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Students' Conceptual Thinking and Teachers' Perceptions about their Classroom Performance in Physics

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Secondary level students traditionally memorize the ideas, principles, concepts and laws in physics, and recall these in examinations. On the other hand, the aims of science education encompass understanding, grasping how a science gains its insights, appreciating how science findings influence daily lifestyles. A test of Concept Application Ability was developed and used with a sample of 1840 grade 10 (age 15-16) physics students. Their performance was related to how teachers perceived their students and their learning as well as to a number of teacher characteristics. It was found that there was little evidence of much difference between teacher's perceptions between private and public school in relation to physics teaching. It was also shown that, while teaching strategies, of themselves, are not important in determining the extent of student performance, encouraging student questioning is important. Teachers being trained in assessment brought benefits to student learning. It was also found that where teachers had grasped better the real nature and purpose of physics as a means of interpreting and explaining how the world works, it tended to generate better learners and it is important that this understanding is emphasized in all teacher training.

Keywords: *Student conceptual thinking, teacher perceptions, student physics performance*
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Introduction

The goals for science education are the development of conceptual thinking, understanding, concept application ability, scientific literacy, and science process skills. Indeed, the overall aim is to enable learners to make sense of the surrounding physical world. The overall aims can be summarized in terms of science literacy as in figure

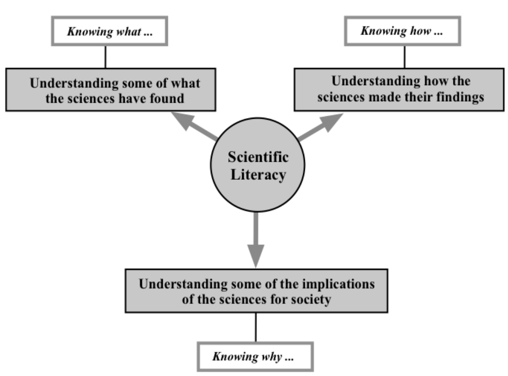

Figure 1 Aims of science education

Numerous factors relate to learning and quality of achievement of students, including parent education, occupation, support and expectation, number of siblings, socio-economic status, home environment, culture, demographic variable, school factors, students perception, attitude, study habits, thinking skills, time for additional study, home work, self-concept, interest, learning style, gender differences, motivation, attitude toward the subject, nature of science and teacher characteristics (Yucel, 2007; Dalgety et al., 2003; Covington, 2000; Schibeci and Riley, 1986; Reid, 2006; Kirmani, 2008; Friedel et al., 1990; Yildirim and Eryilmaz, 1999; Hill Brian, 2009; Heimlich and Norland, 1994). Indeed, numerous other factors also seem to relate to quality of achievement: family factors, students' characteristics and school environment (Bloom,1976; and Knungnit et al., 2004). The examination system, the factual nature of teaching, the quality of text and curriculum are also the hurdles in the way of conceptual understanding (Siddiqui, 2007; Schibeci,1989; Hillel, 2005; Malik, 2002; Afolabi and Akinbobola, 2009) while the interaction of students, teachers, management and activities has its effect (UNESCO, 2002; and Iqbal,1993).

However, it is not clear of any of these actually are causal factors. The fact that it is found that a factor relates to performance does not, of itself, indicate that the factor *causes* the quality of performance. However, one factor certainly is known to control the quality of achievement and this is the capacity of working memory (Johnstone, 1997; Reid, 2009). This is simply because all understanding takes place within the working memory and the capacity of that part of the brain determines whether understanding is possible or not.

Understanding in the sciences often demands that concepts are grasped by the learners. By definition, a concept often involves numerous ideas being brought together in the working memory in order that it can be understood. This immediately makes concept acquisition a demanding tasks for learners. A concept can be described as: a set of rules to categorize and group events, an abstraction of series of experiences (Carl and Perkins, 2005), an idea of an object or event (Huitt, 2003 and Boune, 1966) the characteristics which classify together or set apart two things (Dressel, 1960). Indeed, a concept involves some kind of mental representation, bringing together ideas to make a coherent whole.

The evidence that a concept has been grasped securely is that the learner can apply it (Rebello and Zollman. 2005; and Safdar, 2010) although the capacity to learn and the environment may be factors (Huitt, 2003; and Woolfolk, 2008). When the student can apply the concept in a varying context, then it is claimed that the student has understood the concept. A misconception arises when the learner has created a mental representation that does not match the evidence or is inconsistent with accepted understanding (Rebello and Zollman. 2005). Too often, learners just accumulate information but there is little understanding or conceptual development. Such information has been described as '*inert knowledge'*. Overall, the concept as a unit of knowledge in science plays a unique role to explain and interpret natural phenomenon (Nedim, 2010).

Many years ago, Johnstone (Johnstone,1997) showed that there are multi-levels of thought in the sciences. Thus, in physics, the world around us is interpreted in a specifically known language at three thought levels, the macro, the micro, and the symbolic (figure 2).

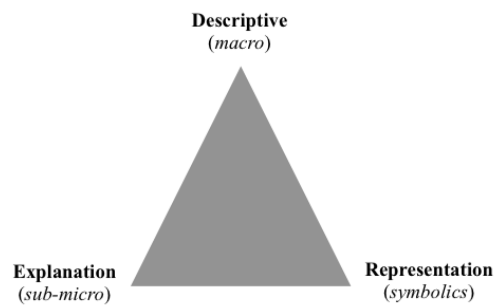

Figure 2 The learning triangle (after Johnstone, 1997)

Often, it becomes difficult for students to work at the three levels *simultaneously*, and hence, they are compelled towards memorization. The reason is the limited capacity of working memory (Johnstone, 1991). There is simply not enough capacity to handle all three levels *at the same time*. Johnstone argued that it was essential to work at one corner at a time with novice learners. Once the ideas at one level were secure (and therefore required little working memory space) then another level could be introduced.

One main feature in the study of Physics is the development of concepts. However, conceptual understanding will be greatly hindered when the instruction in Physics focuses on drilling a standard problem in fixed order, the sign is learned instead of the concept and a gap is produced between scientific practice and science as a subject of formal nature (Dayal et al., 2007). Student get Physics and the world between their own way of thinking and what the teacher as well as the text say (Hill Brian, 2009).

Study Procedure

The aim of the study here is to explore the development of some concepts in physics with secondary level students in Pakistan and relate this to some teacher perceptions about student performance in the classroom. A sample of 1840 grade 10 science students were selected by cluster random sampling, taken from 5 districts out of 25 districts of Khyber Pakhtunkhwa along with a sample of 92 teachers of physics. The sampling involved all the secondary level schools: public and private, girls and boys secondary schools.

The student conceptual thinking in terms of application of physics concepts was measured using a concept application ability test. This included 30 items with a variety of formats. Sample items are shown in the appendix. Half the items were adapted form the work of Al Ahmadi (2008), with permission, the remainder being developed for this study. The validity of her work was established but the overall validity was checked using subject experts. Reliability was ensured by following the procedures outline in Reid (2003).

The test was personally administered by the researcher among all the randomly chosen schools, sixteen from each district in the sampled five districts, Malakand, Mardan, Peshawar, Kohat, and DI Khan. The sample involved a cross-section of learners of varying abilities. The teacher questionnaires were also personally distributed among the teachers who teach physics in the sampled schools. The data obtained were analysed using SPSS (t-tests, correlation) and a suite of programs designed for the purpose (chi-square).

Results of the study

The descriptive statistics for the Concept Application Ability test are shown in table 1.

Table 1 shows a good spread of marks although the mean is slightly low.

The performance in Science Students on Concept Application Ability test for various sub-groups was compared (table 2).

Table 2 shows that there is no difference in performance on the basis of gender. However, the students in private schools out-performed the students in public school sever markedly. This is to be expected in that private schools are selective.

The views of the physics teachers are summarized in table 3.

Table 1 Score of Secondary Level Science Students on Concept Application Ability test

N	Total Test score	Mean	Standard Deviation
1846	30	10.1	3.4

Table 2 Secondary Level Science Students on Concept Application Ability test by sub-groups

Sector	N	Mean	Standard Deviation	t-test	Significance
Public	910	9.4	3	-9.9	$p < 0.001$
Private	936	10.9	3.7		
Boys	1401	10.2	3.7	1.4	n.s
Girls	445	9.9	2.6		

Table 3 Views of Physics teachers about performance of students in classroom

All as % (N Public = 47, N Private = 47)		SA	A	N	DA	SDA	χ2 (df)	p
The students are free to talk with each other when needed during teaching	*Public*	34	25	11	21	9		
	Private	13	32	15	30	11	5.9 (4)	n.s
	Total	23	29	13	25	10		
The students are not free to move anywhere in the class	*Public*	14	21	14	27	25		
	Private	9	7	13	28	44	6.0 (4)	n.s
	Total	11	13	13	28	34		
The students are free to form groups for teaching learning process	*Public*	41	24	13	11	11		
	Private	28	30	22	20	0	7.3 (3)	n.s
	Total	35	27	17	15	5		
The students are free to ask questions at the end of teaching only	*Public*	42	31	13	13	0		
	Private	53	22	18	4	2	3.2 (3)	n.s
	Total	48	27	16	9	1		
Few students ask questions in the class	*Public*	7	4	7	46	37		
	Private	2	19	23	36	19	12.3 (3)	< 0.01
	Total	4	12	15	41	28		
The students are keen to learn	*Public*	21	30	30	21	0		
	Private	21	45	26	9	0	3.8 (3)	n.s
	Total	21	37	28	14	0		
Most students complete the assignments on time	*Public*	20	24	17	30	9		
	Private	9	36	40	15	0	12.5 (3)	< 0.01
	Total	14	30	29	27	4		
The students tend not to participate in the teaching and learning process	*Public*	9	41	27	18	5		
	Private	2	55	16	21	7	4.2 (3)	n.s
	Total	6	48	22	19	6		
The students seem enthusiastic about physics	*Public*	5	38	43	12	2		
	Private	4	24	56	13	2	2.0 (3)	n.s
	Total	5	31	49	13	2		

The most positive results are seen in relation to students working in groups and in their freedom to ask questions. There appears to be quite a high measure of freedom in moving around the class. In the other items, the pattern of response shows a spread of views. It is interesting to observe how few the differences are in teacher opinions when looking at private and public schools. Teachers in public schools clearly see their student asking more questions, as might be expected given the different social intakes. Teachers also note that the public school students have greater difficulty in submitted assignments on time. The differences between the two sectors can be interpreted in terms of the different natures of the students intakes. It is also possible that teacher expectations are different.

It is possible to correlate the student performance in the Concept Application Ability test with the views of the teachers. Because the data for thew latter are ordinal, correlation must be carried out using Kendal's Tau-b correlation. When run on SPSS, the correlation values were all very close to zero with the exception of one teacher opinion:

In the question where teachers were asked: '*Few students ask questions in the class*', it was found that performance in the Concept Application Ability test related slightly to the extent of questions being asked ($r = 0.16$, $p < 0.05$). This makes sense, in that questioning is a mechanism by which understanding can be enhanced.

Many other questions were addressed to teachers relating to their training and their careers. When the response patterns of these were related to the student performance in the Concept Application Ability test using Kendal's Tau-b correlation, very few significant correlations were found. The significant correlations are now shown in table 4.

Discussion

As might be expected the students in the private school perform better, probably simply because they are selected in some way. There is little evidence that the teachers differ in the two sectors for the teacher views are very similar in private and public schools.

Table 4 Teacher Characteristics and Student Performance

Teacher Aspects	r	p	Comment
Length of service of teachers	-0.19	$p < 0.05$	Better performance with younger teachers
Number of course related to assessment undertaken	0.22	$p < 0.01$	Courses bring added value
Increasing belief that physics allows students to understand how the world works	0.21	$p < 0.05$	Better conception of the nature of physics helps learning
Extent of use of worksheet	0.20	$p < 0.05$	Teachers who make this effort gain better outcomes

The data reveal the importance of encouraging questioning among the learners. Indeed, the lack of significant correlations with other aspects of teaching strategies is consistent with the findings of Ausubel over 50 years ago. Ausubel demonstrated that the extent of meaningful learning was unrelated to the extent of teacher-centredness or learner centredness:

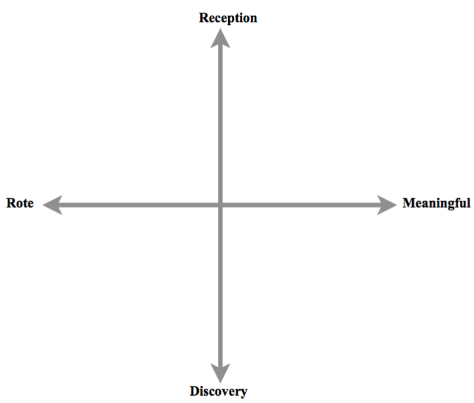

Figure 3 Ausubel's Finding (Ausubel et al, 1968)

The point that Ausubel was making was that reception teaching (teacher-centred) and discovery learning (the most complete student centred learning) were unrelated to the extent of understanding (which Ausubel described as '*meaningful learning'*). His finding is often ignored in much educational literature today. The same point has been demonstrate much more recently by Kirschner et al (2006) in their review paper where they point out that the key to meaningful leaning (understanding) lies in teaching that takes account of the limitations of working memory capacity. The strategy of the teacher is in itself not a relevant factor.

The data also show some advantage with youger teachers, suggesting that more recent training is more helpful. The critical importance of assessment is also seen. Assessment so often controls what is taught and how it is taught and the importance of national assessment can be underestimated. Inevitably, schools will reflect the national assessment approaches and this may well hinder curriculum development (Almadani, et al, 2012).

It is interesting to see that, where the teachers have grasped the real nature of physics as a discipline that can allow learners to make sense of their world, student performance is enhanced. Obviously, teachers who make the extra effort (developing worksheets instead of relying on the textbook) are likely to enable students to understand better.

Conclusions and Recommendations

The following are important:

(a) There is little evidence of much difference between teacher's perceptions between private and public school in relation to physics teaching.

(b) While teaching strategies, of themselves, are not important in determining the extent of student performance, encouraging student question is important.

(c) Training of teachers in assessment is connected with improved student performance.

(d) There is the suggestion that more recent teacher training is generating better teachers.

(e) Teachers have grasped the real nature and purpose of physics as a means of interpreting and explaining how the world works tend to generate better learners and it is important that this understanding is emphasized in all teacher training.

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Appendix
Sample Questions

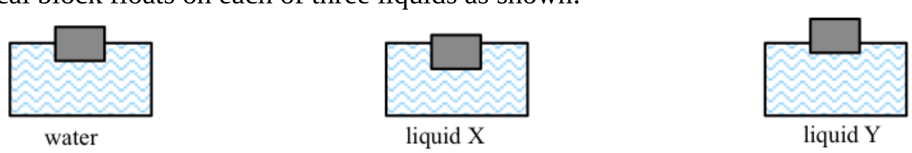
(7) Fill in the blanks with the help of the statements (may be more than one) given in the boxes.

The net force on the car is zero **A**	Velocity = $22 kms^{-1}$ **B**	The velocity of the car has changed **C**
The vertical forces acting on the car are balanced **D**	The momentum of the car has changed **E**	The speed of the car has changed **F**
Speed = $22 kms^{-1}$ **G**	The acceleration of the has changed **H**	The horizontal forces acting on the car are unbalanced **I**

Select all the boxes which contain a correct description of the situation

(1) When a car is traveling along a flat road at a constant velocity. ………………..
(2) When a car accelerates steadily on a straight flat road. ………………..
(3) When a car turns a corner at constant speed on a flat road. ………………..
(4) The driver applies the brakes to a car. ………………..

(9) An identical block floats on each of three liquids as shown:

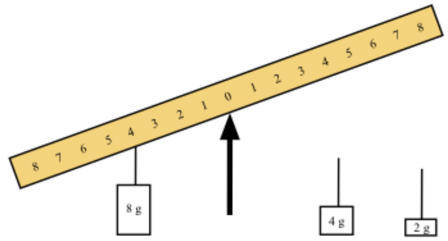


Here are three statements:
(1) The density of the material of the block is less than the density of water.
(2) The density of liquid X is less than the density of water.
(3) The density of liquid X is greater than the density of liquid Y.

Which of the statements are correct?
(A) Both 1 and 2
(B) Both 1 and 3
(C) Both 2 and 3

(10) Khayam and Babur have two masses. One of mass 4g and the other of mass 2g.

Here is a balance with an 8 g mass attached. They wonder if it is possible to use the two mass to bring the balance level again.



*Tick **all** the statements which are true.*

☐ Equilibrium cannot be achieved because the sum of the 4 g and 2 g mass is less than 8 g.

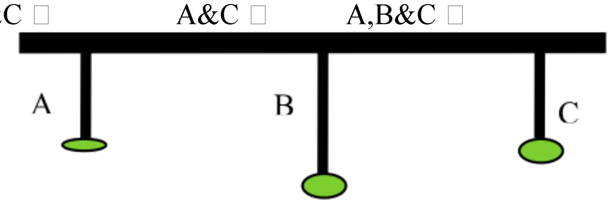
☐ Equilibrium can be achieved by placing the 4g mass at hole number 2 on the right and the 2g mass at hole number 1 on the right.

☐ Equilibrium can be achieved by placing the 4 g mass at hole number 4 on the right and the 2 g mass at hole number 8 on the right.

☐ Equilibrium can be achieved by placing the 4 g mass at hole number 8.

(13) You have three pendulums. A and C have the same length of strings and C have an equal weight attached while A has a smaller weight. Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?

A&B ☐ B&C ☐ A&C ☐ A,B&C ☐



(21) Nora and Omar set up the circuit shown alongside. They predicted that, when they closed the switch, bulb B would light up and bulb A would be unaffected.
When they did close the switch, they found that bulb B DID light up.
However, they noticed that bulb A ***dimmed*** very slightly.

Which of the following are possible explanations for what they observed?
Tick as many as you like.

☐ The wires have a small resistance. ☐ Bulb B takes voltage from bulb A.

☐ Bulb B is of lower resistance than A. ☐ Bulb A is of lower resistance than B.

☐ The battery has some resistance. ☐ Bulbs A and B are in parallel to each other.

☐ When bulb B lights, it reduces the current to bulb A.