An Overview of the Worked-Examples Extension of JiTT

Traditional JiTT keeps the classroom pace going by daily warmups which inform the lesson. JiTT warmups encourage the students to examine their prior knowledge and to get informed about the upcoming topic, before coming to class. At the Air Force Academy we are working on a substantial extension of JiTT by requiring the students to actually do some extensive preparatory studying on their own before coming to class. The technique is based on the worked-examples self-explanation approaches [1, 2].

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In a nutshell, here are the main points of this approach:

• New material is introduced via carefully crafted worked examples of problems
• Students study examples, answer questions about the examples, and prepare questions to ask in class
• In class the examples are discussed and extended with practice workouts, underlying concepts are explained
• After the lesson students work additional homework problems

In 1985 Sweller [3] proposed that some student populations might perform better in technical subjects if the form of instruction were inverted. Students would study worked examples and try to construct a rudimentary version of the conceptual knowledge. In-class time would be spent in elaborating on the self-constructed knowledge and firming it up. According to the researchers’ interpretation of the cognitive load theory [1], when learners confront a conventional end-of-chapter practice exercise, they devote too much attention to the problem goal and to relatively weak search strategies such as means-end analysis. To remedy the situation, the students are first invited to study carefully the procedures developed by experts and engage in a self-explanation exercises, answering a series of questions about the example. If our goal is to teach students certain well-defined domains such as algebra or physics, then giving them problems requiring extensive use of "weak" methods may be counterproductive and may even interfere with learning the domain. "A self-explanation is a comment about an example statement that contains domain-relevant information over and above what was stated in the example line itself"

Before class students study a series of examples. In the class that follows, the teacher answers any questions the learners have. When the learners indicate they understand the problems, they are required to explain the goal of each sample problem and to identify the mathematical operation used in each step of the problem. The teacher provides assistance to any learners who have difficulty with the questions. Then the learners
complete similar problems, repeating them until they are solved with no errors; if too much time elapses, the teacher provides the answer.

This method implies, as do all pedagogies, some consequences for the students, for the instructors, and for the course designers.

**Student Side:**
- The daily assignments are just that, daily. There can be no credit for late submissions.
- Recommended sequence for pre-lesson preparation:
  - Start with examples
  - Reach back into the chapter for background
  - Do your best answering the daily questions in writing in your daily journal
  - Prepare questions to ask in class
  - Do the JiTT warmup
- Recommended post-lesson work:
  - Do the homework
  - Abstract in your own words the main concepts from the lesson

**Instructor Side:**
- Treat the pre-class work as a diagnostic tool not an assessment tool. Give credit for effort not correctness.
- Reward the student pre-class work by taking it seriously. Use the class time to build on pre-class work.
- Classroom participation is necessary for classroom climate and to foster/evaluate student learning.
- Classroom activities can include: boardwork; individual and/or group worksheets; clicker questions; class discussion; etc.
- Point out and discuss the concepts that underlie the examples – students are likely to have missed some or all of them.

**Course Design Side:**
- A high percentage of the course grade is based on the instructor’s assessment of the student’s preparation for class
- Materials must be consistent across all sections and all parts of the course: Examples, worksheets, warmups, workouts, Mastering Physics, etc
- It has to be clearly specified what must happen in all classrooms and where the instructor has some flexibility. For example: the warmups and the worked examples must be discussed and student work on these must be checked. The worksheets can be handled according to the individual instructor preference.
- Credit given for student work must be consistent across all sections.
- All activities and materials must be aligned with learning objectives and tests.
A Summary of Worked-Examples Research
Excerpted from:
Brent G. Wilson & Peggy Cole: COGNITIVE TEACHING MODELS
http://carbon.cudenver.edu/~bwilson/hndbkch.html

Cognitive load theory is based on a straightforward reading of information-processing concepts of memory, schema development, and automaticity of procedural knowledge:
--Human working memory is limited--we can only keep in mind a few things at a time. This poses a fundamental constraint on human performance and learning capacity.
--Two mechanisms to circumvent the limits of working memory are:
--Schema acquisition, which allows us to chunk information into meaningful units, and
--Automation of procedural knowledge.
The first mechanism deals primarily with processing and understanding information; the second deals with the acquisition of skills. Each mechanism helps us overcome the limits of working memory by drawing on our long-term memories, which are very detailed and powerful.

Conventional models of instruction in many domains involve the presentation of a principle, concept, or rule, followed by extensive practice on problems applying the rule. This approach at first glance seems like commonsense--providing ample skills practice is "learning by doing." However, cognitive load theory suggests that such instructional approaches may actually be hurting learners' understanding of the subject matter.

Sweller and Cooper examined the cognitive-load effects of methods for teaching algebra to high-school students. They hypothesized that when learners confront a conventional end-of-chapter practice exercise, they devote too much attention to the problem goal and to relatively weak search strategies such as means-end analysis. Students already know how to use general search strategies to solve problems; what they lack is the specific understanding of how cases relate to the general rule.

Sweller and Cooper hypothesized that learners might benefit from studying worked examples until they have "mastered" them, rather than working on conventional practice problems as soon as they have "obtained a basic familiarity with new material." The authors developed an alternative teaching model that emphasized the study of worked examples. After learners acquire a basic understanding of the algebraic principle, they study a series of examples; then the teacher answers any questions the learners have. When the learners indicate they understand the problems, they are required to explain the goal of each sample problem and to identify the mathematical operation used in each step of the problem. The teacher provides assistance to any learners who have difficulty with the questions. Then the
learners complete similar problems, repeating them until they are solved with no errors; if too much time elapses, the teacher provides the answer. Sweller and Cooper found that in the worked-examples model, acquisition of knowledge was significantly less time-consuming than in the conventional practice-based model. Furthermore, learners required significantly less time to solve similar problems (i.e., problems identical in structure) and made significantly fewer errors than did their counterparts. There were no significant group differences in solving novel problems. Thus learning was more efficient with no discerned loss in effectiveness. The authors concluded that "the use of worked examples may redirect attention away from the problem goal and toward problem-state configurations and their associated moves."

Worked examples and self-explanations. One limitation of the Sweller and Cooper study was that only indirect inferences could be made concerning learners' cognitive processes. Chi and her colleagues addressed this issue in the area of college-level physics. They analyzed the think-aloud protocols of good and poor problem solvers to identify the cognitive processes learners used in studying worked examples in physics. Learners in the study did not differ significantly in their prior knowledge of physics; instead, good and poor problem solvers were identified by their performance on objective tests. Chi's worked examples differed from those used by Sweller and Cooper in significant ways. Sweller and Cooper presented worked-example sheets which were not part of a text and which included no verbal commentary. By contrast, the physics examples were part of the text and included step-by-step verbal commentary, although the learners had to infer the "why's and wherefore's" of each step.

Self-explanations were one kind of student response to the worked examples. "A self-explanation is a comment about an example statement that contains domain-relevant information over and above what was stated in the example line itself." Chi found that good problem solvers generated more self-explanations than poor problem solvers and that poor problem solvers used the examples rotely as prompts for solving subsequent problems. Chi and VanLehn conjectured that "the act of self-explaining may make the tacit knowledge...more explicit and available for use." They identified two general sources for self-explanations: "deduction from knowledge acquired earlier while reading the text part of the chapter,... [and] generalization and extension of the example statements."

In an intervention study, Chi et al. found that high-ability and average-ability students benefited equally from being prompted to generate self-explanations. This finding counters other research on strategy training, which has found that such training generally benefits low-ability students while it doesn't benefit and may even interfere with the performance of high-ability students. These discrepant findings might be partially explained by the fact that the earlier studies tended to teach skills rather than strategies.

Summary. Cognitive load theory bears a strong resemblance to traditional instructional-design theories. The prescriptions for instruction require a careful
task analysis that especially considers the memory load implications of different content combinations and instructional methods. The emphasis on well-defined content, worked examples, and careful doses of presented information is reminiscent of Merrill’s Rule-Example-Practice prescriptions for teaching concepts and procedures. The emphasis on careful control over presentation and pacing, and the strongly positive gains attributable to managing cognitive load, serve as prudent reminders of the importance of task and memory variables.

References:

