Teaching Expert Thinking

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Experts and novices differ:
The study of differences between experts and novices has revealed important distinctions in how they organize and apply their existing knowledge and how they learn new ideas.

- Experts have a mental framework for organizing their knowledge while novices do not have such a structure. Experts exhibit:
    - Effortless retrieval of relevant collected facts from memory.
        - Novices tend to remember piecemeal.
    - Fast reasoning through a chain of possibilities.
        - Novices jump to conclusions without exploring what makes sense.
    - Recognition of data, ideas, or conclusions that conflict with prior knowledge.
        - Novices often do not recognize they are living with a contradiction.
    - Efficient integration of related ideas.
        - Novices tend to memorize new ideas rather than integrate them.
- Experts also have developed abilities to perceive structure in evidence or situations. They:
    - Notice relevant structure that cues them to next steps.
        - Novices miss "obvious" cues that should trigger a new line of thought.
    - Recognize whether disparate instances have the same underlying structure.
        - Novices tend to organize examples based on surface features.
    - Spend time to organize cases and evidence to find structure.
        - Novices tend to "dive" into a task without organizing the information.
    - Identify empirical discrepancies that can drive the high effort of idea revision.
        - Novices do not recognize when it is time to revise their ideas.

How do we put novices on a trajectory to expertise?

Just telling students the expert knowledge seems like an efficient way to teach, but it is efficient because it is a shortcut. The price of the shortcut is that students do not develop integrated knowledge structures. This leaves them with the novice characteristics listed above. Telling students is much more effective if they have already engaged in investigating the structure of a phenomenon or idea. Instructors need to avoid the blind spot of assuming that what is obvious structure for them exists for the student. Investigating the structure does not mean solving a series of discrete or step-by-step problems, because students will treat each step as a separate exercise. Instead, one proven way to get students to explore structure is to have them complete "invention" activities. Students receive a set of carefully selected cases, and their task is to invent a compact description that generalizes across the cases. Students do not need to discover the correct answer. Rather, the invention task helps students notice important structure in the cases and to form an organizational framework that prepares them to understand conventional descriptions. After this task, students can be told the expert knowledge. The added benefits of the invention-then-telling approach do not always show up on routine exercises, of the sort given on most exams (though it doesn't hurt). However, strong differences are evident when students are given more expert-like tasks that include learning new related ideas and applying their knowledge to new situations (Schwartz, et al. 1998; 1999; 2005).

A good invention task has specific characteristics (examples in the appendix):
1. Clear goal: The task should present a clear, challenging goal of trying to develop a compact and consistent description or representation of the "important features" across the cases. Typically, the description entails integrating several features in one representation (e.g., a ratio):

- Find an index for pieces of wood that will allow you to predict if they will float or sink,
- Create a graph that you think displays the important patterns from the experiment.
- Design a cell membrane that allows certain substances to pass through but not others.

Test of goal: Is the goal consistent with the sort of thing an expert does when trying to describe novel findings?

2. Contrasting cases: The task should include multiple cases simultaneously, so students notice structure and structural variations that transcend superficial differences.

- Cases should systematically vary on key parameters so students try to see how these variations relate at a deeper, structural level.
- Two to four contrasting cases provide a reasonable level of difficulty.
- A single case works too, if students will spontaneously generate contrasting cases.

Test of cases: Are the cases structured so that a reasonable (but wrong) description based on just one or two of the cases would fail to work for the rest?

3. Context: The task should involve things relatively familiar and meaningful to the students.

- Students should recognize, maybe with help, when a description does not work for a case.

Test of context: Does the task and cases make sense to the students?

4. Level of difficulty: Students should have partial success, even if they do not come up with the solution that took experts centuries to discover and covers all cases.

- When teaching complex ideas, use multiple activities that are each limited in scope.
- Each contrasting cases activity should introduce one or two new structural parameters.

Test of difficulty: Can the students always get started but seldom find perfect/complete answer?

5. Avoid jargon: these trigger the common "What was that formula we learned?" response, rather than, the "This is new task" response. For example, in the wood task, avoid the term density.
Test of terminology: Will students not try to use some process they have learned or can look up?

6. Design cycle: Try with a few students first and modify as needed before using with a class.
Test of design: Do they slowly begin to notice and try to represent the key structures that an expert can see easily in the cases?

7. Collaboration: invention activities work best when done by pairs of students.
Test of collaboration: Do students make comments to each other like, "But, look here, would that work here, for this one?!", rather than dividing up the task and working independently?

A 5-page version of this document with references and examples of invention tasks is available at http://www.cwsei.ubc.ca/resources/instructor_guidance.htm

REFERENCES

Bransford, Brown, and Cocking, *How People Learn; Brain, Mind, Experience, and School*, NAS Press, 2000. Chapters 2 and 3 provide a good general introduction to what is known about expert novice differences in thinking and learning.

Schwartz, D. L., Bransford, J. D. and Sears, D. (2005). *Efficiency and Innovation.* Transfer of Learning from a Modern Multidisciplinary Perspective edited by Jose Mestre. Information Age Publishing; North Carolina (1-52)**.**

This paper considers a new focus on the type of assessment used to evaluate transfer. Transfer literature includes seemingly conflicting perspectives. Some argue that transfer is rare; others argue that it is ubiquitous; still others say it is an unworkable concept. The authors of this paper argue that all of these perspectives are pieces of the truth. The problem lies in how transfer is evaluated. Two types of assessment are described that help explain the apparently contradictory views of transfer literature. Sequestered Problem Solving (SPS) is the typical type of assessment we usually give on exams. PFL offers new information to the students on the exam and then tests if they were able to learn the new information. There are also examples of invention activities and more theoretical description of innovation versus efficiency.

Schwartz, D. L., Lindgren, R. and Lewis, S. (2008). Constructivism in an Age of Non-Constructivist Assessments. *Constructivist theory applied to instruction: Success of failure?* Tobias, S. and Duffy, T. (Eds.). Taylor Francis.

This paper has a nice description of how students construct their own knowledge. It describes why invention activities (innovation) are a very effective way to motivate the creation of a framework for a specific concept in the student's mind before they learn all the facts and procedures about the concept. It explains why providing the facts and procedures about a concept (efficiency training) before the students have developed a framework "short-circuits" the learning process.

Wineburg, S. (1998). Reading Abraham Lincoln: An Expert-Expert Study in the Interpretation of Historical Texts. *Cognitive Science, 22* (319-346).

This paper shows the difference between how an expert tackles new material in comparison to a novice. It provides a general description of their different approaches making it clear that more structure is needed in the instruction of novices to help them learn. This paper shows how an expert handles a new problem in a related field (not their field of expertise) compared to how novices (high school students) handles the same problem. The historians expressed doubts about their interpretations, second guessing themselves and appending strings of qualifications to their conclusions. The students quickly formed interpretations and typically never looked back. The author points out the expert had extensive factual knowledge but that is not what stood out while observing his solution process. "Once he was immersed in the documents it was what he didn't know that came to the fore: his way of asking questions, of reserving judgment, of monitoring affective responses and revisiting earlier assessments, his ability to stick with confusion long enough to let an interpretation emerge. It was how he responded in the face of what he didn't know that allowed him, in short, to learn something new."

Appendix- Three Proven Examples.

Density invention activity (for 8th graders). Cases highlight ratio structure of density.

Inventing an Index

An **index** is a number that helps people compare things.

Miles per gallon is an index of how well a car uses gas.
Batting average is an index of how well a baseball player hits.
Grades are an index of how well you are doing in school.
Star rating is an index of how efficient an electrical appliance is.

We want you to invent a procedure for computing one kind of index.

THE CROWDED CLOWNS INDEX

Companies send clowns to parties, circuses, amusement parks, sporting events, and so on.

To get the clowns to the event, each company packs the clowns into a bus.
Some companies make the clowns more crowded than other companies.

The more crowded the clowns are, the grumpier they will be.

People who order clowns want to know a company's crowded clown index.

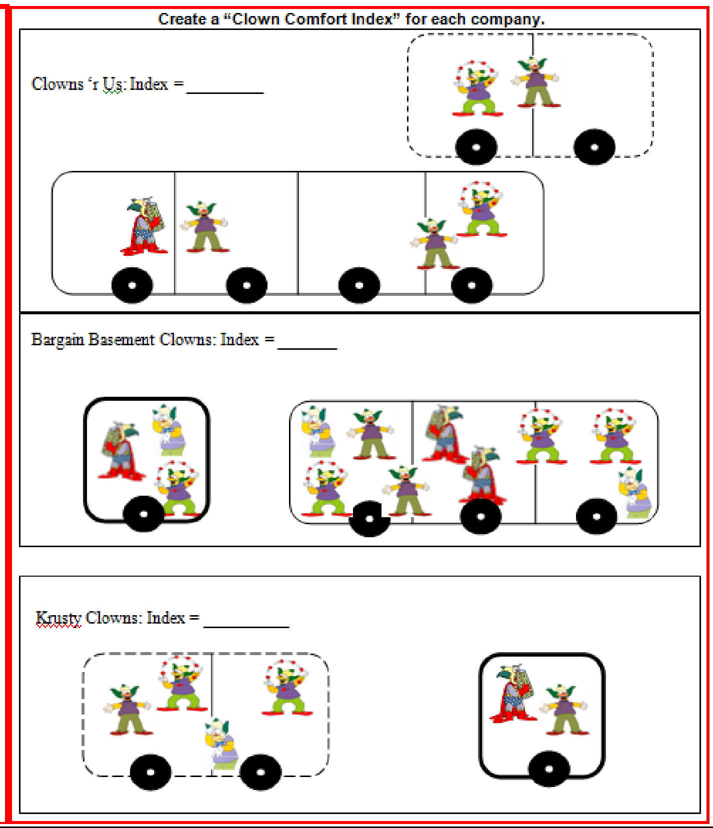
Invent a procedure for computing a crowded clown index for each company.

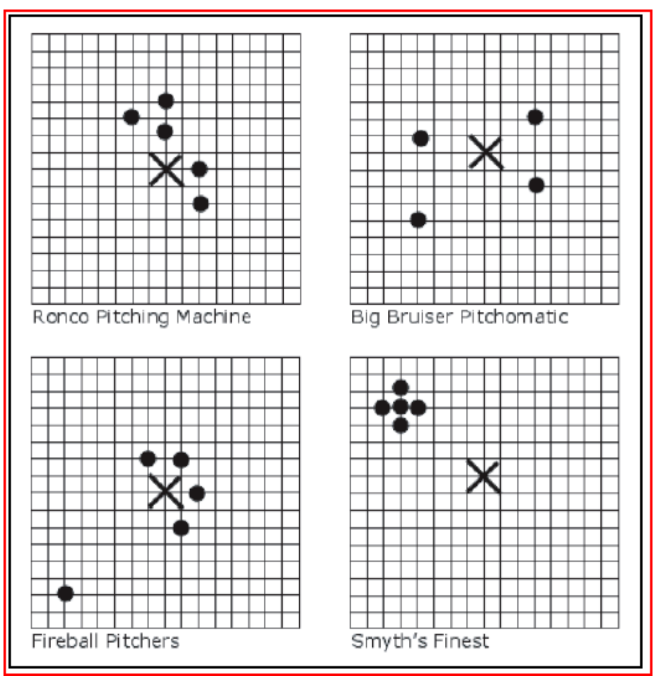
RULES FOR THE INDEX

1. The same company always crowds the clowns the same amount, no matter how many clowns get ordered. So a company only gets a single crowded clown index.

2. You have to use the exact same procedure for each company to find its index.

3. A big index value should mean that the clowns are more crowded. A small index number should mean that the clowns are less crowded.





Variance invention activity. Students have to create "reliability index" for comparing four baseball pitching machines. (Black dots represent where balls landed when thrown at X.) Contrasting cases highlight difference between accuracy and consistency, issue of sample sizes, and so forth.

These cases were followed by focused pair-wise contrasts comparing consistency of trampoline bounciness (values represent height a weight bounced on different drops).
Contrast A: {3 4 5 6 7} v. {1 3 5 7 9}
Contrast B: {10 2 2 10 2 10} v.{2 8 4 10 6 6}
Contrast C: {4 2 6} v. {2 6 4 6 2 4}

<u>Working memory invention activities</u>. Students make 2-3 graphs of the most important patterns (they had to decide what was important). Cases highlight primacy, recency, serial recall.

In the first experiment, researchers asked six people to recall a list of words learned at 1 sec a piece. Here are the words in the order they were studied:

car, sky, apple, book, cup, lock, coat, light, bush, iron, water, house, tape, file, glass, dog, cloud, hand, chair, bag

<u>Here are the words the subjects recalled in the order they recalled them</u>:
Sbj 1: bag, hand, chair, cloud, sky, light
Sbj 2: bag, chair, hand, car, sky, book, house, bush
Sbj 3: hand, bag, chair, cloud, car, lock, dog
Sbj 4: bag, hand, chair, dog, car, apple, sky, water, glass
Sbj 5: bag, chair, car, iron, apple, cup, water, light

In the 2nd experiment, researchers asked 5 people to recall a list of words after a <u>30 second distractor task</u>.

car, sky, apple, book, cup, lock, coat, light, bush, iron, water, house, tape, file, glass, dog, cloud, hand, chair, bag

Sbj 11: car, sky, book, apple, bush, house, glass, chair
Sbj 12: car, sky, lock, iron, water, cloud, bag
Sbj 13: car, apple, coat, bag, hand, file
Sbj 14: car, sky, light, cup, tape, dog
Sbj 15: car, apple, cup, water, glass, house