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Playful fostering of 6- to 8-year-old students' inductive reasoning☆

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ABSTRACT

This paper focuses on a training program in inductive reasoning for first-grade students and presents the direct results as well as the longitudinal effects of the evaluation study. The training is based on Klauer's theory of inductive reasoning and on his "Cognitive training for children" concept (Klauer, 1989a). The training program consists of 120 problems which can be solved through inductive reasoning. The tools for the training exercises were selected to correspond with the age of the targeted cohort. The experimental group in the study consisted of 90 students, whereas the control group was made up of 162. An inductive reasoning test was used in the pre- and posttest as well as in the follow-up study (one year later). The test comprised 33 figural, non-verbal items (Cronbach α = .86). On the posttest, the experimental group significantly outperformed the control group by more than one standard deviation. The experimental group scored significantly higher in each skill area targeted by the training. The most noticeable development was found in system formation. No gender differences were detected on the pre- or the posttest. The effect size of the training program was d = 1.12. In the follow-up study, the experimental group still significantly outperformed the control group; however, their respective levels of development had not changed in this one-year period. Thus, the training effect proved to be stable over time independent of individual students' original level of inductive reasoning. This study provided evidence that inductive reasoning could be developed very effectively at this early age.

1. Introduction

Findings from prior research have highlighted the primary importance of developing inductive reasoning in knowledge acquisition and application (Bisanz, Bisanz, & Korpan, 1994; Hamers, De Koning, & Sijtsma, 2000; Klauer, 1990, 1996; Pellegrino & Glaser, 1982), in problem solving (Chi, Glaser, & Rees, 1982; Egan & Greeno, 1974; Johnson-Laird, 1983; Klauer, 1989b, 1996; Polya, 1954) and in the development of expertise (Cheng & Holyoak, 1985; Chi et al., 1982); therefore, it plays a central role in gaining a deeper understanding of the subject matter in a classroom. This certainly suggests that these thinking skills should become an integral part of the school curriculum (de Konig, 2000; Resnick, 1987) and should play a role in a broad range of learning activities in school.

Nevertheless, the stimulation of thinking skills is not pursued explicitly in schools. Education focuses on reading, writing, and math, which are considered to be the main requirements for participation in western society (de Koning, Hamers, Sijtsma,

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	Attributes		Relations	
	Item class	Item-type	Item-class	Item type
Similarities	Generalization	-Class formation -Class expansion -Finding common attributes	Recognizing relations	-Order series -Series completion -Simple analogies
Differences	Discrimination	-Class exclusions	Discrimination relations	-Disrupted series
Similarities and differences	Cross-classification	-4,6,9 fold schemes, matrix figures	System formation	-Matrix-figures with complex analogies

Fig. 1. Klauer's taxonomy of the classes of inductive reasoning tasks.

& Vermeer, 2002). It is commonly assumed that reasoning skills develop spontaneously as a "by-product" of teaching ordinary school material (de Konig, 2000). That is why inductive reasoning skills were in the focus of the experiment presented here.

Two directions can be distinguished in the development of thinking skills. Researchers belonging to the first believe that thinking skills can only be taught explicitly (see e.g. Feuerstein, Rand, Hoffman, & Miller, 1980; Klauer, 1989a, 1991, 1993; Lipman, 1985). Researchers that identify with the second believe that it should be embedded in school subjects (e.g. the CASE project, see Dienes, 1963, 1973; Shayer & Adey, 1981). In the present study, inductive reasoning strategies were trained explicitly.

In the process of selecting the target population, Piaget's developmental theories (conservation and developmental stages) and the current understanding of skill development in education (Csapó, 1997, 2003; Molnár & Csapó, 2003) were considered, along with the results of preceding training programmes (see e.g. Józsa & Zentai, 2007; Nagy & Gubán, 1987; Pap-Szigeti, 2007) that investigated the effectiveness of intervention in relation to the target population and the success of training. All in all, these preliminary findings suggested that the earlier development starts, the more effective it can be.

The training presented is based on Klauer's theory of inductive reasoning and the German "Cognitive training for children" program (Klauer, 1989a; Klauer & Phye, 2008). Klauer defined inductive reasoning as the discovery of regularities through the detection of similarities, dissimilarities, or a combination of both, with respect to attributes or relations to or between objects (Klauer, 1993). This totals six classes (generalization, discrimination, cross-classification, recognizing relations, discriminating between relations, and system formation). Klauer probably constructed the most elaborate system for inductive reasoning, defining its elements and their relationships. A taxonomy of types of inductive reasoning tasks and item types used are shown in Fig. 1.

2. Methods

2.1. Participants

Existing classes of first-grade students were involved in the study. Five classes ($n = 90$) constituted the experimental group. The control group consisted of similar children in respect of background variables ($n = 162$).

2.2. Instruments

Similarly to Klauer's original program, this training consists of 120 problems, i.e. 20 problems in each class of inductive reasoning, which can be solved through the application of appropriate inductive reasoning processes. Additionally, the scope and quantity of tools applied in manipulative tasks were expanded, the sub-structure of the program was changed, and the images, objects and problems were fit into the program according to the interests of children today and the stories they are familiar with. The program uses objects and pictures that correspond to the age of the targeted cohort, and one quarter of the tasks are manipulative (performed e.g. with colorful building blocks, Dienes's logical set, matches, etc.). The contexts change in a similar way in each class of inductive reasoning throughout the program, from manipulation of objects to use in real-life situations.

Half of the training tasks concentrate on the characteristic features of the objects and images occurring in these tasks and the relations between these objects and images, such as their similarities, differences and co-occurring similarities and differences.

In the tasks that aim at training in the (1) operation of generalization, the students were expected to group objects by (a) creating classes, (b) completing already existing groups or (c) finding common attributes. In the following section, sample items are provided for each type:

(a) *Class formation*. Students were given pieces of Dienes's logical set and asked to classify these pieces into four separate groups (see Fig. 2).

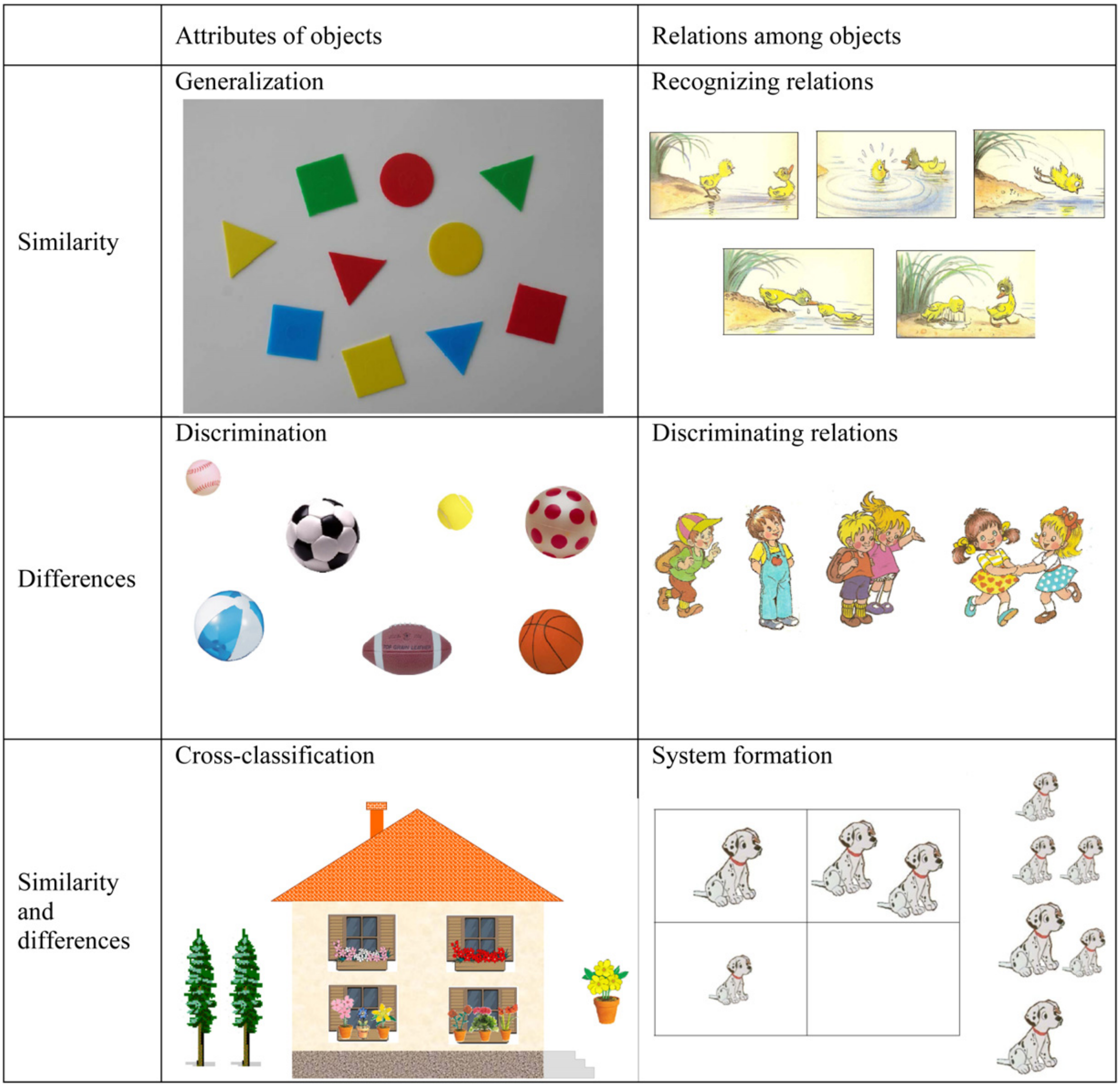

Fig. 2. Examples of tasks in the program.

(b) *Class expansion*. Students were shown images of 4 + 3 objects, e.g. (1) a lemon, an apple, a pear, and a cherry, and (2) a flower, a bug, and a banana. They then had to find the only object in the second group that is characterized by the feature that all the items in the first group had in common.
(c) *Finding common attributes*. Students were supplied with three images: a bird, an airplane, and a butterfly. They were also instructed to describe what the images had in common.

The problems of the tasks targeting the (2) operation of discrimination focused on the differences in the attributes of the objects that occur in the tasks. Students were told to find the one object that differed only in a single feature from all the other objects with similar and identical features. For instance, seven images of different balls were provided (see Fig. 2). The question was to ascertain which of these elements are different from the others and why.

The tasks that aimed at fostering (3) cross-classification included both the operations of generalization and discrimination. Here, students were instructed not only to consider the similarities or differences in the attributes of individual objects, but also to group the objects based on a set of similarities or differences to be taken into account. For instance, flowers of different colors could be seen in the various windows of a certain house. In the upper left-hand window there were only red flowers, in the upper right-hand window flowers of various colors, in the lower left-hand window only red geraniums, and colorful geraniums in the lower right-hand window. Students had to decide where the owner of the house would place a newly bought yellow tulip (see Fig. 2).

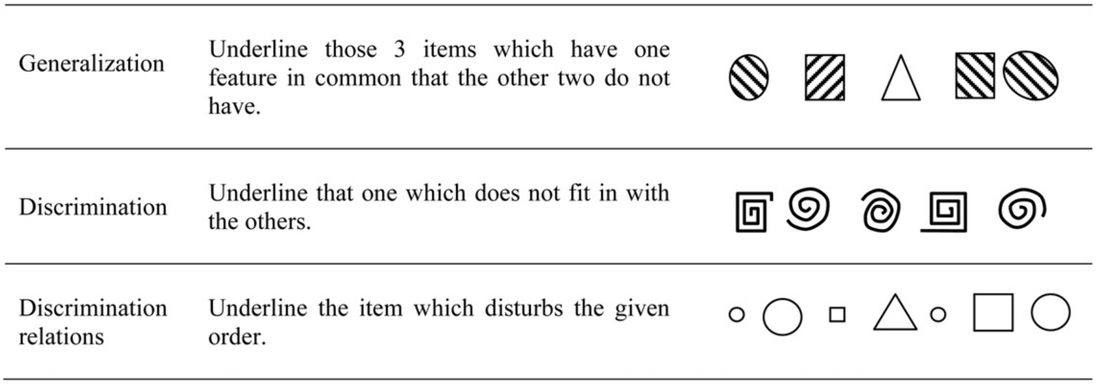

Fig. 3. Examples of tasks in the inductive reasoning test with the measured classes of inductive reasoning.

The other half of the training tasks was based on the relations to or between objects, their similarities, their differences and the co-occurring similarities and differences. In the tasks targeting (4) recognition of relations, students were instructed to (a) organize items into series, (b) complete series or (c) find simple analogies between objects or pictures. In the following section, sample items are provided for each type:

(a) Ordering tasks required students to order objects, images or events. In one such task, they were expected to organize pictures from a bedside story into a meaningful sequence (see Fig. 2).
(b) In the completion tasks, students were asked to continue a series while keeping the original relationships of the items in the series. For instance, Winnie the Pooh keeps eating honey from a pot that is naturally becoming ever more empty. Following the pace of honey consumption, students were to select the appropriate pictures from among those depicting pots of various levels of fullness.
(c) In the tasks that aim at fostering simple analogies, students were meant to recognize the relationships between pairs of objects and apply this same relationship to another pair of objects. For example, honey is to a bear as . . . (cheese) is to a mouse.

Two kinds of “biased” series could be found in the tasks containing (5) operations of discriminating relations. In the first case, students were instructed to recognize which two elements of the sequence had been exchanged, while in the second type they had to find the extra element that does not follow the rules of the sequence. For example, three boys and two girls are standing next to each other. Exchange a boy with a girl in the row so that a girl is always standing next to a boy (Fig. 2).

In the tasks for (6) system formation that require matrix figures with complex analogy, students had to consider both the fact that relations should be identical and that not only one (horizontally or vertically appearing) relation is important, but a complex of two (horizontal and vertical) or even three relations. For instance, there is a big puppy in the upper left-hand cell of a four-cell box. There is a small puppy under this cell, and next to this first cell there are two big puppies. The question is: what goes in the lower right-hand cell? A small puppy, two small puppies, a small and a big puppy, or one big puppy (see Fig. 2)?

It was intended that the tasks for the training program be constructed such that students would perceive the work of development as playing games, not as learning, hence suiting students' development and other age-specific considerations. The basic structure of the program starts with manipulative tasks in which students can play and draw using colorful building blocks, elements of the logical set, color pencils, matches and cards. These manipulative tasks gradually give way to playful tasks with images of various objects, toys or story characters which, by the end of the program, are replaced by symbols and real-life situations. Carrying out the tasks requires no reading, since it would be unfair to expect students to read at such an early age.

The effectiveness of the training was measured with a 33 item paper-and-pencil test of inductive reasoning, developed specifically for young learners. Due to the young age of the target population, special care was taken to ensure the non-verbal character of the test; i.e. it had to contain numerous pictures, figures and images and as little reading text as possible. This is to avoid measuring students' reading skills instead of their inductive reasoning skills. The structure of the test is based on the definition of inductive reasoning, cited above; i.e. the items belonged to the six sub-classes of inductive reasoning (see Fig. 3). The reliability index for the whole test was Cronbach $\alpha = .87$. Validity of the test was ensured by construction and a precise alignment between the framework and the test.

2.3. Procedures

In terms of the methods and work forms of the training, the students were given the training individually or in pair or group work. The main benefit of individual work is its intensity, while the drawbacks include high time consumption and faster student exhaustion. Only children with around the same level of skills were put into pairs and groups (3–4 children) such that each student was individually supplied with the task and the assistance needed to carry it out and then, after the task was carried out, each was expected to provide her or his solution one-by-one. We do not have data about what proportion of the sample was trained individually, in pairs or in small groups.

The working methods might further include directed discovery, thinking aloud and following the teacher's demonstration of the solutions. For further details, see Molnár (2006). The time required for the work of development depended on the individual students. It is recommended that each session should last for 20 min and contain 12 tasks at most. This meant that the 120 tasks were divided into 10 sessions on average, depending on the students' skill level, ability to concentrate, motivation and level of exhaustion. The training was performed after the lessons, during day care, when the remaining part of the class could go out to the school yard and play.

There was a team of implementers, namely the class teachers, who introduced the activities to the children. Two weeks before the training the implementers received a short (2–3-h long) on-spot group training from the researchers about (1) how skills and abilities, especially thinking skills and abilities develop during the age-range of schooling (e.g. development is logistic and not linear) and what questions could be raised from these features of skills and abilities (e.g. questions of early selection and its effects). To present the theoretical framework I primarily drew on national sources e.g. Csapó (1997) and Molnár and Csapó (2003) (2) the role of context and issues regarding transfer in connection with different development programmes (3) the definition and characteristics of inductive reasoning and abilities targeted in the training, (4) the structure of the training, working methods and time required for the work of development, (5) the processing of the training tasks with examples, (6) results and experiences of the first pilot study, where the training was performed. The working method of the first part of the training was frontal, while the remaining part of the training was common group work, where concrete examples were studied. At the beginning of the training the implementers were given printed materials to follow as well, in which all of the above mentioned topics were described in a more detailed form with several examples given from the actual training. Besides the printed material, every task included methodological suggestions for the implementers that could be raised and applied in the actual training situations: e.g. in connection with task 7: "As part of a game let's find the right shapes together with the students and let's place them onto the picture! Let's put one more red triangular prism, a yellow square, a green prism and a red square. Then ask the students to continue the sequence. Draw their attention to the dependent and independent variables! If we do not succeed, let's help them to find out the rules with clues and its application. If the student manages to do the task, ask them what the rule is!" [A játék kedvéért a diákokkal együtt keressük meg a megfelelő alakzatokat és tegyük azokat rá a képre. A diák elé tegyünk le még egy-egy piros háromszög alapú hasábot, sárga kockát, zöld hasábot és piros kockát. Kérjük meg őket, hogy folytassák a sorozatot. Tudatosítsuk bennük a független és függő változókat. Ha nem megy, vezessük rá őket a szabályra és annak alkalmazására, ha megy, kérdezzük meg, mi a szabály.] and sample questions (in connection with task 7 the original question was: "Please continue the task with one building block" [Folytasd a sort egy építőkockával] and the alternative questions were: "According to what rule could I have put/place the building blocks?" [Milyen szabály szerint tehettem le az építőkockákat?] "And based on that rule which building block could come next?" [És az alapján melyik építőkocka következik a sorban?]).

The study design made it possible to measure not only the direct effect of the training, but also its longitudinal effect. Three stages of data collection were required to assess both the direct and the longitudinal effect. The first two data collection stages took place before and immediately after the training process. The interval between the pretest and the posttest was 8 weeks, the period in which the training was performed. The third data collection stage, the follow-up study, was conducted one year after the end of the training. All groups took the same pre- and posttest before and after the development process and the same follow-up test one year later.

Students were not allowed to use any kind of aids in doing the test, but, due to their young age, the teachers were permitted to read out the instructions for the tasks, thus compensating for the differences in students' reading skill development. One school session was provided to do the test.

Before the research questions were answered, the raw scores were transformed into percentage scores. To compare both students' performance in the experimental and control groups and the sub-groups of the sample (e.g. gender differences), mean and standard deviation were computed and an independent sample t-test was used. To answer the research questions of whether the training resulted in a similar effect on students with a different original level of inductive reasoning and whether the training effect was stable over time, the distribution curves for the sub-samples were compared. To place the program into an international context by effect size, Cohen's (1988) categorization was used.

3. Results

No significant differences were found between the performance of the experimental and the control group ($t = 1.2$, $p = .22$) prior to the experiment. On the posttest, the experimental group significantly outperformed the control group by more than one standard deviation (see Table 1). Some of the students managed to achieve significant development in the experiment period (8 weeks) even without participating in the training program, while others' skills stagnated or even decreased. On the whole, there is a significant change in performance in both the experimental and control groups. A year after the end of our training program, the follow-up study still indicated a significant ($p < .001$) advantage for the experimental group compared to the control group in level of inductive reasoning skills.

Table 1
Means and standard deviations of the test for inductive reasoning (%).

	Pretest		Posttest		Follow-up test	
	M	SD	M	SD	M	SD
Exp. group ($n = 90$)	37.1	15.8	61.0	16.3	60.4	15.0
Contr. group ($n = 162$)	39.3	16.2	47.0	16.7	54.5	15.1

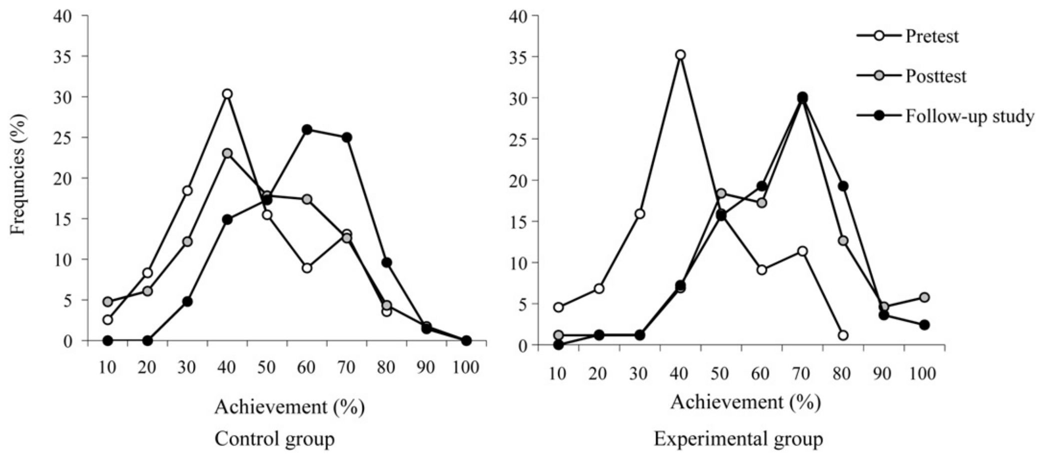

Fig. 4. Distribution curves of experiment and control group in the pre-, post- and follow-up test.

In the case of the control group, the distribution curve for the pretest (see Fig. 4) is inclined to the left, while for the posttest it leans slightly to the left. The delayed posttest showed a distribution curve skewed slightly to the right, reflecting the effect of spontaneous school development. Furthermore, each member of the experimental group attained significant improvement in performance as a result of the training. The original curve skewed to the left turned into one skewed to the right by the end of the training program and retained this shape in the following year.

The results above are supported by the two diagrams in Fig. 5 that show the changes in experimental and control group performance on the student level, the curves for performance during the first and second data collection stages are projected onto each other. The abscissa shows comparative performance from the first data collection stage and the ordinate displays this from the second. The symbols for those students who performed identically in the two cases fall on the line. If a point is positioned above the line, it means that the given student showed development from one data collection stage to the other, while if it is below the line, it represents worse performance on the posttest than on the pretest. The broken lines indicate one standard deviation. In the case of the control group (graph on the left), the symbols are distributed homogeneously around the mean line; i.e. the majority of these students performed quite similarly in the two data collection phases. The increased standard deviation mentioned above was a result of some students outdoing their pretest performance by more than 50% in the posttest, and some underachieving by almost 30%. A wholly different tendency is displayed on the right-hand graph,

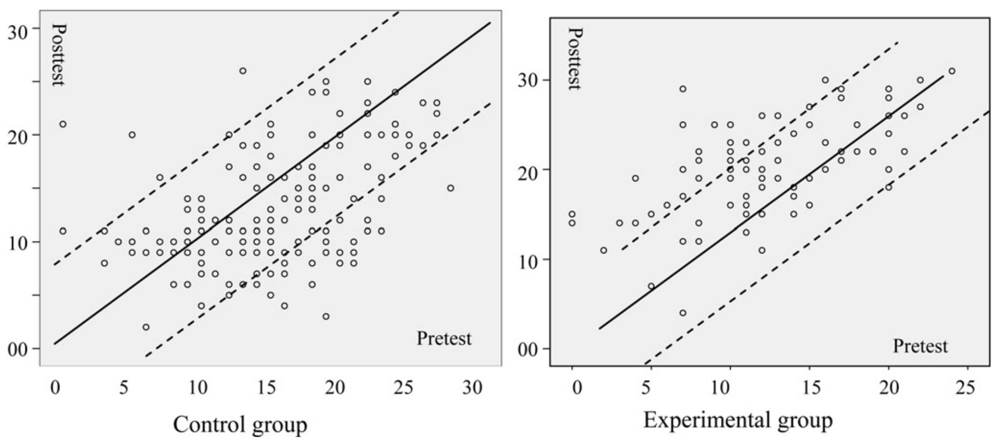

Fig. 5. Changes of the achievement of the control and the experimental group from pretest to posttest.

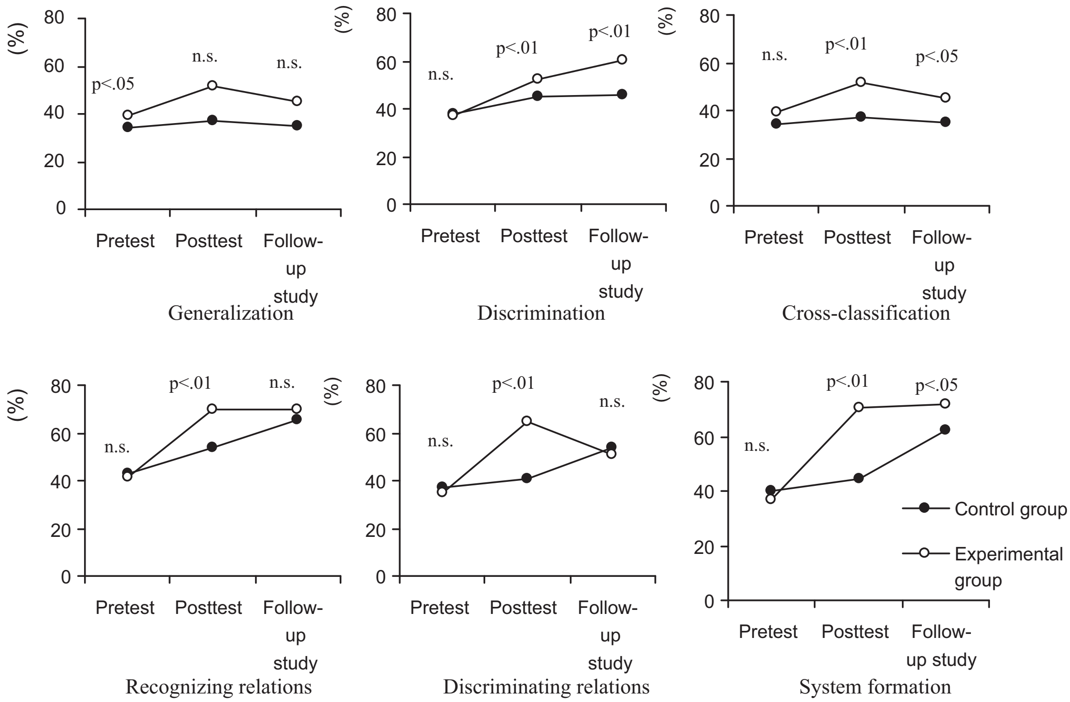

Fig. 6. The mean achievement of the control and experimental group in the pre- and posttest and the follow-up study in terms of the six basic structures.

showing the performance of the experimental group. A significant number of symbols are located on or above the mean line. There were no students in this group whose performance dropped significantly from pretest to posttest; moreover, several students improved by more than one standard deviation. In addition, there was one participant who reflected a development of 67%.

The training resulted in a significant ($p < .001$) improvement for the experimental group in all six classes of inductive reasoning. Fig. 6 displays the changes in skill levels for each class of inductive reasoning immediately after the training and a year later.

Posttests revealed no significant difference in performance between the experimental and the control groups in items that measure generalization skills, since there had been a significant difference on the pretest which had been offset by the training. Hence, the experimental and control groups reflect no difference in their spontaneous development between the two posttests in this domain.

The performance of the two sub-samples, however, had not been statistically different in the items that measure discrimination prior to the experiment. Yet they indicated a more than 10% ($p < .001$) mean difference on the posttest. This advantage for the experimental group was even increased by the time of the follow-up study.

Experimental group performance improved by more than 15% in the cross-classification items as well. Here, the complete lack of change in performance among the control group students as well as the slight deterioration of the experimental group in the year following the training suggest that school does not manage to enhance these skills in this age group at all.

We find a different picture in the items for recognition relations. According to the first posttest, the training resulted in an extra 20% improvement in the performance of the experimental group beyond the spontaneous development of the control group. The experimental group reached the same level of development in this eight-week period that the control group did only a year later. That is, lacking additional stimulation in school, members of the experimental group did not display any more improvement; instead, they waited for their schoolmates.

The findings are similar in the domain of discriminating relations. The advantage of the experimental group reached 20% by the end of the training; however, it increased no further in the following year. Moreover, members of the experimental group scored lower on the second posttest than on the first one, demonstrating the same level of development as the students in the control group.

The most considerable developmental effect was found in system formation. The development measured in this domain was almost 35% at the time of the first posttest. However, experimental group students did not develop further in the following year, while the control group manifested significant improvement in this domain as well. In spite of this phenomenon, the experimental group maintained some of the advantage it had gained in the training, since the follow-up study still detected a significant difference between the sub-samples.

Table 2
Means and standard deviations of the test for inductive reasoning in relation to gender (%).

		M	SD	t	M	SD	t	M	SD	t
Exp.	Male	33.7	15.7	ns	61.0	14.7	ns	57.5	13.2	ns
Exp.	Female	39.6	15.6		60.9	17.6.		62.4	16.0	
Contr.	Male	38.0	15.6	ns	45.1	16.0	ns	54.9	15.5	ns
Contr.	Female	41.0	17.0		49.4	17.2		54.1	14.7	

Table 2 shows the mean performance of the experimental and control groups in gender division. No sub-samples displayed significant differences in the relative performance of boys and girls, i.e. the development is not gender-specific. Similarly, the spontaneous improvement measured in this period is independent of gender.

The effect size of the training program was $d = 1.12$ ($p < .01$). Using Cohen's (1988) convention for describing the magnitude effect size, it is clearly a large effect. Placing the program into an international context according to its effect size allows for favorable conclusions. Similarly to many other researchers in the 1980s, de Konig (2000) attained an effect size of .79 with third-grade students using Klauer's original program.

4. Discussion

This paper addresses a training program of inductive reasoning for Grade 1 students and presents the direct result and the longitudinal effect of the evaluation study. According to the results, the developmental level of the experimental and control group students did not differ prior to the experiment, meaning that the control group meets the requirement for a control group in the study. As a result of the training, the inductive reasoning skills of the experimental group showed greater improvement than that of the control group. The operations of inductive reasoning skills developed more in the eight weeks of the experiment than they would normally have in a year of conventional schooling.

Comparing the distribution curves made it possible to consider the changes in experimental and control group performance with regard to students' original level of inductive reasoning skills. The shape of the distribution curves showed a significant difference in the relative performance of the experimental and control groups. In the case of the control group, the change of the distribution curves corresponded to the expected development, while each student in the experimental group attained significant improvement in their performance as a result of the development. The training had a similarly strong effect on students with highly diverse levels of skills. This means that the skills of all the 6- to 8-year-old students who participated in the experiment were enhanced to a similar degree. In the case of the experimental group, the shape of the distribution curve did not change by the time of the follow-up study. This finding suggested a long-term effect on development independent of individual students' original level of inductive reasoning. The effectiveness of the program proved to be stable over time.

The effectiveness of the training program in each dimension of basic structures resembled significantly that of the whole program. The manipulative, playful training resulted in a significant improvement in all six basic structures of inductive reasoning skills. The most considerable advance, more than 30%, took place in the domains of system formation, differentiating relations and recognizing relations. The lowest, but still considerably significant development took place in cross-classification. In each dimension of inductive reasoning, members of the experimental group developed the same or more in the eight weeks of the training than they would normally have in a year of conventional schooling.

The effect of the training proved to be stable in each dimension of inductive reasoning, though further improvement was not attained due to the lack of conscious training. Probably, students do not develop any further until mates who did not participate in the experiment reach their level. Then they might develop together spontaneously. Expanding the training program could effectively increase the advantage of the experimental group further. On the other hand, the application of the existing program could encourage those lagging behind to catch up with their schoolmates with an average or even above average level of skills in this crucially important domain.

The effectiveness of the program proved to be unrelated to gender; i.e. it had a similar effect on boys and girls. No gender-based differences were found in any of the domains for most of the measurement points. The effect size achieved is outstanding not only in the Hungarian context but internationally as well.

The results suggest that the elaboration of this domain-general development program can be considered successful, which, when applied in pair and group work, develops students' inductive reasoning in a playful way. It was not an aim of the study to explore how the improvement in inductive reasoning transfers to other areas of cognition. However, a number of other studies reported strong correlations between inductive reasoning and successful learning of several school subjects, for example, second languages (Csapó & Nikolov, 2009).

The findings of the training program suggest that inductive reasoning skills can significantly and effectively develop between the ages of 6 and 8. A non-verbal, figural test of inductive reasoning was also constructed as part of the program package which – according to its reliability and validity – can be effectively applied to measure the development of elementary students' inductive reasoning even independently of the rest of the training program.

Future plans include digitization of the entire developmental program and release in the form of computer software. This step might improve applicability and foster the availability of the program.

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