What should schools teach?

• What’s the problem?
  • Not a problem of mastering repetitive, routine procedures
  • Weakness: inference, problem-solving, critical thinking
• Bruer: Making intelligent novices
  • Develop expertise
  • Develop expertise at becoming an expert
• What is expert problem-solving?
A Nation at Risk (NCEE 1983):

• “Unilateral educational disarmament”

• 1986 NAEP results:
  • Math: multi-step problems w/ variables; exponents & roots; basic functions & coordinate systems
    • passed by 6% of 17-year-olds
  • Science: how data support a theory; experimental design
    • passed by 41% of 17-year-olds
  • Reading: comprehend, summarize, elaborate moderately difficult text:
    • passed by 42% of 17-year-olds
Can Problem-Solving be Taught? Problem of transfer

- Learning [content] vs. Learning-to-learn
  - Can *general* problem solving skills be learned?
  - Can metacognition be taught/fostered?
    - e.g., Paris’s study (cited in Bruer)
Problems of transfer

• Content knowledge is critical:
  • Johnson-Laird IF-THEN problem (Bruer pp. 61-62):
    • in math/logic, novices don’t transfer what they learn
  • adult experts vs. novices solving physics problems:
    • categories: “Newton’s 2nd law” vs. “has springs”
  • child dinosaur experts:
    • infer new dinosaur properties; connectives & comparisons
• MANY studies show failure of transfer. However...
Categorizing physics problems

No. 11 (Force Problem)
A man of mass $M_1$ lowers himself to the ground from a height $X$ by holding onto a rope passed over a massless frictionless pulley and attached to another block of mass $M_2$. The mass of the man is greater than the mass of the block. What is the tension on the rope?

No. 18 (Energy Problem)
A man of mass $M_1$ lowers himself to the ground from a height $X$ by holding onto a rope passed over a massless frictionless pulley and attached to another block of mass $M_2$. The mass of the man is greater than the mass of the block. With what speed does the man hit the ground?
Child dinosaur experts...

- Infer diet of new dinosaurs:
  - Experts used specific physical feature (i.e., teeth); novices cited visible features

- Logical connectives in reasoning:
  "...if they saw a giant meateater, they would duck their heads... so it couldn’t take a bite out of them, or else they’d get the big prickles in them"

- Comparisons:

<table>
<thead>
<tr>
<th></th>
<th>Dino-Dino Property</th>
<th>Dino-Dino</th>
<th>Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert</td>
<td>18</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td>Novice</td>
<td>0</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

- content experts: better inductive inferences
So how do we improve problem solving?

• Is lots of specific content info necessary?
  • Experts make different discrimination; conceptualize problems differently (not distracted by irrelevant info!)
  • Siegler balance scale: Make children aware of relevant features
    • Might be induced from lots of experience, but more efficient to point it out! [But: doesn’t always work]

• What about metacognition?

• Can general skills be induced from expertise in another domain?
Metacognition & high-level problem-solving

- **Metacognitive practices/standards:**
  - Standards of performance (self-assessment)
  - Knowing when & how to learn more (Wineburg)
  - Can these be taught? We don’t know
Naïve reflection; errors prep for “deep” learning/transfer:

- Schwartz & Moore: Compare distribution cases
  - [2,4,6,8,10] vs. [4,5,6,7,8]
  - [2,4,6,8,10] vs. [2,2,10,10]

- Schwartz & Bransford: Learning about memory
  - Summarize → lecture vs. Compare → lecture
  - Transfer correct predictions: ≈ 20% vs. 45%!
...continued

- Critical role of metacognition
  - Self-tests; self-evaluation
  - Comprehension monitoring
How can novices see expert knowledge?

- Learn by discussion (include “expert”)
  - Finding out more using others’ expertise
    - Let students become “local” mini-expert
- Focus on critical information to encode; why (theories!)
  - Balance scale
  - Teaching force vectors: ThinkerTools
Example: ThinkerTools for force vectors

Problem 1. A coin is tossed in the air and follows the path shown in panel A of figure 5.1. In which panel, B or C, do the arrows correctly show the forces acting on the coin on the upward (a) and downward (b) parts of its trajectory?

- Force vectors errors (counting) persist after 1 semester of college physics
Thinker Tools continued...
...continued

- What is slow/hard to learn from experts?
  - THEORIES!
  - “to get ahead, get a theory!” (Karmiloff-Smith):
    - Knowing “why” vs. knowing “that”
- There are examples, but no unified big-scale effort
- Such an effort might include:
  - Teacher expertise in content & metacognition
  - Resources to pose realistic problems
  - Time to teach content and theory and elicit errors/confusion
“Schools for Thought” summary

• Weak methods in schools

• Problem of transfer

• What makes experts experts?
  • Expose expert thinking; teach relevant information, model/make explicit expert problem solving

• Make students aware of relevant info
  • Struggle with ignorance/error, get them to reflect on the reasons for ignorance/error, and best ways to reduce ignorance/errors (efficiently)