The EOAS-SEI Times
Sept 2015, Vol. 8, No. 2

Raising the standards in undergraduate education*
http://www.eos.ubc.ca/research/cwsei/eossei-times.html

How can we make good (and gradable) homework problems?

Welcome back – another school year begins! Improving courses is often most practical in small, manageable increments. Here are a few tips for optimizing **homework problems**, derived from a recent summary by Carl Wieman[1].

"To show you how well I understand fractions, I only did half of my homework."

Homework may be where student put in the most hours of intense thought about your subject, and intense thought is known to be essential for developing mastery.[2] But assignments must be carefully crafted to optimize the benefits of that effort. Applying the ideas of reference 2, essential features are:

- Challenging and prolonged practice are key components of expert thinking;
- Students are motivated to invest the necessary time and effort;
- Feedback to students is timely and gives guidance about how to improve.

Large learning gains can be made by analyzing the thinking experts use, then having students practice and get feedback on such thinking in class.[3] Let's apply the same approach to design of homework problems. First, consider the components of expert thinking that students should develop.

Generic components of expertise in all fields of science and engineering. Experts are able to[2]:

a) Use specific criteria to decide which concepts are relevant and which are not;
b) Identify necessary concepts for solving the problem;
c) Separate surface features from underlying structural elements that determine which concepts apply;
d) Identify information needed to solve the problem AND what is irrelevant;
e) Look up, estimate or deduce values and/or information that is needed but not given;
f) Make appropriate simplifying assumptions;
g) Break down a complex problem into appropriate pieces;
h) Plan a solution;
i) Move fluently between multiple specialized representations of information to gain new insights. Also identify criteria for deciding which representation is most useful in a given situation;
j) Use specific criteria for choosing when a specific procedure should be used;
k) Carry out routine solution procedures quickly and correctly;
l) Use specific criteria for evaluating and articulating whether a solution or intermediate result makes sense.

Remember those typical back-of-the-chapter physics problems? Rarely are most of these components practiced. Eg:

- a) and often b) get missed since problems tend to focus on concepts in the current chapter.
- d) gets missed since usually all necessary information is with no extraneous information.
- e) gets missed since simplifying assumptions are usually stated ("neglect friction and air resistance").
- Student efforts to address g) and h) are hidden when only a final solution is required (or graded) so feedback cannot be provided.
- i) is rarely practiced since problems tend to be restricted to a context.
- l) is also rarely explicitly articulated in problem sets.

Typical problems end up having student practicing and getting feedback mainly on k) only.

Also, the context of a problem is often stripped away to avoid complicating the routine practice. How many *apparently* meaningless chemical equations have you balanced or frictionless-block-on-ramp problems have you solved in your past? Definitely not very motivating and hence seriously detrimental to mastery of the subject.

***Contact EOS-SEI:** To talk about your course(s) or teaching and learning in general, visit EOS-South 361, or contact Francis Jones, Tara Holland, Sara Bean Sherman (fjones@eos... tholland@eos... ssherman@..., or see http://www.eos.ubc.ca/research/cwsei/.*

Regarding motivation, do your homework tasks pass the "*Why should anyone care about this problem?*" test? The best problems are obviously - to *students!* - relevant and useful to their immediate surroundings or intended careers. This can be challenging. But … if it really is hard to find a useful context, ask yourself why you are bothering to teach this material.

And of course there may well be other aspects of expert thinking you want to include, both more discipline-specific aspects and less (e.g. "*be able to write an articulate well-reasoned explanation …*").

Recommendations

Make some of the design features a) through l) explicit parts of the work students are required to deliver, or make stand-alone problems for specific features. Examples:

1) ask for a list of the concepts that apply and what features of the problem determine that choice;
2) ask students to articulate the quantities, information or assumptions they will need;
3) have them estimate values of quantities not given;
4) require an articulation of procedures or techniques that will be used;
5) have students justify why an answer makes sense and give the criteria used to support that justification.

The aim is to ask for more specific components of the effort other than just a final number or fact. You want to cause far more explicit practice and enable feedback on how to develop and improve expert skills.

YES … I hear you say … BUT IS THIS PRACTICAL?

Grading homework

Here are some options for making such improvements practical, and reducing the grading & feedback burden.

1) Automated grading:
   a) Asking what concepts apply can be made into a multiple choice question, where options are the 20 or so concepts covered in the entire course and students have to choose all that apply. Give these choices for all such problems.
   b) Consider a similar list of criteria for checking if an answer or intermediate result makes sense.
   c) More demanding multiple choice problems can also be made using ranking or ordering tasks of the items.
2) Collect and number feedback comments in a separate document and label individual students work with those numbers. THEN, the numbered feedback list goes to ALL students. This is will save TAs a huge amount of time!
3) Use peer grading, in which students grade each other's solutions. There are computer programs to facilitate the process. An example of one system that has worked well is discussed in reference [4].
4) Grade selectively. Consider grading some fraction (1/2 - 2/3) according to whether or not a solution was handed in, and grade the remainder on correctness with more detailed feedback.
5) Ask your local teaching and learning fellows or colleagues for ideas. Automatic or efficient assessment of high level thinking or specific components of the problem solving task is not easy - until you've seen and done a few!

BUT … "Students never attend to the feedback we so laboriously provide." … Right?

Tips for getting students to USE feedback on homework

Seeing and using feedback to improve is vital for learning. So, here are three ways to encourage students to do this.

1) Include a "reflection" problem in each homework. Eg: "*Review your previous homework and the solution set, and list one (or all) problems you did incorrectly. Identify what you did incorrectly, AND how you need to do it differently on future problems of this type. If you did all the problems correctly, identify how you could improve a solution or which problem was most difficult and explain why.*"
2) Ensure exam problems involve tasks (not the problems themselves) that are *very* similar to homework problems and advertise to the class that this will be the case. It is easier to do this if you have explicit skills-oriented learning goals which make it clear how homework and exams will assess achievement of the learning goals.
3) Explicitly practicing the application of skills or techniques in "novel" settings can be a learning goal with explicit problems that make use of components a) – l).

References: 1. http://cwsei.ubc.ca/resources/files/HomeworkProblems_CWSEI.pdf 2. A. Ericsson, R. Krampe, C. Tesch-Romer, Psychological Review 100, 363-406 (1993); 2. T. Byun and G. Lee, Am. J. Phys., Vol. 82, 906 (2014); 3. Deslauriers, Schelew, and Wieman. 2011. Science 332:862-864; 4. J. Wright, C. Thornton, and K. Leyton-Brown, http://www.cs.ubc.ca/~jrwright/wright2015mechanical.pdf