

# ACCELERATING INTELLIGENCE DEVELOPMENT THROUGH INDUCTIVE REASONING TRAINING

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## INTRODUCTION

In most human endeavour, including science, we can distinguish two forms of reasoning, that is, inductive and deductive. Both forms are considered higher-order thinking skills. According to Willis, Hovey, and Hovey (1987), a higher-order thinking skill is the ability to absorb information, organize it into meaningful units, identify the essentials or principles included in the information, and then put them to work solving other problems.

Inductive reasoning is described as deriving a general principle from specific examples (see, among others, Jacobs, 1982). In inductive reasoning, for instance, investigators observe a number of facts, find a pattern, generalize the pattern into a “law” or organizing principle, and then explore whether and to what extent the principle could be applied in practice, or try experimentally to discover the boundaries of possible applications.

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An illustrative example of this form of reasoning is Kepler, who studied the data on planets, analyzing the numbers in all kinds of ways, before discovering a striking relationship between a planet's distance from the sun and the time it takes to complete an orbit. Darwin devoted years to examining the essential statistics of different species before formulating the principle of natural selection (Lightman, 1997).

A recurrent question is whether training in higher-order thinking skills—for instance, inductive reasoning—affects the level of intelligence as measured by traditional tests. The aforementioned issue not only concerns raising the level of intelligence test scores; the question as to whether a change in cognitive representation has occurred is just as important.

Many researchers postulate that higher-order thinking skills are essential for learning, and inductive reasoning is considered a basic higher-order thinking skill (Csapó, 1997). Adey and Shayer (1995), for instance, have shown that the greater the mastery of higher-order thinking skills, the more children benefit from regular education. Besides Adey and Shayer (1995), Resnick (1987) emphasizes the teachability of higher-order thinking skills and argues that it is necessary to activate higher-order thinking even in basic skills like learning to read, write, and do mathematics. As a consequence, different training programs emerged based on diverse theoretical approaches to higher-order thinking skills. In all the various studies involving training programs, the assumption has been that the subjects could be trained in higher-order thinking skills. Besides trainability, another important issue is whether the programs bring about a change in cognitive representation.

In general, one can distinguish three mainstream theories of cognitive representation (Tomic & Kingma, 1996). The first theory was developed by Piaget, the second by Bruner, and the third by Vygotsky. The latter theory was worked out in greater detail by Galperin (1966) and others. However, the above-mentioned theorists and the researchers who conducted experiments according to the three classic theories think quite differently about the effects of training in higher-order thinking skills. A survey of various training experiments shows that different evaluation standards are used to measure training effects (Kingma, 1981; Tomic, Kingma, & TenVergert, 1993; Tomic, 1995a, 1995b; Tomic & Klauer, 1996). This means that researchers disagree as to when it can be assumed that a child's cognitive representation has changed.

### **TRANSFER AS A CRITERION FOR EVALUATING THE SUCCESS OF TRAINING**

The concept of transfer is a *conditio sine qua non* for observing any change in cognitive representation. One of the most important detailed and feasible standards was devised by Brainerd (1975a, 1975b), who describes the success of training in terms of near-near transfer, near-far transfer, and far-far transfer. In the first

instance, the posttest contains the same problems in which the subjects have been trained. The point is to study whether the children trained in these tasks score better on the posttest than the control group children, who receive no training. In the case of near-far transfer, the posttest contains problems similar to those in which the children were trained but which were not themselves included in the training program. A training effect is said to have occurred when the trained children are able to solve the near-far transfer problems better than the untrained children. Finally, far-far transfer also requires the children to have made progress in other types of tasks. For example, they might demonstrate a significant improvement in solving seriation problems even though they have only been trained in conservation problems.

We will continue this section with an observation related to the three mainstream theories of cognitive representation and their criteria for evaluating the success of training. According to Piaget (1957, 1975), a training effect only reflects a change in the child's cognitive structure if it meets the following standard, consisting of three criteria. First, the training or learning effect should be evaluated from the perspective of spontaneous cognitive development. The crucial question is whether training has brought about a change in the entire cognitive structure. Second, skills should have been transferred to concept areas in which the child has not been trained. Third, the training effect should be durable.

The first criterion implies that the child's cognitive level must be determined before and after training. With respect to the level after training, the researcher must establish that cognitive functioning has undergone a definite change compared to the pretest level. The focus is on determining whether the learning experience has resulted in a more complex structure.

The second criterion is an operationalization of the first: the translation of the theoretical concept of change into measurable terms. Transfer means the application of newly acquired knowledge and skills in different situations. To measure the range of the transfer, the posttest includes problems related not only to the specific area in which the child was trained, but also to other conceptual fields. For example, if training involved conservation of number, then the posttest would include not only conservation of number problems but also conservation of quantity (Inhelder, Sinclair, & Bovet, 1974). However, even if a child can solve both types of conservation problems correctly (that is, in addition to finding the right answer, the child also offers the right arguments for his or her solution), we still cannot conclude that training has given rise to a more complex cognitive structure. To determine whether this is so, the posttest must also contain different types of tasks enabling the researcher to examine whether the change in the cognitive structure is such that we can detect an improvement in representation (Tomic & Kingma, 1996).

Determining a change in the cognitive structure is a necessary, but inadequate, criterion for determining whether training has been successful. The change observed must also meet the third criterion: it must be durable. In the Geneva train-

ing studies, the long-term effectiveness of training was established by means of a second posttest administered a few weeks after the first one.

The sharp rise in the number of training experiments in which children were taught Piagetian concepts culminated in a gigantic database concerning training effects.

Researchers within the action psychology approach also formulated criteria for evaluating the success of training. The standard used by Galperin (1966) to determine the success of a course of training is highly similar to the requirements set by Piaget (1964) for successful training. Broadly speaking, Galperin's requirements (Obuchova, 1966) consist of the following elements: first, instruction must induce a transferable action structure; and second, the effect of training must be durable.

To determine whether training has resulted in a transferable action structure, children are given a wide range of tasks to perform after being trained. These action-psychology researchers do not use the term transfer, however; rather, they talk of research into the functioning of the learning outcome, indicating by this that in the case of a positive training effect, the action structure (meaning the representation) has changed. Such a change can be deduced from the children's performance on the three types of transfer problems described previously. A significant similarity to Piaget's standard with respect to the assessment of training effectiveness is, therefore, the inclusion of a variety of tasks set for the children on the posttest.

The second requirement, that the effect of training should be durable, also resembles Piaget's standard. Closer analysis reveals that Galperin's (1967) standard for evaluating the success of training is in fact much stricter than Piaget's criterion (Kingma, 1981). When this strict standard has been met, there is a sound basis for determining, first of all whether an action has been internalized and, second, whether that cognitive representation has consequently advanced to a higher level.

Many educational experiments employ Bruner's method for inducing a conflict between the forms of representation (appearance and reality). In most of these studies, researchers have not included a check to determine whether representation has been influenced by learning. According to them, the child's ability to find successful solutions to the problems in which it has been trained is often decisive in determining whether training has been successful (see Kingma, 1981).

Bruner's ideas concerning the positive influence that education has on cognitive development appeal to a great many teachers. While it is true that Bruner's pedagogic instructions have been adopted, the issue of actual teaching success—that is, a change in representation—is never raised.

In the 1960s and 1970s, many American researchers shared a great deal of optimism about the possibility of influencing cognitive development through short-term training. In general, research could be characterized by simple training experiments conducted in specific well-controlled settings and producing small-scale significant but nevertheless weak effects (Kingma & Koops, 1988). In most of

these studies, researchers did not include a check to determine whether representation has been influenced by learning. If the results of these American studies are analyzed by applying Piaget's standard for measuring the effect of training, as well as his criteria, then they appear to have produced rather specific, short-term training effects with only a small degree of transfer. What stands out is that many of these studies do not even bother to investigate durability of effects (Kingma & Koops, 1988).

Despite the large number of researchers who took Bruner's ideas concerning the development of representation as the starting point in designing their training studies, more than 97% of these studies did not investigate whether training did in fact bring about a change in the students' representation (see Kingma, 1981).

Nevertheless, according to Piaget and Galperin, only when stringent criteria for evaluating training effects are met—that is, when the child can solve a wide range of transfer problems after training and when the results of training are durable—can one conclude that the child's representation has changed.

## TRAINING FOR INDUCTIVE REASONING

Klauer designed a complete program for training subjects in inductive reasoning skills (Klauer, 1989c; Klauer & Phye, 1994). The rationale of the training program is that the aptitude of inductive reasoning consists of cognitive processes that refer to using analogies, calling on psychological processes such as generalization, discrimination, and a metacognitive monitoring strategy that implies the checking of objects and relationships for similarities and/or differences. The purpose of the inductive reasoning training program is to invoke a change in cognitive representation.

To evaluate the success of a training program in cognitive development, stringent transfer criteria should be used. Far-far transfer is considered to be especially strong evidence that a change in the child's cognitive structure has occurred. For this reason, in our own study, described below, we included some far-far transfer tasks in the posttests; that is, arithmetic problems relating to inductive reasoning which were not covered during training.

During the last 20 years, there has been growing interest in classroom instruction focusing on teaching and learning in small groups. According to some researchers (Slavin, 1990; Johnson & Johnson, 1992), this form of instruction, sometimes also characterized as team learning in small groups, seems promising for all children. Learning in small groups appears to be an intriguing instructional substitute for particularly heterogeneous classes. In the present study, it was therefore decided to administer training in small groups.

With regard to training, a type of feedback was chosen whereby after each task, the child is told whether the given response is correct or incorrect. In the case of an incorrect response, this type of feedback extends to telling the child why its

response was incorrect. This resembles the concept of corrective feedback as described by Bloom (1976). One particular advantage of feedback is that the child is given the opportunity to change his solution strategy. Moreover, providing feedback leads to a more natural situation between trainer and child, since in the regular classroom situation the child is also used to hearing from the teacher whether the answer to a question is correct or incorrect.

The purpose of the present study was to investigate the effect that a training program in inductive reasoning has on childrens' performance on intelligence test tasks and the range of transfer according to the criteria of Piaget and Galperin, in order to determine whether cognitive representation has changed. Second, in addition to any observed effects, it seemed important to also investigate the durability of the observed effects. To study the after effect of training, an interval of four months was chosen, which satisfies both Piaget's and Galperin's stringent criteria for successful training. Third, an important goal was to determine the range or types of transfer induced by the training program. The fourth issue was whether training could be implemented in, and was effective when, administered in small groups (to enable children to provide feedback to each other) rather than on an individual basis. Two advantages of this approach are that it is an attempt to do justice to standard teaching practice and that children can provide one another with feedback about their solutions to inductive reasoning tasks (Kingma & TenVergert, 1993a, 1993b).

## METHOD

### Participants

The study was conducted at a primary school that has a population of about 220 students from kindergarten to sixth grade. The population consists of students from relatively diverse ethnic backgrounds. The school is situated in the suburb of a city of about 100,000 inhabitants.

Forty-seven third grade primary school children from two classes participated in this investigation. The experimental and control groups consisted of two classes from each grade. The third grade level was chosen in order to compare findings with similar populations in previous training studies (Klauer, 1989a, 1990a, 1990b, 1992; Phye & Sanders, 1993; Resing & Verbaecken, 1993; Tomic, 1995; Tomic & Klauer, 1996). Of the 23 children in the experimental group, there were 12 boys and 11 girls. The experimental group had a mean age of 82.4 months (*S.D.* = 3.6), and a mean IQ row score of 8.4 (*S.D.* = 1.6). The control group consisted of 24 children and was made up of 14 boys and 10 girls. The control group had a mean age of 81.2 months (*S.D.* = 4.0) and a mean IQ row score of 8.9 (*S.D.* = 1.8). The Raven's Coloured Progressive Matrices Test (1990) was used to measure (fluid) intelli-

gence. All children were treated in accordance with American Psychological Association guidelines for human subjects.

### Design

In the present study, a two-factor pretest-posttest control group design was used (Cook & Campbell, 1981). The first factor concerns the training and has two levels: (1) training (experimental group), (2) no training (control group). The effect is the second factor (two posttests) and has two levels: (1) scores on the Raven Coloured Progressive Matrices Test, and (2) scores on arithmetic tasks.

During the pretest, 47 third grade primary school children were administered the Raven Coloured Progressive Matrices Test, Set A (Raven, Court, & Raven, 1990). No other tests were administered. The assignment of classes to the experimental (training) condition ( $N = 23$ ) and the control condition ( $N = 24$ ) was random. The 23 children from the experimental group received training—ten 30-minute sessions—on each school day for a period of three weeks. Within the same time frame, their control group counterparts—24 children—had to complete tasks from the regular school curriculum. One day after training was completed, the first posttest was administered (consisting of Raven Coloured Progressive Matrices Test, and arithmetic tasks) to the trained children and their counterparts in the control group. This test was repeated four months after the first posttest was administered.

Analyses were conducted to determine the main effects of training on the immediate and delayed near-far and far-far transfer performance of the trained and untrained group of children. To test the significance of the differences between the trained and untrained children, an analysis of covariance was conducted. During data analysis, we controlled for variation in age and intelligence between conditions. Within each condition, however, there was variation on the two variables. The level of statistical significance was established at  $p > .05$ .

### Materials and Procedure

#### *Training*

A training program was used which was designed for the development of inductive reasoning and to foster problem-solving strategies in the domain of inductive reasoning (Klauer, 1989b). In the training program, there are six forms of inductive reasoning tasks—namely, generalization (similarity between attributes), discrimination (difference between attributes), cross-classification (similarity and difference between attributes), recognizing relations (similarity between relations), discriminating relations (difference between relations), and system formation (similarity and difference between relations). The program includes 120 tasks. In 15% of the tasks, abstract, meaningless material is used. The remaining

85% consists either of concrete material, such as blocks that could be manipulated by the children or picture and figure problems from the children's everyday life (for more details about the training program, see Klauer & Phye, 1994, and chapter 10 of this volume). All the tasks were administered to the children. The design was a fixed trial training experiment. The training program was designed for at least 10 sessions. All training tasks were administered during eight sessions, 15 tasks per session. During the last two sessions (ninth and tenth), all training program tasks were reviewed. Previous research shows (Klauer, 1989a, 1990, 1992; Tomic et al., 1993, 1995) that all materials, the inductive reasoning program, and the training procedure employed in the experiment are appropriate for average third-grade children.

Following the pretest, the children assigned to the training group received treatment each school day for a period of three weeks. Each of the ten training sessions took about 30 minutes. The children assigned to the training group ( $N = 23$ ) were trained in six groups (five groups of four children, and one group of three children) by six researchers, who were not involved in administering the pretests and posttests.

Prior to training, the trainers were briefly instructed in the program's rationale and the training approach. Because trainers changed groups after two sessions, not every group of children got the same trainer during all sessions. At the beginning of the first training session, the child was given the opportunity to become familiar with the questions. When the child gave an incorrect response in a training trial, the researcher asked "How do you know that?" or "Can you demonstrate that?" The child was then asked to perform the item again until he or she gave a correct response and understood the principle of this type of problem solving. When a child gave a wrong solution or was unable to respond correctly, the trainer or fellow students could provide some assistance. When the children generated different solutions, all these alternatives were evaluated. After a positive evaluation, the children were allowed to proceed. Due to the importance of feedback in fostering transfer (Kingma & TenVergert, 1993a, 1993b), the children got feedback from one another as well as from the trainer.

### *Transfer*

Pretest and posttests, administered prior to and following training, consisted of the Raven Coloured Progressive Matrices Test (1990), Set A. The test was scored according to the instructions given in the test manual. The test was administered to the training and the control group prior to training (pretest), after training (as a measure of near-far transfer), and four months following training (second or delayed posttest) as a measure of the durability of training for transfer. Before and after intervention, an identical test was administered. A strong advantage of this option is that the intervention program does not specifically prepare the children for the immediate and the delayed posttests, as "teaching the test" is a frequent



familiar to the children were used; arithmetic tasks, however, were not. An arithmetic test was constructed asking children to discover relations between numbers and to reveal common attributes of numbers. The arithmetic tasks could be solved using inductive reasoning strategies. The arithmetic test consisted of three parts and 20 items. Relatively little research has been done until now on far-far transfer.

In general, children of this age, about 6.8 years, possess the acquired arithmetical knowledge to solve such tasks. However, they are not sufficiently able to understand relations between the given numbers, nor are they able to name the common attributes of those numbers. The range of transfer between the training tasks and the arithmetic tasks would be considered far-far transfer, because no numbers were included in the training program. Following the Raven Coloured Progressive Matrices Test (near-far transfer), the arithmetic test was also administered as a posttest. The arithmetic test was administered immediately after training and again four months following training. An introductory trial was given to familiarize the children with the arithmetic problems (see Figure 1).

## RESULTS

Overall comparisons between the groups indicated that the average total scores of the training group on the near-far transfer tasks were significantly higher than those of the control group on the first (immediate) near-far posttest,  $F(1, 46) = 9.7$ ,  $p < .001$ . On the second posttest (four months later), the near-far performance of the training group was still significantly better than that of the control group,  $F(1, 46) = 6.0, 10.0, p < .05$ . The difference between the experimental and the control group was still significant.

No significant interaction effects were observed. Thus, it is clear that training in inductive reasoning successfully induced near-far transfer in reasoning skills, and

**Table 1.** A Survey of the Mean Total Near-Far and Far-Far Transfer Scores and Standard Deviations for Both Training and Control Groups on Immediate and Delayed Transfer Tasks.

Posttest	Condition	Task			
		Raven Colored Progressive Matrices Test*		Arithmetic**	
		(Near-far Transfer)		(Far-far Transfer)	
Immediate	Training Control	9.7	1.4	13.1	3.3
		8.7	1.6	11.5	3.5
Delayed	Training Control	9.9	1.1	14.8	3.1
		9.3	1.3	13.1	3.8

**Notes:** \* Maximum score was 12.

\*\* Maximum score was 20.

that this transfer effect persisted at least four months after training (i.e., the second posttest). Means are shown in Table 1.

In order to determine whether the training program induced an immediate and delayed far-far transfer involving childrens' inductive reasoning skills, the childrens' scores on the arithmetic test administered following training were analyzed. Analysis showed that there is transfer to arithmetic tasks. Significant main effects were observed. The experimental group's arithmetic task scores were significantly higher than the scores of the control group (arithmetic first posttest  $F(1, 46) = 13.1, p < .05$ ; arithmetic second posttest  $F(1, 46) = 14.8, p < .05$ ). These results demonstrated that training in inductive reasoning induced a far-far transfer, that is, that students were able to apply the newly acquired skills in another conceptual domain, arithmetic, even after four months. The results show a significant far-far transfer of inductive reasoning skills in the domain of arithmetic.

## DISCUSSION

The study investigated the effect of a training program in inductive reasoning on childrens' performance on intelligence test tasks and the range of transfer according to the criteria of Piaget and Galperin, in order to conclude whether cognitive representation had changed. The durability of the effects was also investigated. The study determined the range or types of transfer induced by the training program.

Training in inductive reasoning was shown to be effective in teaching third grade primary school children inductive reasoning skills and strategies. This is a strong indication that the implementation of the inductive reasoning training program in small groups was successful. Besides the significant differences between the trained and untrained children, the positive training effects have important implications for education. In order to depart as little as possible from current educational practice, the children were not trained on an individual basis as in Tomic et al. (1993), but in groups. Durability was also demonstrated.

Researchers who are engaged in training inductive reasoning within the educational context are particularly interested in long-term effects. According to Piaget and Galperin, training for transfer occurs when a more or less long-lasting change is observed in a child's ability to solve a certain type of problem after completion of a training program. A positive transfer effect is considered an indication of such a change. While influencing cognitive development, it is especially important to investigate the range of transfer.

To evaluate the success of training, various transfer standards can be used. Researchers think differently about this matter. There is a standard for transfer of training commonly used in Europe which progresses from less to more stringent criteria (Tomic et al., 1993).

The magnitude of the training effect reflects a broad near-far transfer, because transfer occurred in an untrained concept area (intelligence tasks). The training program also induced a far-far transfer in arithmetic. Since arithmetic tasks were not part of the training program, this is a noteworthy result. From an educational psychology point of view, a training effect which is observable for at least four months and an induced near-far and far-far transfer are considered sufficient evidence of training effectiveness (Tomic et al., 1993). Such a training effect implies the durability of childrens' inductive reasoning skills. By giving children a wide range of tasks to perform after being trained, the results show that training has resulted in a transferable action structure. Noteworthy as well is that the arithmetic scores of the experimental group are significantly higher than the control group arithmetic scores. This finding indicates that the trained children benefited more from regular education than their control group counterparts.

The question remains why the training program induced a wide range of transfer, that is, far-far transfer. From the literature, it is known that the likelihood of transfer can be increased by building certain techniques into the training program's design (Garavaglia, 1993). Possible explanations for far-far transfer as it occurred in the present study might be: first, that the training program uses many different examples and presents them in various contexts in which children can expect to use the skills and knowledge learned in training. Second, the program consists of many analogies which also help increase transfer. Third, the training program helps to increase transfer by showing how inductive reasoning principles can apply in various situations. Fourth, transfer tends to be better when learners understand the general principles behind the skills they are learning. Children are encouraged to discover the general principles in the training tasks. By giving children a broader, deeper knowledge and more tools for problem solving, the likelihood of understanding those principles increases; neophytes can turn into experts (Goldstein & Musicante, 1985). Finally, transfer is more likely to occur when identical elements appear in different test situations. Tasks taught in training to children closely match the tasks children do in the posttests.

Although the results of our study confirmed the earlier findings of Klauer (1992) and Phye and Sanders (1993), our study deviates in some important respects. The training was administered in a different educational system. The experimental and control groups consisted of children from various ethnic backgrounds. The trainers were very briefly instructed in the program. Unlike the designer of the training program, who has had very experienced staff members administer training in his own research, training in this experiment was provided by trainers who had very limited experience in instructing young children. The experimental group received fewer training sessions than Klauer is used to utilizing. The concept of feedback was emphasized during training. The study used far-far transfer as a measure for whether cognitive representation had changed by implementing the training program.

In view of the above-mentioned points, it can be concluded that the results of our study strengthen the findings of Klauer (1992) and Phye and Sanders (1993), with the additional evidence of transfer durability. These results also demonstrate that inductive reasoning training can have a significant educational impact when conducted in the context of regular schools with average intelligence children. It would be advisable to apply the training program as part of a regular primary education curriculum.

Although the mean score of the experimental group is significantly higher than the mean score of the control group, Table 1 shows that the control group children also demonstrated slight progress in intelligence and arithmetic tasks. The time interval between the pretest and the first posttest was about four weeks; the second posttest was administered five months after the pretest. This might explain the small increase in intelligence and arithmetic scores for these control group children during that period. This merely represents the “normal” acquisition rate of the three tasks. First, this result corresponds to similar research (Kingma, 1986; Tomic et al., 1993). Second, the educational and developmental psychology literature have made clear that children of about seven years acquire a relatively large amount of knowledge and a relatively large number of skills in a quite restricted time span (Woolfolk, 1995). Third, although from early youth to the sixteenth year of life, a child’s raw score on an intelligence test increases, the scores of the experimental group increased more than the scores of the control group.

Although a number of researchers consider the requirement set by both Piaget and Galperin for far-far transfer too stringent, in the present study the effects of the intervention based on Klauer’s (1989c) inductive reasoning training program fulfilled this requirement. The results indicate that training provided according to the description given above can have a significant educational impact when conducted in the context of regular schools with average intelligence children.

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