Classroom Applications of Top-Down & Bottom-Up Processing

Neuropsychological research has added to the understanding of cognitive processes
Recent research in cognitive neuroscience has yielded a more comprehensive understanding of brain function. Some of these diagnostic techniques include the event-related potential (ERP), which depicts brain electrical activity, and magnetic resonance imaging (MRI) and positron emission tomography (PET), which are particularly sensitive to the delineation of brain areas. These techniques provide an insightful look at cognitive processes that are not readily studied by behavioral measures such as surveys or reaction time.

The advances in neuropsychological research have greatly added to our understanding of top-down and bottom-up processing. However, top-down and bottom-up processing is a neglected issue in education even though it is a critical component in language, attention, object recognition, and problem solving. Awareness of its role by teacher and student, though, may improve student learning.

Defining top-down and bottom-up processing

Bottom-up processing is stimulus-driven processing whereas top-down processing is driven by our knowledge, experience, and intentions, which are relatively voluntary and stimulus independent. For example, during bottom-up processing of a word, we notice the orthography and phonology of the word—the arrangements and sounds of letters in words. Our senses convert these stimuli to neural signals that are sent to primary, low-level areas of the brain. We then integrate the features in high-level areas.

During top-down processing of a word, we can use our lexical knowledge, for instance, to identify the incoming word as we connect the word to our knowledge of other related words and concepts. Areas of the brain that coordinate information would be activated first during this high-level thinking.

A similar analysis is possible with attention. When a child is given a cue about where an image will appear during a video game, the child will use top-down processing to selectively attend to that particular area. The child later uses bottom-up processing to analyze details of the image once it appears so he or she can make a response decision.

In problem solving, excessive top-down processing can impede achieving one's goals. "A Ladder of Thinking for Students" (Lovrich 2004) used ambiguous pictures in a metacognitive lesson so students could discover how using their previous knowledge prematurely—before they finished bottom-up processing of all of the details—could cause them to misinterpret words or diagrams. Besides its application to cognition, this up-down directional nature of our thinking also manifests itself in neurophysiological measures. Intriguing findings from recent MRI, PET, and ERP studies of attention and language continue to be critically evaluated for evidence of top-down and bottom-up processing (for example, Federmeier and Kutas (2001), Frith (2001), Lovrich, Cheng, and Velting (2003), and Deacon et al. (2004).) See Figure 1 for an illustration of bottom-up and top-down processing.

Relevance to education

The existence of neurophysiological indicators of a cognitive process does not make an idea educationally fruitful. However, there is concern in science education that assessments reflect not only a student's scientific knowledge but other abilities as well (Clerk and Rutherford 2000; Harlow and Jones 2004). In the classroom, I often have motivated students who appear to have a deep level of understanding yet perform poorly when asked to read questions and solve problems on an examination. When reviewing test corrections, students sometimes miss a word or part of a figure, suggestive of too much top-down processing. These observations and recent research findings made me suspect that these students were having difficulties in the encoding stage of problem solving.

Helping students become more aware of top-down and bottom-up processing might enhance their ability to adjust their thinking productively during problem solving. Thinking about how one is accomplishing a task, or metacognitive processing, has usually meant asking children to reflect upon their work after they finish a task (e.g., White and Fredericksen 1998). The current classroom approach usually involves presenting and modeling metacognitive techniques for students; however, the context from which the techniques derive...
1. The diagrams below represent some events in a cell undergoing normal meiotic cell division.

Which diagram most likely represents a new cell resulting from meiotic cell division of the cell shown above?

2. If cell 2 has 30 chromosomes, cell 3 should have

A) 30 chromosomes  
B) 15 chromosomes  
C) 45 chromosomes  
D) 60 chromosomes

3. Which diagram best represents part of the process of sperm formation in an organism that has a normal chromosome number of eight?

4. The diagram to the right can be used to illustrate a process directly involved in

A) tissue repair  
B) recombination  
C) sexual reproduction  
D) meiosis

importance is usually not explained. This is analogous to students learning a laboratory technique without knowing why they are doing the procedure. Telling why improves comprehension. Knowing why may be one of the most important dimensions for the construction of a language-based mental model of a situation (Zwaan and Radvansky 1998) as well as encoding (Calin-Jageman and Ratner 2005).

Using top-down and bottom-up processing in the classroom

To this end, I often include a lesson in my classes on the importance of top-down and bottom-up processing (Lovrich 2004). Recently, I have tried to help students apply these concepts to reading examination questions, which seemed to be a circumscribed yet meaningful activity. While students were investigating metacognition, they were also gaining practice answering questions on topics such as DNA, ecology, the cell, diffusion, osmosis, cell division, and enzymes.

Experimentation, metacognitive instruction, and reflective assessment were used to “challenge students to accept and share responsibility for their own learning” (NRC 1996, p. 32). The learning cycle, consisting of discovery followed by a lesson and concept application, was modified to include metacognitive activities (Blank 2000). Both discovery and concept application stages ended with reflective assessment about the strategic thinking involved, not the scientific content of the questions. In order to have published data for comparison, the reflective assessment was adapted from the Thinker Tools Curriculum, a program involving computer simulations, scaffolding, and extended experimentation (White and Fredericksen 1998). The assessment included questions on the following categories: understanding main ideas and experimentation, being inventive and systemic, reasoning carefully, communicating well, and teamwork.

Questions with subtle details in diagrams or wording were chosen
**FIGURE 3**
Sample student strategies for answering biology questions before and after the metacognitive lesson.

<table>
<thead>
<tr>
<th>Before lesson</th>
<th>After lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student Group 1</strong></td>
<td><strong>Student Group 2</strong></td>
</tr>
<tr>
<td>1. Read the question.</td>
<td>1. Look for key terms (i.e., words you know) and underline them.</td>
</tr>
<tr>
<td>2. Look for key words and most important text.</td>
<td>2. Read the question and cover your answers and try to think of the answer, and once you have, look and see if it is one of the choices.</td>
</tr>
<tr>
<td>3. Read answers.</td>
<td>3. Take your time reading and answering the questions; pace yourself.</td>
</tr>
<tr>
<td>4. Use your knowledge from biology.</td>
<td>4. If you are stuck on a question, move on to the next one and go back to it later.</td>
</tr>
<tr>
<td>5. Choose the best answer for the question.</td>
<td>5. After you have completed the test, go back to all questions and double-check them to make sure the answer you chose is the best one.</td>
</tr>
<tr>
<td>6. Reread the question.</td>
<td>6. Eliminate the choices you know are not correct.</td>
</tr>
</tbody>
</table>

Out of 48 participating students, 41 students (85%) handed in their work. The reflective assessment rating scales were analyzed with Wilcoxon Matched-Pairs Signed-Ranks statistical tests. The main finding was evident in the "being inventive" category. There was a developing a strategy about how to answer a question. Using a neighboring lab group, students tested their plan with the second question set from their packet. Finally, the neighboring lab group evaluated the plan with rating scales, ranging from 1 (not adequate) to 5 (exceptional) with 3 (adequate) as the midpoint, for each of the reflective assessment categories.

During a 40-minute period the following day, the students participated in the metacognitive lesson (Lovrich 2004). During the final double period, students tried to apply the concepts from the lesson to the third question set by modifying their original strategy. Students again tested their new plan on the same neighboring student group, and the group evaluated the new plan. Students then completed their report by graphing the scores on each of the categories of the assessment questionnaire and answering questions. Their reports were graded as part of a course requirement.

Out of 48 participating students, 41 students (85%) handed in their work. The reflective assessment rating scales were analyzed with Wilcoxon Matched-Pairs Signed-Ranks statistical tests. The main finding was evident in the "being inventive" category. There was a
significant increase in student perception of the inventive-ness of the strategies ($Z=3.07; p=.002$), with a score of 4.1 after the lesson as compared to a score of 3.6 before the lesson. Two samples of student groups’ plans from before and after the lesson on bottom-up and top-down processing are displayed in Figure 3 (p. 31). At the end of the packet, students were asked additional questions about the impact of the lesson on their thinking. Some of the most enlightening responses are listed in Figure 4.

**Impacting student thinking and learning**

The metacognition lesson had its greatest impact on being inventive, indicating that students thought their neighbors’ strategies improved in creativity and originality. In the White and Fredericksen (1998) study, the “being inventive” question was combined with “being systematic” to form a summary design variable. In that study, scores for design as well as reasoning carefully and teamwork were significantly better for the reflective assessment group than the controls. The current demonstration was not an experiment with controls and objective assessments. Although the present findings are not definitive, they suggest that the metacognitive lesson on bottom-up and top-down processing had a positive impact on student thinking and learning.

When taking tests, students repeatedly neglect routine words and details in questions. It was a revelation for some of my weak students that reading slowly and deliberately—employing bottom-up reasoning—was a productive strategy. Understanding and reflecting upon processing with material in a specific content area has the potential to improve both skill set and knowledge base simultaneously, facilitating student improvement wherever it is needed. Especially in the context of a biology course, educational programs that promote metacognitive awareness and better understanding of brain functioning provide rewarding experiences for both student and teacher.

**References**


COPYRIGHT INFORMATION

TITLE: Classroom Applications of Top-Down & Bottom-Up Processing
SOURCE: Sci Teach 74 no1 Ja 2007
WN: 0700100742014

The magazine publisher is the copyright holder of this article and it is reproduced with permission. Further reproduction of this article in violation of the copyright is prohibited. To contact the publisher: http://www.nsta.org/highschool

Copyright 1982-2007 The H.W. Wilson Company. All rights reserved.