34 Operational Enrichment
Improving Operational Reasoning through the Content of Teaching

Benő Csapó, Attila József University, Hungary

The philosophy of Operational Enrichment

Schools today are having to cope with two different sets of cognitive goals. On the one hand, they are expected to cultivate pupils' intellectual abilities, to improve their higher order thinking skills or even to teach intelligence per se. On the other hand, the natural sciences and, more recently, the social sciences as well are producing knowledge at an accelerated pace and schools are supposed to teach a large part of it. Given the limited time within which schools have to reach these goals, only one set of goals, usually the teaching of domain knowledge, receives sufficient attention.

The main reasons why goals concerning domain knowledge receive greater emphasis are that (1) thinking skills are difficult to define, (2) methods for developing thinking skills are less elaborated, and (3) programmes aimed at improving thinking are difficult to accommodate in regular school instruction.

The basic assumption of Operational Enrichment is that the goals concerning domain knowledge and thinking skills are not contradictory. They should not compete for instruction time; instead, they can be harmonised by integrating the transmission of subject matter knowledge and the development of thinking abilities. Teaching domain knowledge, if it is well structured and rich in thinking operations, may best improve thinking. Furthermore, practising thinking operations helps to improve the understanding of subject matter.

Operational Enrichment is not just a collection of training exercises; rather, it is a technique that can be applied to most school subjects. It comprises (1) defining the target skills (thought operations), (2) analysing teaching materials to identify points where specific thinking operations occur or can adequately be placed, (3) devising training exercises and (4) implementing them in regular classroom instruction.

Theoretical sources

According to Piaget's theory of cognitive development, logico-mathematical structures are the central components of the intellect and the environment is the source of the development of these structures. Through acting with the objects around us, we internalise the structure of the operations and then we become able to carry out these operations with symbols and propositions as well.

When we are looking for a framework for improving operational reasoning, we can learn a great deal from Piagetian theory. In particular, the impressive description of the system of thought operations is a useful basis for defining the thinking skills to be developed.

However, several experiences indicate that further considerations are also necessary. For example, the logical operations internalised in one familiar content domain cannot simply be used in another, unfamiliar content domain. Recent theories of cognitive psychology take into account these experiences by emphasising the importance of content related skills, domain specific thinking schemata and specific contexts.

To define the thinking skills to be developed, we reformulated the original Piagetian system of formal operations and identified three groups of operations: (1) the group of logical operations, which contains the binary operations of propositional logic; (2) the system of combinative operations, which is enhanced by taking into account further combinatorial structures not studied by Piaget and his co-workers; and (3) the group of systematising operations, which contains the operations of ordering (binary relations), class inclusion, classification, and multiple classification. This analysis resulted in approximately three dozen operations that form the target skills in Operational Enrichment (see Csapó, 1985a, 1985b).

Devising training materials

In this training programme no new materials are introduced. The existing teaching materials are restructured and the teaching and learning methods are modified and enriched with specific activities and exercises. The purpose of these activities is not only to practise operational reasoning, but also to improve the understanding and mastery of subject matter. The method can best be illustrated with several examples.

Science textbooks often contain complex sentences. The texts are logically consistent, but children are often not equipped with the thinking skills that would allow them to comprehend the meaning of the sentences. Exercises like the following may help to improve understanding and at the same time train logical reasoning.

Example 1   Systematic evaluation of the truth-table of a complex proposition.

Newton's first law of motion states: A body remains at rest or in uniform motion in a straight line unless acted upon by a force. Which combinations of the three simple propositions (a body 'is acted upon by a force', 'remains at rest', 'remains in uniform motion in a straight line') can be true at the same time according to Newton's first law?

1   Is acted upon by a force. Remains at rest. Remains in uniform motion in a straight line. (All pairs of the three statements are mutually contradictory.)

2   Is acted upon by a force. Remains at rest. Does not remain in uniform motion in a straight line. (The first and second statements are contradictory.)

3   Is acted upon by a force. Does not remain at rest. Remains in uniform motion in a straight line. (The first and third statements are contradictory.)

4   Is acted upon by a force. Does not remain at rest. Does not remain in uniform motion in a straight line. (True according to Newton's law.)

Etc.

The next example shows how the elements of teaching material can be used to practice combinatorial reasoning.

Example 2   Distinguish between the existing, the possible, and the impossible
(but conceivable) combinations of things.

Let us enumerate the words Sun, Earth and Moon in all possible sequences.
Which sequences reflect a possible position of the sun, the earth and the moon?
If the three celestial bodies are in one straight line, in which cases can there be an
eclipse of the Moon, and in which cases an eclipse of the Sun?

Sun - Earth - Moon (lunar eclipse)
Sun - Moon - Earth (solar eclipse)
Earth - Sun - Moon (not possible)
Earth - Moon - Sun (solar eclipse)
Moon - Sun - Earth (not possible)
Moon - Earth - Sun (lunar eclipse)

Designing exercises and integrating them into the teaching process can take
place at different levels of the educational system depending on the type of
administrative organisation of the school system in a specific country.
Curriculum developers, textbook writers and designers of educational materials
can directly integrate these operations into their materials. Teacher source books
can also be published from which teachers can choose exercises according to their
intentions and the needs of their pupils. Groups of teachers in a school or in a
school district can also develop exercises for the teaching materials they use.

Principles of application in the classroom

The training exercises designed to practice operational reasoning should be
seamlessly integrated into the teaching of subject matter. They can be applied to
any usual way of teaching, e.g. in the form of pupil-teacher interaction, group
work, individual work, homework, etc.

No additional time need be used to carry out the exercises. The training mater-
ial is not an addition; rather, it should substitute for traditional materials or exer-
cises. Nevertheless, the original goals of instruction should not be reduced or
replaced with the goals of teaching thinking skills; instead, accelerated develop-
ment should be an additional benefit of the modified teaching. In other words,
the training should only be used if it can be expected to improve the acquisition
of content knowledge as well.

From a few exercises only a small effect can be expected, so the training should
be allowed a longer period of time. The experiments suggest that the optimum
number of exercises is between 30 and 50 tasks per year in a school subject. If it is
used only in one domain only, the transfer to other domains may be limited, so it
would be better to apply it simultaneously in several school subjects. The more
school subjects are enriched with the specific operations, the broader the transfer
that can be expected.

Experiments, assessments and further research

To assess the applicability of Operational Enrichment in regular school instruc-
tion and to measure its effects on reasoning, several feasibility studies with vari-
ous teaching materials have been carried out. Among others, combinative ability
was successfully improved through the enriched mathematics teaching materials
(Csapó, 1989).

The most systematic assessment took place during a one year experiment which also examined at what ages the particular skills of operational reasoning can be best improved. The experiment took place in two age groups in Hungarian primary schools. In the fourth grade integrated science and grammar, and in the seventh grade chemistry and physics formed the content of the training tasks. Some 50 specific exercises were integrated into regular instruction. Altogether more than 70 classes in 28 schools participated in the experiment. The results indicated that in combinatorial reasoning significant improvements took place in both age groups and in logical reasoning only in the younger age group. No significant improvement took place in systematising ability, but results suggested that these operations probably could be developed at younger ages (Vidákovich and Csapó, 1988; Csapó, 1992).

In one of the most interesting applications, combinatorial exercises were devised and applied to art education. The exercises fostered pupils' creativity in producing a larger variety of figures, shapes and colours in their drawings (Zombori, 1992).

The generalisation of Operational Enrichment is in progress. A more general theoretical framework (Procedural Enrichment) is to be developed that extends the scope of research in two dimensions: (1) involving more general thinking skills (e.g. inductive reasoning), and (2) involving older pupils (up to 17 years of age) in the training.

References

Csapó, B. (1985a). Development of combinatoric operations from 10 to 17 years of age. Eighth Biennial Meetings of ISSBD, Tours, France. *Cahiers de Psychologie Cognitive, Vol.5.* No. 3/4, 439.

Csapó, B. (1985b). Untersuchung der kombinativen Fähigkeit und ihrer Operationen bei 14-jahrigen Kindern. In H. J. Henning, & P. K. G. Günther (Eds.), *Causal and Soft Modeling (Ergebnissband der 2. Bremer Methodenkonferenz, 1984).* Bremer Beiträge zur Psychologie, Nr. 43. 29-75.

Csapó, B. (1989). Integration of the development of the operational abilities of thinking and the transmission of knowledge. In Mandl, H., De Corte, E., Bennett, N., & Friedrich, H.E. (Eds.), *Learning and Instruction. European Research in an International Context, Vol. 2.2.* Oxford: Pergamon Press.

Csapó, B. (1992). Improving Operational Abilities in Children. In A. Demetriou, M. Shayer & A. Efklides (Eds.), *Neo-Piagetian theories of cognitive development. Implications and applications for education.* London: Routledge and Kegan.

Vidákovich, T., & Csapó, B. (1988). *Changes in students' logical structures after a 10-month period of experimental training.* Poster presented at the Third European Conference on Developmental Psychology, Budapest, 15-19. June, 1988.

Zombori, B. (1992). Visualität und Variationen: Zeichenaufgaben zur Förderung kombinationatorischer Fähigkeiten. In I. Bak, A. Kárpáti, O. Scholz, & A. Volger. (Eds.), *Aesthetische Erziehung in Ungarn.* Berlin: Hochschule der Künste.

Developer	Benö Csapó
Goal	To improve children's operational reasoning; to provide curriculum developers, textbook authors, designers of educational materials and teachers with methods of composing well-structured exercises that are related to the content of teaching.
Sample skills	Understanding and interpreting complex propositions in the context of school subjects; combining concepts, elements and attributes in the framework of acquiring subject matter knowledge.
Assumptions	Teaching materials offer rich possibilities to compose exercises for pre-defined operational structures. Operational reasoning can be improved through content-base exercises. Working with content-based operational exercises enhances the understanding and mastery of subject matter as well.
Intended audience	Primary school children through 8th grade.
Process	Working with exercises with a specific operational structure that are embedded in the teaching materials, within the framework of regular school instruction.
Time	One to three tasks per week up to approximately 50 exercises per school year.
Further information	Benö Csapó, Department of Education, Attila József University, 6722 Szeged, Petöfi sgt. 30-34, Hungary Telephone & Fax: + 36 62 321034 E-mail: csapo@sol.cc.u-szeged.hu