

Increasing Student Understanding

In the first Teaching Tip (TT)^[1] on Lang's book^[2] retrieval, making predictions, and interleaving were discussed as methods for increasing students' retention of knowledge. In order to use knowledge, it needs to be retrieved at appropriate times. Since knowledge in our brains consists of neural networks, retrieval is easier and understanding is greater when the network of connections is dense. Instructors can increase student understanding with small interventions by: helping students make connections, providing practice and immediate feedback, and requiring self-explanations.^[2]

Students always have some previous knowledge about the course material. Find out what they know, and if it is basically correct make connections to it. Connections to experiences in daily life are particularly powerful for making connections. The experiences are usually accurate (*e.g.*, touching a hot iron pan is painful but touching hot aluminum foil is not), but the explanations will often be incorrect (*e.g.*, students will confuse temperature, heat capacity, and conduction). Connection with their experiences can be used to help students understand why their previous knowledge was incorrect and to start understanding the principles. Students will learn more if your explanation is just enough to get them on the right track to explain the principle themselves. I frequently make the mistake of presenting erudite explanations that are counter-productive because they overload the working memories of my undergraduates. I need to save these explanations for graduate students who already have a knowledge structure for the topic.

Productive practice of skills is Lang's second principle for increasing understanding. Chemical engineering skills such as problem solving are complex. Help the students by scaffolding (providing supporting structure) initially. Divide the skill (*e.g.*, problem solving) into a number of smaller parts and have students practice the individual steps. Multi-step problems are difficult partially because working memory is of limited size. Practicing a step such as converting from mass to mole fractions until it becomes routine helps students solve multi-step problems because routines require much less space in working memory.

If tests require paper and pencil solutions students need to practice paper and pencil solutions in class in addition to practicing with homework. Since practice is not productive if a skill is done incorrectly, the best initial practice is in class with immediate feedback. To provide immediate feedback circulate among the students and ask what they are doing. If an incorrect solution pattern becomes evident stop the exercise and provide feedback to the entire class. Learning will be greatest if practice is spaced as frequent 10 or 15 minute end-of-class sessions.^[2]

Lang's third method for increasing understanding is self-explanation.^[2] Students who explain out loud (to themselves or to others) what they are doing while problem solving are much more likely to self-diagnose and self-correct than students who do not explain out loud. Prompting students to self-explain the principles used to solve problems improves their ability to solve both similar problems (close transfer) and problems that use the same basic principles but superficially look very different (far transfer). You can require self-explanation for in-class exercises with worked-out problems, on homework, and on quizzes by adding a question (*e.g.*, what principle did you use and why?). Initially, give the students a multiple-choice list of principles to select from (*e.g.*, mass balance, energy balance, 2nd law of thermo, momentum balance). The presence of a list provides scaffolding and avoids overloading the working memory of new problem solvers.

Scaffolding is most productive when the initial scaffold is gradually removed. For example, student use of solved examples can be improved with backward fading.^[2] The steps are: 1. Students observe/review solved examples. 2. Students complete one or two short steps in the example. 3. Students complete more steps. 4. Students do the entire problem.

REFERENCES

1. Wankat, P.C., "Teaching Tips: Helping Students Learn Knowledge," *Chem. Eng. Educ.*, **50**(4), 237 (2016)
2. Lang, J.M., *Small Teaching: Everyday Lessons from the Science of Learning*, San Francisco, Jossey-Bass, 2016 □

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This one-page column presents practical teaching, advising, and diversity tips in sufficient detail that others can adopt the tip. Focus on the teaching method, not content. The column should be maximum 550 words, but subtract 50 words for each figure or table. Submit as a Word file to Phil Wankat <wankat@ecn.purdue.edu>.