Pencil and Paper Pitfalls:
The PDD

AAPT Summer 2003 PERC

Dr. Dave Van Domelen
Kansas State University

This is the story of how one can be successful in trying to understand problem solving skills, yet also fail.

OUTLINE

I. What is Problem Solving?

<u>At its heart, "problem solving" is what we do when we don't know what to do</u>. It is more than simply working exercises, and involves a great deal of "feeling around".

While there are certain strategies that lead to more successful problem solving, it's never as cut-and-dried as when we find answers in familiar tasks. Therefore, it's difficult to create an objective test of true problem solving ability, simply because there will usually be more paths to a solution than we can anticipate.

It's not impossible to make such a test, just a lot more complicated.

II. The PDI
Problem Decomposition Inventory

Here's a sample from my first serious attempt at an objective test of a single problem-solving skill, the ability to break a complex problem into more manageable bits:

(13 - 16)

You're enjoying a day at the park with friends, and are currently sitting in an old tire swing (a tire hung from a rope or chain) at rest. Someone tosses a softball to you, but catching it causes you to start swinging. You try to throw the softball back while at the bottom of the swing's arc, but your aim is off and the softball hits a soccer ball that rolls to a stop nearby.

Here's some pieces the situation could be broken into if you wanted to figure out where the softball finally landed:

13) Catching the softball while in the swing.
14) Swinging back after catching the softball.
15) Throwing the softball.
16) Motion of the soccer ball before it gets hit.

II. The PDI

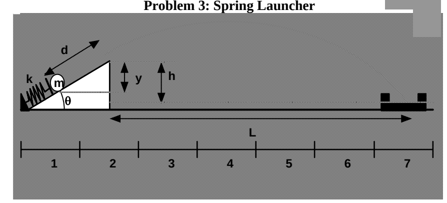
Students were asked to rate each of the "possible pieces" as being either one step, more than one step stuck together, or something so trivial it didn't need to be solved for.

The core problem with the PDI was that it was too vague. There were far too many ways to correctly solve each of the problems posed in the PDI, to the point where the same piece could be correctly identified as a single step by one student, multiple steps by another, and wholly irrelevant by a third.

It was necessary to change the test to give a situation that could be well-defined in terms of the physics.

III. PDD v1.0

Problem 3: Spring Launcher



A ball rests on a compressed spring attached to a frictionless ramp. When released, the ball should fly through the air and land in the tray at the right side of the page. When the spring is relaxed, it reaches the top of the ramp.

The goal of this problem would be to find the amount **x** that the spring must be compressed in order for the ball to land in the tray. You would know or be able to measure **k**, **m**, **h**, **θ**, and the distance **d**. The ball is dense enough that air friction can be ignored.

Interval	Parts in Interval
1	______
2	______
3	______
4	______
5	______
6	______
7	______

Part	Type of Problem

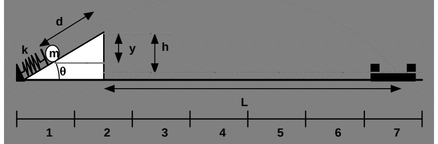
III. PDD v1.0

Accompanying the problems in the PDD v1.0 was a sheet of multiple choice options covering a wide range of problem types. 26 options, in fact, all of which were based on the results of interview tasks. The idea was to narrow the range of "types of problems" and make it easier to interpret the results.

However, while the "splitting apart" aspect of the task worked very well, the "types of problems" aspect did not, with fully half of the sample group of about 200 students turning in unanalyzable data in the lower right hand box.

Further, analysis of the "splitting apart" section suggested that only certain types of split gave students trouble.

IV. PDD v2.2



A ball sits on a frictionless ramp, resting against a spring which is compressed by an amount **d**. When released, the ball should move up the ramp and then fly through the air to land in the tray at the right side of the page. The spring stops pushing the ball when it reaches the end of the ramp. The top of the ramp is a height **h** above the landing pad, and the ball starts a height **y** below the top of the ramp. Both the tray and the ramp are attached to the floor and do not move.

The goal of this problem would be to find the amount **d** that the spring must be compressed in order for the ball to land in the tray. You would know or be able to measure **k**, **m**, **h**, **θ** (relating **y** and **d**), and the distance **L**. Air friction can be ignored.

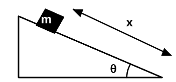
(2) How many subproblems are there in this problem, and what intervals do they cover?

- **a)** Two subproblems: 1, 2-7
- **b)** Two subproblems: 1-2, 2-7
- **c)** Three subproblems: 1, 1-2, 2-7
- **d)** Three subproblems: 1, 2, 3-7
- **e)** Three subproblems: 1, 2, 2-7

IV. PDD v2.2

This instrument was split into two sections, one for decomposition (as seen to the left) and one for identification of problem type (below):

6) A block slides down an incline. Values for gravity **g**) and a coefficient of friction μ are known. How fast is the block moving after it has slid a distance **x**?



I would:

- **a)** Apply energy principles at the beginning and the end of the block's slide and figure out where all the energy goes.
- **b)** Compare this situation to other inclined plane problems in my textbook and notes and see if the problem has been solved there.
- **c)** Find an equation with velocity, change in height and friction and see if I could solve for velocity.
- **d)** Draw a force diagram, sum the forces and find the acceleration of the block, and then use the acceleration to find the speed

IV. PDD v2.2

Results from the administration of the PDD v2.2 to students in three different courses were very encouraging. Variations between groups made sense, results were fairly consistent within groups, and the test did seem to be telling us something about student abilities and problem-solving behaviors.

Unfortunately, with only five items in each section, it was difficult to establish reliability statistically...and, of course, the material being covered was pretty restricted in scope, especially section 1, which really only tested students on springs, collisions and ballistic paths (with a little bit of energy conservation).

V. Conclusions I Drew

After defending my thesis based on the PDD, I had time to think about how I could extend the instrument into something more useful. I'd devised a number of additional items as part of the thesis, but I soon realized that even if they proved to be good items, that didn't answer the question, "Is this test worth giving?"

The PDD met the technical criteria for a good test of an aspect of problem solving skills, yes. But in order to meet those technical criteria, I had narrowed the focus so tightly that the aspect in question was of limited interest, compared to the broader focus of instruments like the FCI or CSEM.

VI. A Cautionary Tale

Problem solving is a complex subject. It is not impossible to create an objective test of problem solving skills, but you have to be very careful, lest you paint yourself into a statistically very reliable and valid sort of

corner.