On New System of Grading for Students' Learning of Physics

A.K. Mody

V. E.S. College of Arts, Science and Commerce, Mumbai, India

atulmody@gmail.com

Presently, students' increased stress level due to examination system has become an issue of prime importance. It is therefore important to look into the examination practices being followed and possible changes that can be brought in to make the process of teaching-learning and assessment more effective and stress free.

Keywords: Grading, Assessment, Physics learning

Existing Practice

In *Taxonomy of educational objectives*, Bloom, Engelhart, Furst, Hill, & Krathwohl (1956) talks about six major classes: *Knowledge; Comprehension; Application; Analysis; Synthesis; Evaluation.* In class XII physics examination as per Higher Secondary Certificate (Maharashtra, India) Board's specification, four types of questions are asked in examination to test students in their – *Knowledge, Understanding, Application and Skills.*

What do we test in these classes respectively? What are students expected to do? – *reproduce principles, laws, theorems, definitions etc., reproduce derivations, numericals: a so called problem where students are supposed to write formula and substitute given numbers and do numerical calculation, reproduce diagrams, describe some theory, experiment etc., write notes, multiple choice questions mostly involving fill in the blank type of questions.*

Those who are familiar with question papers will agree that all we test is only memory. The categorization of four types of questions is misleading. All we emphasize is on the lowest level of intelligence, that is, memory, and our focus is only on the first objective. Students are not expected to think at all. In fact now what is available as textbooks in market are not even subject notes. They are merely what one writes in such examinations. The conceptual development of the subject is completely missing. Now it is the kind of examination that dictates educational objectives. In fact if one looks at three to four consecutive papers, and then look at the fifth one, one would find 90% of the questions are mere repetitions of previous question papers. We would like to give benefit of doubt for the remaining 10%.

It is the experience of many students that while assessing their answers or solution to problems (even if we accept plug-ins), they are awarded zero marks in spite of their method being correct. A minor numerical error in the initial steps which subsequently results in a wrong answer gets treated as if students have not learned any thing. This is completely demotivating for the students. This kind of assessment drives students towards rote memorization. Even class X Central Board for Secondary Education (CBSE) model answers does not clarify criteria for partial credit in their marking scheme.

Let us see what this leads to when the same criteria are adopted for grading at undergraduate examination with an example: Consider a question in the examination that expects students to derive expression for *Compton shift*. A student who genuinely tries applying conservation principles but makes a mistake in carrying certain factors would end up not reaching the final answer or reach the wrong answer. Another student does not understand but has memorized the entire derivation and reproduces selected steps and manages to arrive at right answer even if he writes one of the equations somewhere in between incorrectly. It is common experience that the student in the second category would be rewarded with more marks than the first one and would be subject to whims of the examiner. These are the root causes of stress.

What should be done

In any case how much of physics (knowledge) that students acquire, is needed to be used in real life and needs to be on their fingertips? In real life, whatever career student takes up, they would be required to solve problems. These may be from physics or non–physics. Thus it is important that education focuses on problem solving skills and let students learn to construct their knowledge through problems. Problem solving is one of the constructivist teaching learning methodology (Pradhan & Mody, 2009a, 2009b). Tan (2000) has noted that in their attempts to innovate learning, educators are exploring methodologies that emphasize these facets; *real-world challenges, higher-order thinking skills, problem-solving skill, interdisciplinary learning, independent learning, information-mining skills, teamwork, communication skills.*

Problem based learning (PBL) approaches appear to be promising in addressing most of these needs. More importantly, PBL is able to address these holistically. Tan (2003) has argued that PBL brings curriculum shift of three foci of preoccupation as illustrated in Figure 1.

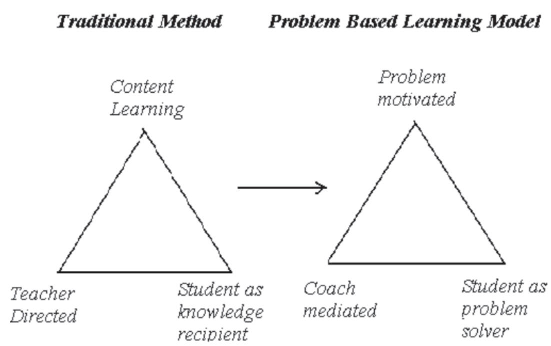

Figure 1: PBL model

According to Tan (2003), it is not how much content we disseminate in our classrooms but how we engage students' motivation and independent learning that is important. For science teaching he has noted that:

'Breakthroughs in science and technology are often the result of fascination with problems. Great learning often begins with preoccupation with a problem, followed by taking ownership of the problem and harnessing of multiple dimensions of thinking. Problems and the questions associated with them when strategically posed can enhance the depth and quality of thinking. What is often lacking in education today is the effective use of inquiry and problem-based learning approaches'.

Good problem design takes into consideration the goals of PBL, *students' profiles, problem characteristics: authenticity, curriculum relevance, multiplicity and integration of disciplines*; the problem context: *ill-structuredness, motivation of ownership, challenge and novelty, the learning environment and resources, problem presentation*. The teacher's role in PBL is very different from that in a didactic classroom. In PBL, the teacher thinks in terms of the following:

— How can the teacher design and use real-world problems (rather than what content to disseminate) as anchors around which students could achieve the learning outcomes?

— How does the teacher coach students in problem-solving processes, self-direction and peer learning (instead of how best to teach and give information)?

— How will students see themselves as active problem solvers (rather than passive listeners)?

Similary, in PBL the teacher focuses on:

— facilitating the PBL processes of learning (e.g. changing mindsets, developing inquiry skills, engaging in collaborative learning)

— coaching students in the heuristics (strategies) of problem solving (e.g. deep reasoning metacognition, critical thinking, systems thinking)

— mediating the process of acquiring information (e.g. scanning the information environment accessing multiple information sources, making connections)

Savin-Baden (2000) has discussed five different models of problem-based learning (see Table 1).

Among the models listed, Model I is suitable for teaching science and specifically physics. An experiment to teach physics at undergraduate college level has been tried in Indian colleges and has been found to be successful in building capacity of students (Pradhan & Mody, 2009a). Such constructivist teaching requires assessment, which does justice to students in testing according to higher educational objectives, i.e., beyond simple memorization test.

Holt and Holt (2000) emphasize the concept of dynamic assessment, "which is a way of assessing true potential of learners that differ significantly from conventional tests… assessment is a two way process involving continuous interaction between both instructor and learner… that measures the achievement of the learner, the quality of the learning experience and courseware".

According to Poehner (2008), Dynamic Assessment (DA) is an approach that takes into account the result of an intervention. In this intervention, the examiner teaches examinee how to perform better on an individual item or on the test as a whole. The final score may be a learning score representing the difference between pre-test (before learning) and post-test (after learning) scores, or it may be the scores on the post-test considered alone. The interactionist DA focuses on the development of an individual learner or even a group of learners, regardless of the effort required and without concern for pre-determined endpoint. The result of DA procedures must report the mediating moves as well as the reciprocating behaviours that contribute to the overall performance. Importantly, this information can highlight aspects of development that would likely remain hidden in non-DA, as learners who are not yet ready to perform independently may exhibit changes in the form of mediation they require or in how they respond to mediation.

As Mayer (1997) puts it, "If the goal of problem solving instruction is to improve the cognitive processing of students

Model I	**Model II**	**Model III**	**Model IV**	**Model V**	
	PBL for Epistemological Competence	**PBL for Professional Action**	**BL for Interdisciplinary Understanding**	**PBL for Transdisciplinary Learning**	**PBL for Critical Contestability**
Knowledge	Propositional	Practical and performative	Propositional, performative and practical	Examining and testing out of given knowledge and frameworks	Contingent, contextual and constructed
Learning	The use and management of a propositional body of knowledge to solve or manage a problem	The outcome-focused acquisition of knowledge and skills for the work place	The synthesis of knowledge with skills across discipline boundaries	Critical thought and decentring oneself from disciplines in order to understand them	A flexible entity that involves interrogation of frameworks
Problem Scenario	Limited-solutions already known and are designed to promote cognitive understanding	Focused on a real-life situation that requires an effective practical resolution	Acquiring knowledge to be able to do, therefore centred around knowledge with action	Characterised by resolving and managing dilemmas	Multidimensional offering students options for alternative ways of knowing and being
Students	Receiver of knowledge who acquire and understand propositional knowledge through problem-solving	Pragmatists inducted into professional cultures who can undertake practical action	Integrators across boundaries	Independent thinkers who take up a critical stance towards learning	Explorers of underlying structures and belief systems
Facilitator	A guide to obtaining the solution and to understanding the correct propositional knowledge	A demonstrator of skills and a guide to 'best practice'	A coordinator of knowledge and skill acquisition across boundaries of both	An orchestrator of opportunities for learning (in its widest sense)	A commentator, a challenger and decoder of cultures, disciplines and traditions
Assessment	The testing of a body of knowledge to ensure students have developed epistemological competence	The testing of skills and competencies for the work place supported by a body of knowledge	The examination of skills and knowledge in a context that may have been learned out of context	The opportunity to demonstrate an integrated understanding of skills and personal and propositional knowledge across disciplines	Open-ended and flexible

Table 1: Models of problem-based learning (Savin-Baden, 2000)

when they are confronted with a novel problem, then the goal of problem-solving assessment is to describe the cognitive processes they use in their problem solving".

How can this be done

This report or description advocated by Poehner (2008) and Mayer (1997) may be translated into grading system as follows, since it is important that weightage be given to students' construction (progress in learning) through out the term rather than just end of the term examination. Atleast 1/3rd weightage must be given to regular process (these would be certainly addressing students learning process), 1/3rd (or 1/4th) to periodic tests/assessment to make sure students go over through what they are supposed to have learned and 1/3rd (or 1/4th) to the final examination. Final examination should contain genuine test items including problems that students should be able to work through but not merely plug-in problems or fill in the blank questions. These problems may be designed as per course objectives and to achieve objective numbers two to five of Bloom's taxonomy. This way we would certainly be able to address to higher educational objectives and yet keep burden of students reasonably low. As learning process is given more weightage this has potential to keep burden of subjecting students to extra coaching away and give them necessary time for recreation. This can also empower teachers to a good extent.

EXAMPLE

Let us consider an example from class VIII science textbook (2009) of reflection at a plane surface to illustrate *how to employ dynamic assessment*. Students learn about laws of reflection at a plane surface that (i) incident ray, reflected ray and normal to the surface all lie in the same plane and (ii) angle of incidence is equal to angle of reflection. Teacher can teach this experimentally using pin and mirror and constructing ray diagram. These days it is easy to demonstrate using simple LASER torch. Having established this, students can be asked or shown construction of position of image due to point object using laws of reflection and two or more rays.

Having done this, following is what can be done for dynamic assessment: Students can be asked to construct (i) image of an extended object and (ii) image/s of a point object in case of two mirrors inclined at an angle è (say 90^o). These are meaningful activities that can be part of activity or problem based learning. Teacher can help students construct their knowledge by giving them support in terms of guided intervention, by challenging them through cognitive conflict if they are off the track or auxiliary activities/problems. Students learn by building upon knowledge they already possess themselves and guided interventions are used to correct errors, which have crept in their understanding. Most importantly, there will be effective scaffolding. That is, students are not given answers to any questions, but are guided (using interventions like auxiliary problems, counter questions, cognitive conflicts) to converge to the right answer themselves. Students can be assessed while they perform these activities depending upon how well they employ their resources (previous knowledge about laws and geometry). Suppose these activities are to be evaluated on a scale from 0–5 then they can be given 5 to start with and can be given –0.5 (negative marks) each time they need teacher's intervention. Since they will complete this activity any way and can be made to reflect upon their construct or solution, each one would score at least 2 (40%).

A student who succeeds without any assistance would have achieved all the educational objectives of Bloom (1980). Others would still be partially achieving it with instructor facilitating their construction of knowledge. If we allot 50% weightage to such (dynamic) assessment, students definitely become active learner and eventually this helps enhance their cognitive capabilities and reduces importance of rote memorisation. We can certainly keep periodic tests (25% weightage) of traditional type but without too much importance to memorization, i.e. MCQ or small problem type, and final examination (25% weightage) carrying similar activities/problems will generate meaningful grades.

Instead of translating marks to grades as it is done by CBSE (which reduces importance of marks by bunching to some extent but meaningless otherwise), we can assign grades A, B, C, D with following reflection.

A: Have successfully completed and mastered the course

B: Have satisfactorily completed the course but need to put more efforts

C: Have completed the course but need to be given remedial coaching before next level of learning.

D: Need to repeat the course before student can be allowed for the next level of learning.

With these strategy (dynamic assessment as discussed) most students would succeed with A and B grades. It may be exceptional case who scores C and extremely rare to score D. One may justify the grading by statistically grouping students rather than merely translating marks from 0-100 into grades. It is this grading that would not only do justice to students' true potential but also reduce stress level significantly. Lot of work needs to be done to develop this type of grading system. This also demands training teachers to achieve higher objectives.

The only hurdle here is student to teacher ratio. However, if we need to make education stress free and do justice to students' true potential, this ratio have to be brought down to right number. This is the major challenge. Merely by having more (100) students in a class room would not achieve 'education for all' and yet keep it 'stress free for all'.

REFERENCES

Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R., (1956). *Taxonomy of educational objectives: The classification of educational goal, Handbook 1: Cognitive domain*. New York: McKay.

CBSE (2009). *Science, class VIII textbook*. India: CBSE.

Holt, D.G., & Willard-Holt, C. (2000). Lets get real-students solving authentic corporate problems. P*hi Delta Kappan*, 82 (3).

Mayer, R.E. (1997). *International encyclopaedia of education* VII (4730) Pergamon.

Poehner, M.E. (2008). *Dynamic assessment: A Vygotskian approach to understanding and promoting L2 development.* New York: Springer.

Pradhan, H.C., & Mody, A.K. (2009a). Constructivism applied to physics teaching for capacity building of undergraduate students, *University News*, 47(21), 4-10.

Pradhan, H.C., & Mody, A.K. (2009b). Physics teaching and learning through problems, *Bulletin of Indian Association of Physics Teachers*, 1(12).

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. Buckingham: Open University Press.

Tan, O.S. (2000). Reflecting on innovating the academic architecture for the 21st Century, *Educational Developments*, 1, 8-11.

Tan, O.S. (2003). *Problem-based learning innovation: Using problems to power learning in the 21st century.* Singapore: Cengage Learning.