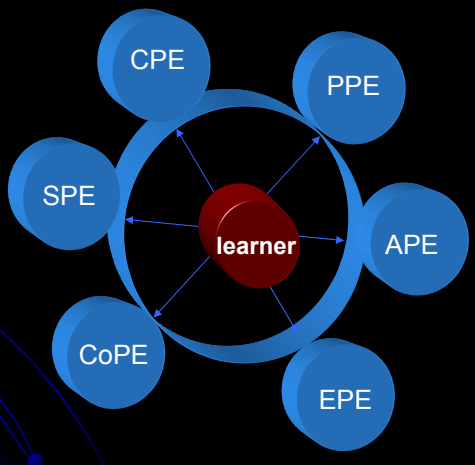
The Comprehensive Interactive Process Model



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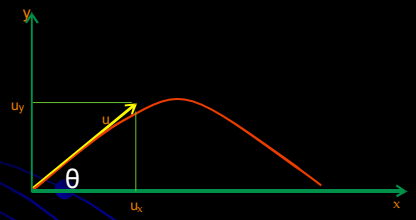
Core-constructs

Teaching physics using core constructs

Projectile motion

- motion of a body in two directions



$u_x = u \cos \theta$

$u_y = u \sin \theta$

What does u_x and u_y represent (wrt maths knowledge)?

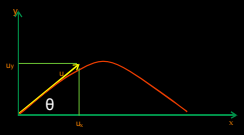
Core-constructs

Teaching physics using core constructs

Projectile motion

- Velocity along horizontal & vertical directions

What is the graphical relationship of v wrt θ?



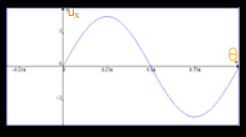
$v_x = u_x + a_x t$

$v_x = u \cos \theta + a_x t$

$a_x = 0$

$v_x = u \cos \theta$

?



$v_y = u_y + a_y t$

$v_y = u \sin \theta + a_y t$

$v_y = u \sin \theta - g t$

Why –ve?

$y = c$

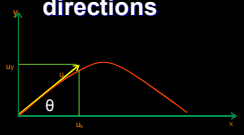
$y = c - mx$

Core-constructs

Teaching physics using core constructs

Projectile motion

- **Displacement along the horizontal & vertical directions**



$$s_x = u_x t + \frac{1}{2} a_x t^2$$
$$a_x = 0$$
$$s_x = u_x t$$
$$s_x = u \cos(\theta) t$$

$$s_y = u_y t + \frac{1}{2} a_y t^2$$
$$s_y = u_y t - \frac{1}{2} g t^2$$
$$s_y = u \sin(\theta) t - \frac{1}{2} g t^2$$

What is the graphical relationship of s_x wrt t?

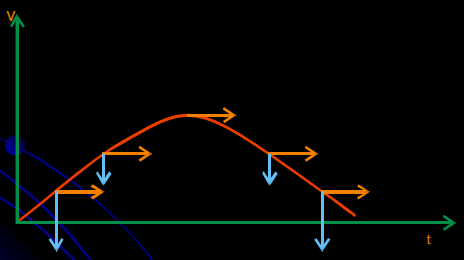
$$y = kt$$
$$y = k_1 t - k_2 t^2$$

Core-constructs

Teaching physics using core constructs

Projectile motion

- **Component of v**



Projectile motion

Core-constructs

Students' Questionnaires

The following items were considered:

- whether students appreciated the teaching,
- whether the questions were challenging,
- whether the question helped them to better understand the concepts,
- whether they liked the moment that mathematics was linked with physics,
- whether all physics lessons should be taught this way.

Core-constructs

Summary

The lessons were mostly teacher centred, students were merely passive learners and their participation consisted mainly in answering closed questions set by the teacher. Opportunities were not given to students to make the link between mathematics and physics.

Though teachers claimed to be aware of the importance of logico-mathematical concepts in the learning of physics, there was no evidence that their teaching strategies contained elements of core constructs.

A thinking model paradigm has been constructed with a view to enabling the researchers to develop a conceptual framework of core constructs. In addition to that the Comprehensive Interactive Model (CIP) of Evaluation was used during the teaching phase to better evaluate and provide corrective measures during the lessons.

Core-constructs

Recommendations

Core-constructs which are used to describe the process of coherence and association related to the process of schematic learning should be adopted in the teaching and learning of not only physics and mathematics concepts but other subjects as well. This is a pre-requirement for constructing purposeful knowledge structures in the mind.

Teachers need to adopt a pragmatic approach to teaching so that students are constantly set in a state of cognitive dissonance. The construction of cognitive structures is a painful process and can only happen if core-constructs are catered for.

Core-constructs

Recommendations

Learners should be engaged in the learning process. The teachers is simply a facilitator in the classroom as much of the painstaking preparation has been done *behind the curtains*.

Our physics modules at the MIE at the level of the PGCE incorporates core-constructs.

Core-constructs

What next?

Based on core constructs, lessons are being developed and uploaded on the MIE website so that students are able to benefit from this research study.

Thank you