

# Problem Solving in the Physics Classroom



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“Students are not easily weaned away from a formula-hunting problem solving strategy that has been successful in the past.” (Hestenes, 1987, p. 449)

As physics teachers, we can readily agree that our students should be able to solve challenging and meaningful physics problems. At the same time, many students report that framing a problem is the most difficult task they encounter in both high school and undergraduate physics courses. To cope with increasingly challenging physics problems, many students will engage in “formula hunting” behaviours in an effort to match given information to formulae that seem likely to produce reasonable answers. Although formula hunting sometimes yields correct answers, its utility as a long-term learning strategy for physics students is questionable.

### **What is a problem?**

In many cases, the words question and problem are used interchangeably at all levels of schooling. When approaching the issue of problem solving in a physics classroom, however, it becomes important to distinguish between a question and a problem. The difference between a question and a problem might be thought of in the following way:

- A question is a situation where the route between what *is* and what *is desired* is readily apparent.
- A problem is a situation where the route between what *is* and what *is desired* is not readily apparent.

Desjardins and van Oostveen (2008) define problems (P) more specifically:

$$P = \left( \frac{S_D - S_C}{K + R} \right) Role$$

$S_D$ : Desired Situation

$S_C$ : Current Situation

K: Relevant Knowledge of the Problem Solver

R: Resources Available to the Problem Solver

Role: Contextual factors related to the Problem Solver (perspective, prior assumptions, etc.)

This model is not meant to be a mathematical formula, but it does help to characterize the level of difficulty associated with particular questions or problems. We can readily see, for example, that the “value” of P is at a minimum when the sum of K (Relevant Knowledge) and R (Resources Available) is large. Conversely, a problem is quite challenging when the difference between the desired situation and the current situation are large in comparison with the problem solver’s relevant knowledge and the resources he or she has available. The model also demonstrates that a problem can become a question as variables change (and vice versa).

## Problem Solving: Beyond Examples

Problem solving is traditionally taught by providing examples for students to emulate. The drawback is that students tend to emulate what they see. What they see, typically, is that after a little talk some formulas are written down from which a numerical solution is obtained by manipulation and substitution. The teacher or textbook may say that it is important to do such things as to “draw a diagram,” but they seldom say why, and the students can see that the answer comes from a formula, so why bother with a diagram? Little wonder that students come to see selection of the correct formulas as the key to problem solving. Thus, they tend to develop a *formula-centred problem solving strategy* (Hestenes, 1987, p. 449).

There are many statements in the above quotation that likely ring true for both physics teachers and physics learners. In the same article, Hestenes makes the case that physics experts use a *model-centred strategy* when they approach physics problems. While we might suggest that we want students to develop sophisticated models of how to approach physics problems (and there is certainly nothing wrong with such a suggestion), I believe that discouraging formula-centred problem-solving strategies begins with providing learners with additional resources to bring to bear on problems. It is unrealistic to expect students to move from formula-centred problem solvers to model-centred problem solvers unless they have experiences with resources other than formulae.

## Problem Solving: Beyond Just Formulae

*Multiple Representations of Knowledge* (Knight, 2004, pp. 76–80)

Knight makes a strong argument for encouraging students to represent problems in a variety of ways. Students are typically used to seeing a written representation, a mathematical representation, and in the case of dynamics problems, a free-body diagram. Knight’s approach separates the pictorial representation (including a sketch, a coordinate system, and labels for given information) from a physical representation (motion diagrams, free-body diagrams), which can often be helpful for students as they frame a problem.

Drawing on work from Van Heuvelen (1991), Knight (2004, p. 76) presents the motion diagram as the kinematics equivalent of the free-body diagram, defining it as “an ordered series of dots showing the position of a moving object at several points in time.” Each dot can have a velocity vector attached to it. The average acceleration can then be determined by finding the difference between  $\vec{v}_2$  and  $\vec{v}_1$ . Motion diagrams can be linked directly to motion graphs.

*Problem Sorting and Classification* (Project for Enhancing Effective Learning [PEEL], 2010)

Most students will begin solving problems (or answering questions, for that matter) by starting with the first question assigned by their teacher. Students have been conditioned by years of doing textbook problems to expect that the easier problems (which are often *questions*) will precede the harder problems, so they should begin at the beginning. Unfortunately, this approach often tacitly underscores an algorithmic approach to problem solving, as some students might simply get “on a roll” with the problems they are trying to solve.

PEEL Procedure E5 challenges students to group problems (usually at least 10) into a number of different “problem sets.” Each problem set must be characterized by fundamental differences in the problems. Students should not be asked to solve any of the problems until significant discussion has occurred regarding why students grouped problems in particular ways. For

example, students might group 10 dynamics problems according to the presence or absence of a friction force, an incline, or a tension force. The procedure is also a useful way to help students analyze sample tests and examinations.

#### *Where and Why Is It Wrong? (PEEL, 2010)*

Students who adopt a *formula-centred* problem-solving strategy are often unable to check their own work for accuracy. Instead, they have focused on memorizing algorithms and producing answers. It can often be difficult for students to consider their own solutions critically because of the personal effort and emotion they have invested in a particular problem.

PEEL Procedure E1 provides an opportunity for students to learn to edit their solutions by removing the personal element from a solution to a problem. Students are provided with a problem set and sample solutions, but are warned that most solutions are incorrect. The mistakes in the provided solutions can vary widely, but I recommend providing a few that are easily identified. Students are asked not only to find the mistakes in the solutions, but also to provide the correct solutions *as well as* an explanation of the thinking that led to the incorrect solution. Students should be encouraged to ask themselves “How might someone be thinking if they make this mistake?” This procedure is particularly effective if students are encouraged to work collaboratively.

#### **The Road Ahead**

As with many issues of teaching and learning, it is often easier to point out difficulties in traditional approaches to problem solving than it is to suggest solutions. The alternatives presented during this workshop, however, seem to offer promising avenues to help students develop resources for solving problems that go beyond searching for the correct formula. Knight (2004, p. 44) reminds us of the dangers of formula hunting: “Although such a simple strategy fails when facing the increasingly complex problems of college courses, students have no other alternative strategy at their disposal. Exhortations to “just remember a few principles” are meaningless because they don’t know — unless they’re taught — how to reason this way.”

Humanity faces global challenges that require the general population to have meaningful understandings of basic science and the ability to solve non-trivial problems. It seems reasonable that physics teachers make the development of a thoughtful approach to problem solving a central goal of our courses. We owe it to our students to provide experiences that discourage formula hunting and encourage the development of a model-centred problem-solving strategy.

#### **References**

- Desjardins, F. J. & van Oostveen, R. (2008). *Implementing PBL online as a collaborative learning strategy for teachers: The COLE*. Paper presented at the Eleventh IASTED International Conference on Computers and Advanced Technology in Education, Crete, Greece.
- Hestenes, D. (1987). Toward a modeling theory of physics instruction. *American Journal of Physics*, 55(5), 440–454.
- Knight, R. D. (2004). *Five easy lessons: Strategies for successful physics teaching*. San Francisco: Addison Wesley.
- Project for Enhancing Effective Learning (PEEL). Retrieved April 28, 2010, from <http://peelweb.org>
- Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics*, 59(10), 891–897.