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Can emphasising cognitive development improve academic achievement?

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Background: Children ordinarily begin their formal education at the age when the great majority of them are capable of understanding the role of addition and subtraction in changing number. In determining critical differences they can apply the oddity principle – the first *pure* abstraction that children ever develop – understanding that when all but one item are alike on some dimension, it is the relation between items, not their absolute qualities, which determines which belongs to a different set, i.e. is 'odd'. They are also capable of inserting items into a unidimensional series, a form of abstraction which develops a bit later. Children slow to develop such abilities often experience difficulty understanding classroom instruction in the first year of school.
Purpose: The purpose of the research was to teach children oddity, insertions and conservation and compare their subsequent literacy and numeracy with that of children taught literacy and numeracy directly. All children develop oddity, insertions and conservation through unstructured interaction with the environment, but some do so belatedly, after patterns of school failure have been established. Is it worthwhile to spend classroom time teaching these thinking abilities? This research was designed to test whether teaching them produced better academic achievement than equal time spent teaching academic material.
Programme: Teachers can use a wide variety of common objects to teach in an efficient and structured way the abstractions 5 year olds ordinarily learn less efficiently in their daily lives. This method, called a *learning set* approach, is easily applied by teachers or assistants without the need for special training.
Sample: The participants were culturally diverse 5 year olds, generally of low socio-economic status, enrolled in five urban schools. Students from 25 classrooms were screened to determine whether they already understood the concepts which were to be taught. The final sample had 82 boys and 74 girls. Fifty-two were Hispanic/Latino, 36 African American, 33 White US born, 21 Mideastern, 7 East African, 3 Asian Indian, 2 West African, and 2 East Asian.
Design and methods: In an experimental design, the children were randomly assigned to one experimental and three control groups. The former were taught number conservation, the oddity principle, and how to insert objects into a series. One control group was taught numeracy: recognition and identification of numbers, counting by 1s, 5s, or 10s, and other aspects of numeracy. Another control group was taught literacy: upper and lower case letters, letter sounds, rhyming and blending. A third control group was taught social studies: family structure and activities, the major senses and body parts, community resources, mapping and citizenship. The instruction was conducted from October through February. In May and June, the children were tested on oddity, insertions, number conservation, literacy and numeracy. Numeracy was measured with

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the Woodcock-Johnson III and literacy with the *Stanford early school achievement test*. Research instruments were used to measure the cognitive concepts.
Results: The children taught the three thinking abilities outscored the control children on tests of these concepts. They surpassed the literacy control group in numeracy and matched it in literacy, surpassed the numeracy group in literacy while matching it in numeracy, and surpassed the social studies group in both.
Conclusions: Small group lessons on the oddity principle, insertions into series and number conservation may benefit kindergartners who lack these concepts. Mastery of these abstractions may enable them to understand academic subject matter which they would otherwise have difficulty comprehending.

Keywords: abstraction; numeracy; literacy

Introduction

Many different early education curricula offer numerous positive experiences that improve most children's knowledge. However, some children do not prosper. Often these children have been slow to develop the abstractive abilities that their classmates possess and hence do not grasp significant elements of what the instruction is intended to impart. Pasnak et al. (2007) reported a 15-minute daily instructional programme for five-year-old children that produced general cognitive gains and also improved scores on objective tests of numeracy and, in one comparison, literacy. This is a potentially important finding. Although the production of cognitive gains is always a goal of educators, it becomes problematic when it takes time away from mastery of important academic material. Were cognitive gains to be accompanied by gains in mastery of verbal or quantitative material as great as the gains produced by a narrower focus on numbers and letters, devoting instructional time to teaching children how to think in an age-appropriate way would find more favour with educators. Hence, the present research was designed to show whether the result reported by Pasnak et al. (2007) for numeracy could be replicated and the evidence of literacy gains clarified.

Those researchers used synthesis of two approaches as an instructional method. *Learning sets* were used to teach the abstractions that the children had not developed in a timely manner. This 'learning to learn' approach consists of using scores of problems that are quite variable perceptually to represent in a concrete manner any abstract principle. The term 'learning set' is sometimes used to refer to these problems, but may refer instead to the understanding and insight the learner develops as problem after problem is mastered. Instruction in its simplest form consists of simply identifying correct and incorrect solutions, thus enabling the learners to teach themselves the solution to each problem in turn. This method succeeds easily with children and takes little skill on the part of the instructor, beyond an ability to keep children motivated (Kingsley and Hall 1967; Gelman 1969; Pasnak 1987; Pasnak et al. 1991; Pasnak, Hansbarger et al. 1996a). The initial learning is by rote, but children gradually internalise the principle that allows solution of all the problems and generalise it readily to new problems. Strengthening helpful habits of observation and comparison (Gagné 1968; Gagné and Paradise 1961) and weakening tendencies that produce errors (Harlow 1959) are parts of what makes learning sets successful. The most troublesome error-producing tendencies for cognitively immature children are efforts to solve problems in a concrete, perceptual way when they can only be solved by abstractions. Besides strengthening supporting tendencies and gradually eliminating approaches that produce errors, learning sets induce generalisation of the abstraction within the range of examples it provides. This makes the number and variety of exemplars in learning sets critical and is the secret of their success. There is some generalisation outside this range and it is accompanied by freedom from reliance on specific cues. A congenial and supportive form of learning set instruction was employed in the present research.

The second element of the approach employed by Pasnak et al. (2007) was to teach children the oddity principle, to insert items into a series, and number conservation. These abstractions are normally fully developed at about the time children encounter formal schooling and are foundations for general cognitive growth. Children who have not developed them show immature tendencies to try to make sense of their environment by attending to concrete properties of objects and events. They base problem-solving upon consideration of such qualities, and success depends on whether they have considered the ones that have important implications or consequences. In contrast, children who have, through interaction with their environment, come to recognise relationships between properties of objects have become capable of better decision-making. The child who can abstract relationships between objects and events, and is not limited to response only to absolute qualities, is capable of superior understanding and problem-solving. By the time they enter school, most children have internalised key principles of abstract thought (Inhelder and Piaget 1964), and curricula are designed for children who can think at that level. The extent to which they have mastered such abstractions predicts their performance in kindergarten and the early grades, according to studies carried out in several countries (Dudek, Strobel and Thomas 1987; Freyberg 1966; Kingma and Koops 1983; Silliphant 1983). Pasnak et al. (1991) and Pasnak, Hansbarger et al. (1996) showed specifically that the abstractions intrinsic to the oddity principle, insertions into series and number conservation were important predictors of academic performance in kindergarten (the classes that bridge the gap between preschool and the first grade in US schools).

The first *pure* abstraction that children ever develop is usually the oddity principle (McCormick et al. 1990). This is the understanding that when all objects but one are alike on some dimension, it is not their absolute qualities, but rather the relation between items determines which belongs a different set – i.e. is 'odd'. The objects may be alike in all irrelevant dimensions – a unary relationship (Chalmers and Halford 2003) or they may all be unalike in some irrelevant dimension – a binary relationship. The latter are particularly difficult for cognitively immature children, who tend to try to make sense of their world perceptually and be relatively unaware of abstract relationships. For example, if one has a blue spiral bead and red, green, pink and yellow oblong beads, the blue spiral bead is odd. If a subsequent problem has blue, red, green and pink spiral beads and a yellow oblong bead, the yellow oblong bead is odd. This will be obvious to most children in a class, who can readily solve such problems mentally. However, some children, especially those who are functioning closer to the floor than the ceiling of their natural abilities, try to solve such a problem on the basis of color, a favored but irrelevant dimension. Instruction in the classroom presumes the comprehension of such simple relationships. However, it will be over the heads of some children who will be forever lost in trying to solve problems on a concrete basis. The ability to abstract oddity arises sooner for some dimensions, such as color or shape, than for others, such as size or orientation, but is ordinarily well developed by age five years. Some children still have not mastered it by age six years (Pasnak et al. 2007). The ability to solve complex oddity problems is in itself predictive of success in the first two years of schooling and is consequently measured and used for this purpose with the *Otis-Lennon School ability test* (Otis and Lennon 1997).

At about the same age, children develop the ability to insert items into the interior of a series: three and four year olds can put objects into an ordered series by the 'method of extremum' (Piaget and Inhelder 1969; Leiser and Gillieron 1990). This is a very concrete process that involves starting the series with the largest object in a set, then surveying the set to find the largest remaining object and placing it second, surveying the set again to find the largest remaining object and placing it third, and continuing the process until all objects have been placed. (A child may as readily build from the smallest up.) If a child is careful and patient, quite a long series can be built, and the method seems quite orderly. However, a successful child may have no understanding of the relationships between objects in the series, as strange as that seems. This becomes apparent when a child is given a new, medium-sized object to insert in the place where it should go. A cognitively immature child will be baffled, will place the object at the end of the line, even though it manifestly is not the right size, and is unable to correct the error (Leiser and Gillieron 1990; Southard and Pasnak 1997; Young 1976). Insertions involve abstracting the relation between three or more items. This understanding of interrelationships between items in a series also is well developed by the time most children reach age five, but for a child who has not developed it, it will be easier to destroy the whole series and rebuild it from scratch than to find the place for an object within it.

A key aspect of number conservation is the understanding that, regardless of appearances, addition or subtraction must occur or number cannot have changed. However, children who have not developed this understanding will think that the number of objects in a set has changed even when there has been no addition or subtraction, if the objects have been rearranged so it *looks* like there are more or fewer of them. Such children can, of course, learn to count, add and subtract by rote, but they lack a fundamental understanding of a basic principle of numeracy, and also of the abstract principles of reversibility and identity involved in conservation. Children usually conserve number after they have internalised the oddity principle and insertions into series, but the majority accomplish it before they turn six.

Is understanding the abstractions involved in the oddity principle, insertions into series, and number conservation really important in understanding the instruction offered in a classroom? If it is, improving children's abilities to abstract in these ways should produce general academic gains. If it is not, mastering these abstractions would produce little in the way of academic progress. The present research was conducted to determine which is the case. More specifically, would teaching children oddity, insertions and conservation produce better understanding of the lessons in numeracy and literacy (letters and letter sounds) that are taught in kindergarten? If this were to prove true, the correlations others have observed would indeed be a matter of cause and effect (Silliphant 1983; Pasnak, Willson-Quayle and Whitten 1998). The hypotheses tested were as follows:

(1) On measures of oddity, insertions and conservation, children taught these concepts would surpass children not taught them.
(2) Children taught oddity, insertions and conservation would match or surpass in literacy children who were taught literacy and would surpass children who were taught numeracy or social studies.
(3) Children taught oddity, insertions, and conservation would match or surpass in numeracy children who were taught numeracy and would surpass children who were taught literacy or social studies.
(4) Children taught literacy would surpass in literacy children who were taught numeracy or social studies.
(5) Children taught numeracy would surpass in numeracy children who were taught literacy or social studies.

Method

Participants and setting

The participants were kindergarten students of diverse cultural and socio-economic backgrounds who attended five Alexandria City public schools in the state of Virginia, USA. These schools were selected because their principals were agreeable to hosting the research project. This urban school system adjoining Washington, DC, served many families of low socio-economic status – 56% of the children enrolled qualified for government-subsidised lunches. There were many immigrant families with diverse languages and cultural and educational backgrounds. Initially, the eligibility for the study of all 592 students enrolled in all 25 kindergarten classrooms in these schools was determined by screening them with 10 insertion and 12 oddity problems. (Kindergarten is the first level of instruction in local schools; children must be five years old by 1 October to attend.) Those who scored 80% or higher on either test were excluded because they appeared to be too cognitively advanced for the experimental instruction. No children were withdrawn from the study, *per se*, during the ensuing school year, but there was 22.2% attrition because of changes of residence by children's families. The final sample had 82 boys and 74 girls: 52 were Hispanic/Latino, 36 African American, 33 White US born, 21 Mideastern, 7 East African, 3 Asian Indian, 2 West African and 2 from the Far East. A sample of this size has a power-efficiency coefficient of 0.80 for detection of medium or large, but not small effects, according to Cohen's (1992) analysis.

Materials

Instruction

Sixty sets of objects purchased in craft, sewing, toy, grocery or drugstores, or found in nature, were used to teach the oddity principle. Each set had three objects that were identical in one dimension and one that differed. The odd object differed only in shape for 20 sets (e.g. a triangular paper clip and three oval clips, or a trapezoidal plastic piece and three rectangular pieces). Twenty sets each had one object that differed from the other three only in size (e.g. one small florist pick and three large ones, or one large electric fastener and three small ones). In 10 cases the odd object was larger; in 10 it was smaller. Twenty sets of objects (plastic lizards, space cannons, etc.) were used for orientation oddity problems. Each set had four identical objects, but three were presented horizontally and one vertically (or vice versa), or three were slanted 45° one way and the other 45° the other (or vice versa) or three faced left and the other right (or vice versa).

Sets of objects ranging from beans to washers were used for insertion problems. Fifteen sets had three objects, 20 had four, 15 had five, five had six, five had seven and five had eight. The objects in a set might, or might not, have the same shape, but differed in height, length, width or overall size.

The sets of 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33 and 35 objects were used for conservation games. The objects in each set were identical, and ranged from miniature plastic bows to electric end caps. Foam numbers, many items that could be counted (cylinders, jacks, etc.), and cardboard 'coins' were used for numeracy instruction. Foam letters (upper and lower case) and letter bags were used for literacy games. Letter bags were labelled with a letter or consonant blend, and each contained many small objects or pictures of objects whose name began with that letter or consonant blend. All of the letters and consonant blends in the English language were represented. Worksheets, simple maps and drawings were used for social studies instruction.

Tests

Oddity, insertion and conservation tests were constructed from novel objects not used in instruction. The oddity test was designed to determine whether the children solve oddity problems that involved new objects but were similar in format to those they had previously solved – 'near' generalisation. It had four form, four size and four orientation oddity problems. Scores ranged from 0 to 12.

The insertion test had two three-object problems, two four-object problems, two that required insertion of a fourth object after the child had seriated three, two that required the child to insert a fifth object after seriating four and two that required insertion of a sixth object after seriation of five. This test also measured near generalisation; i.e. application of what the children had learned to new objects. Scores ranged from 0 to 10.

The conservation test had ten problems each with two rows of 3–10 equally spaced objects, with equal or different numbers of objects in each row. Children were questioned as to which row had more objects or whether they had the same number. For eight of the problems, one or more objects were added to or subtracted from a row, which might equalise the number of objects in the rows or make them more different. As the last step in every problem, the objects in one or both rows would then be spread out or pushed closer together while a child watched. The child would be queried as to which row had more objects, or whether they had the same number. The terms more, less and the same, and the order in which the rows were named, were varied systematically. Children were asked to explain their answers. Scores ranged from 0 to 10.

The *Listening to stories* subscale from the *Stanford Early school achievement test* (SESAT), which has a Kuder-Richardson reliability coefficient of 0.82 was used to measure early literacy. It consists of 30 short (3–5 sentence) passages read by the tester. The child is asked to answer a question about each passage in turn by selecting one from three possible alternatives depicted by drawings of things or events. Scores ranged from 0 to 30.

Early numeracy was measured by the *Woodcock-Johnson III Applied problems (numeracy) scale* (W-J III), which has a Kuder-Richardson reliability coefficient of 0.86. This scale begins with 'Show me just one finger' and escalates into problems concerning measurement, money, addition and subtraction. The first 36 questions were used in this research, and so scores ranged from 0 to 36.

Experimental design

The children who had not mastered oddity and insertions were formed into quartets. For practical reasons, the children in each quartet were from the same classroom. The members of each quartet were matched on the screening test results as well as possible, but this matching could only be approximate. After the quartets were formed, a random numbers table was used to assign the one member of each quartet to the experimental instruction and one to each of three control conditions. Oddity, insertions and number conservation were taught to the experimental group of children. In sessions matched in timing and duration, lessons in literacy were given to one control group, numeracy to another and social studies to a third. The literacy and numeracy groups had equal contact with research personnel, and received equal investment of time and resources in constructive activities with expectations of consequent improvement on relevant dependent variables. They were 'active' control groups (Pasnak and Howe 1993). The social studies group was a passive control group (Pasnak and Howe 1993). These children also had equal contact with research personnel, and received equal investment of time and resources, but in activities which were not directed at any dependent variable. Many problems which plague educational research were controlled by this superior design. If the children taught abstractions matched or exceeded the control children taught numeracy on numeracy, and exceeded them on literacy, the cognitive instruction would have been fruitful. Likewise, if the cognitive group matched or exceeded in literacy the children given literacy instruction, and surpassed them in numeracy, it would again be evidence that the cognitive instruction had been fruitful. Having learned to abstract at an age-appropriate level, the experimental children might have been in a position to learn more from the classroom instruction offered to all of the children by the teacher. If so, they could have been able to equal or exceed in a specific subject matter the achievement of children who had received some additional instruction from the researchers on that subject matter, while surpassing them in the other subject matter. All should have exceeded the passive control group, which matched the other groups in all respects except that of receiving instruction specifically in abstraction, literacy or numeracy.

Procedures

Four to 12 children from each classroom participated, depending on the number of children in each class who had failed the screening test, yielding one to three children from each class to receive each kind of instruction. If a child left school, the instruction of other members of the quartet continued at the usual time, but the data from the partial quartet was not included in the analysis of results.

Each group of children – cognitive, literacy, numeracy and social studies – had three 10–15 minute sessions of experimental instruction per week during 'centers' time. This is a time when the children customarily divide into very small groups and work on a rotation of diverse activities for 10–15 minutes each, sometimes supervised by the teacher or her assistant, sometimes working independently. Hence, the experimental instruction was just an additional center. The authors of the study supervised the instruction every day, and the children's progress was recorded after each session.

Cognitive instruction

First, children were instructed on the shape oddity problems. The four objects for any problem were presented in a row, and the position of the odd object was changed from trial to trial. To be considered to have mastered these or any subsequent problems, a child had to be correct on the first try at selecting the odd object on three consecutive days. When children met this criterion on all of the shape problems, they were instructed on the size oddity problems. From problem to problem the relative size of the odd object, large or small, was alternated. When the criterion was met on each of these problems, instruction on oddity by orientation began. Instruction began with problems nearly all children find very easy: three objects were placed horizontally and one was placed vertically, or vice versa. After the children met criterion on these problems, the objects were presented again but three objects were slanted 45° in one direction and the different object was slanted 45° in the opposite direction. These orientation oddity problems are much more difficult. When the children met the criterion on these problems, problems with three objects facing left and one facing right, or vice versa, were presented. When the criterion was met on these problems, instruction on insertion began.

First, the children were asked to line up three objects in a row from smallest to largest and instructed as much as needed to meet the criterion of success on three consecutive days. After the criterion was met for all 15 three-object problems, they were taught to do the same for the 20 sets of four objects. When the criterion was met on each of these, the same 20 sets objects were used for insertion problems. Now only three objects in a set were given to a child, who was asked to seriate them – an easy task at this point. One of the mid-sized objects was held back until after the other three had been lined up correctly. Then it would be presented and the child asked to place it where it belonged in the series and given as much instruction as needed. When the criterion was reached on these problems, instruction began on the five-object problems. The children were taught to line up four objects from smallest to largest, then insert a fifth object where it belonged in the interior of the series. Instruction on six-, seven- and eight-object problems began when each criterion was reached on the five-object problems, with the child always given all but one object for the initial seriation and then required to insert an object of intermediate size. This instruction was continued until each criterion had been met on all of the problems.

The conservation instruction began with two rows of three or more equally spaced items. The child would be asked: 'Do we have the same number of [hearts, stars, etc.], do you have more or do I have more?' The order of the terms in the question varied from trial to trial. When the child agreed that the same number of objects were in each row, the instructor spread out the objects in one row and pushed closer together those in the other. Then the child was asked: 'Are there still the same number of [hearts, stars, etc.] in my row and your row, or are there more in your row or more in my row?' Again, the order of the terms was varied. As the children's understanding of conservation developed, rows with more objects were introduced, the rows might not have the same numbers of objects initially, and objects were added to or subtracted from one or both rows before the rows were expanded or contracted. The number of objects in the rows might be made equal or unequal by the addition or subtraction. Instruction continued until the children understood conservation so well that they could not be fooled by any question asked.

Literacy instruction

Initially, upper and lower case foam letters were used to teach letter identification to children in the literacy group. The child might be asked to name a letter the instructor picked out or to pick out a letter the adult had named. Only three letters – A, B and C – were presented for the child to choose between initially, and instruction proceeded until a child could name a letter correctly on the first attempt on three consecutive days. New letters were added in alphabetical order but presented in an inter-mixed array, until the child learned the whole alphabet. Then the instructor modeled the short vowel and consonant sounds that for each letter, a few letters at a time, and the child was taught to make the sounds appropriate for each letter, until all had been learned to the criterion above. Next the instructor pronounced one-syllable words and asked the children what the initial letter of the word was. When the children met the criterion of being correct on three consecutive days, the letter bags were introduced. The letter bags had a dozen or more objects or pictures of objects whose names began with the same letter. The children were to name each object or picture. Objects whose name they did not know were named for them, and they were asked to repeat the name until they learned it and associated it with the picture or object. When a child could name all of the objects in several bags, those from two of the bags were intermixed, and the child was asked to sort them by their initial sound. After a child had sorted all of the letter bags, instruction proceeded to identifying words that rhymed and, finally, to making syllables or one-syllable words by blending the sounds of letters. The second author, an experienced educator specialising in developing early literacy skills, devised all of these procedures.

Numeracy instruction

The children in the numeracy group were first taught the numbers 1–10 with foam numbers. The children were first taught to select from several numbers those which the instructor named (number identification). After reaching a criterion of being correct on all ten numbers on three consecutive days, they were taught to name numbers as the instructor pointed to them (number recognition). When the criterion was reached for the numbers 1– 10, the child was given some small objects. The adult then named a number and asked the child to count out that number of objects. Initially, there would only be one or two items more than the number named. As children became better at counting, extra items were added, increasing the chances for an error. The numbers 1–10 were taught one by one, but as numbers became higher and the children more proficient, several numbers were taught in the same session. Numbers which children had already counted successfully on three consecutive days were always mingled with the new numbers.

The children were also taught to play number bingo with numbers they knew well. For number bingo, cards have no letters but instead have spaces bearing numbers up to 5, 10, 15 or 20. As the instructor names numbers, the children cover those numbers on their card with chips until five chips form a row or column.

When children knew all numbers up through 30 and could also count that far, they were taught to count by fives, using small blocks, stars or other items grouped in fives as aids. Finally, the instructor would hold up a number and ask the child to give a higher number. For example, the instructor would hold up an eight and ask: 'Will you give me a number that is higher than eight?' Alternatively, the request might be: 'Please give me a number less than eight.' All of these activities were standard instructional methods designed to meet state standards for the development of early numeracy.

Social studies instruction

The social studies lessons were designed to meet the state Standards of Learning for five year olds. These involved having discussion with the instructor and doing worksheets designed to teach the pledge of allegiance, rules for the use of the country's flag, the structures of families, the relations between family members, activities in the family such as typical morning and evening hygiene routines. Children were taught about the senses of hearing, touch, smell and taste, and the main body parts. They were also taught about community resources – library, fire station, police station, recreation center, post office – and neighborhood transportation. The concepts of simple maps and directional location (top, bottom, left, right, above, below, between) were also taught.

Ending and assessing the intervention

When a child receiving instruction on oddity, insertions and conservation met each criterion on these, their instruction was terminated. The instruction of the children who were yoked with them and being taught literacy, numeracy and social studies was simultaneously terminated. Thus, number of sessions it took a child in the experimental group to master the cognitive instruction was the only determinant of how many sessions that child and the three yoked children received. This resulted in the average number of sessions being the same (51.4) for all of the groups. The last instruction took place at the end of February. The children were tested over a three-week period from the middle of May and the first week of June on insertion, oddity, conservation, the *W-J III Applied problems (numeracy) scale*, and the *Listening to stories* subscale from the SESAT by testers who did not know which instruction which child had received.

Results

After attrition of quartets caused by household changes of residence, complete data were collected from children in 39 quartets (i.e. 156 children, 39 in each group). The results obtained are presented in Table 1. Statistical analysis shows that they were close to those predicted. Scores on the screening tests were not significantly different. After the instructional programme, the cognitive group became significantly better than any group on these concepts and on conservation. Analysis of Covariance was used in significance tests to completely equate the starting points for all groups on oddity and seriation (see Table 2). Size of overall effects ranged from small (oddity, numeracy and literacy) to medium (insertion and conservation) according to Cohen's (1992) criteria, but it is the comparisons of specific groups that are of interest.

For all dependent variables, at least two of the groups which received no instruction on that variable should make similar scores. For example, on the SESAT, at least the numeracy and social studies group should not differ. If the cognitive instruction was

Table 1. Scores on measures of abstraction and achievement.

Group	Cognitive	Literacy	Numeracy	Social Studies
Oddity screening scores (12 possible)				
Mean	7.19	8.26	8.53	8.42
SE	3.42	2.75	2.60	2.56
Insertion screening scores (10 possible)				
Mean	3.21	3.26	3.28	3.82
SE	2.22	2.18	2.24	2.16
Oddity scores (12 possible)				
Mean	11.21	9.56	10.24	9.90
SE	0.29	0.30	0.30	0.32
Insertion scores (10 possible)				
Mean	8.99	5.81	7.12	6.58
SE	0.41	0.44	0.43	0.46
Conservation scores (10 possible)				
Mean	7.54	4.68	3.33	5.00
SE	0.51	0.54	0.53	0.57
Numeracy (W-J II) scores (36 possible)				
Mean	19.06	17.62	19.52	17.43
SE	0.51	0.54	0.53	0.56
Literacy (SESAT) scores (30 possible)				
Mean	15.61	14.95	13.64	13.79
SE	0.56	0.60	0.59	0.63

Table 2. Analyses of covariance for cognitive and achievement scores.

Source	df	Mean square	*F*	*p*	Partial eta^2
Corrected model					
Oddity	6	22.88	6.64	0.001	0.21
Insertion	6	42.53	6.00	0.001	0.19
Conservation	6	71.45	6.56	0.001	0.21
W-J III	6	100.36	9.37	0.001	0.28
SESAT	6	29.38	2.24	0.044	0.08
Intercept					
Oddity	1	860.15	249.48	0.001	0.63
Insertion	1	325.99	46.01	0.001	0.24
Conservation	1	34.79	6.77	0.010	0.04
W-J III	1	73.67	2147.87	0.001	0.58
SESAT	1	1932.89	146.32	0.001	0.50
Covariates					
Oddity screening					
Oddity	1	63.12	18.31	0.001	0.11
Insertion	1	20.97	2.96	0.087	0.02
Conservation	1	34.79	3.20	0.076	0.02
W-J III	1	234.34	21.85	0.001	0.13
SESAT	1	51.55	3.90	0.050	0.03
Insertion screening					
Oddity	1	0.61	0.18	0.675	0.00
Insertion	1	18.69	2.64	0.106	0.02
Conservation	1	55.09	5.06	0.026	0.03
W-J III	1	105.56	9.86	0.002	0.06
SESAT	1	25.69	1.94	0.165	0.01
Differences between outcomes for instructional groups (independent variable)					
Oddity	3	19.70	6.64	0.001	0.10
Error	147	3.45			
Insertion	3	71.47	6.00	0.001	0.17
Error	147	7.09			
Conservation	3	121.68	6.56	0.001	0.19
Error	147	10.89			
W-J III	3	40.70	9.37	0.012	0.07
Error	147	10.71			
SESAT	3	34.52	2.61	0.054	0.05
Error	147	13.21			

ineffective in improving literacy, then three groups – the cognitive, numeracy and social studies groups – should not differ. When two or three of four groups do not differ, there may be no overall difference between groups on that variable. This is a limitation of the omnibus *F*-test, and it is what happened with the SESAT. The usual remedy of comparing each pair of groups – also necessary to test the experimental hypotheses – was employed here. For the number of planned comparisons made here, Bonferroni methods suggest that a *p*-value of 0.037 be employed (Scheffé 1959). Pair comparisons based on the ANCOVA showed that the cognitive group had become significantly better than the others by the end of the school year in oddity, seriation and conservation. There were no significant differences between the three control groups on these concepts (Table 3). Hence, the cognitive instruction was effective in teaching the abstractions involved in oddity, insertions and conservation.

Table 3. Significance of pairwise comparisons on predicted ANCOVA marginal means.

	Oddity	Insertion	Conservation	WJ III	SESAT
Cognitive vs Literacy	0.001	0.001	0.001	0.008	>0.037
vs Numeracy	0.002	0.001	0.001	>0.037	0.001
vs Social Studies	0.001	0.001	0.001	0.003	0.003
Literacy vs Numeracy	>0.037	>0.037	>0.037	0.024	0.008
vs Social Studies	>0.037	>0.037	>0.037	>0.037	0.032
Numeracy vs Social Studies	>0.037	>0.037	>0.037	0.008	>0.037

Note: Comparisons are one-tailed. Values of p of 0.001 or less are reported as 0.001.

Differences on the academic measures – the SESAT and W-J III – favored the cognitive group over the social studies group and were statistically significant. This indicates that the cognitive instruction positively affected both literacy and numeracy. The children receiving the cognitive instruction were also significantly better on numeracy than those receiving the literacy instruction. This is a second line of evidence that the cognitive instruction had a positive effect on numeracy.

The cognitive group was also significantly better than the numeracy group at literacy. This comparison, like the comparison between the cognitive and social studies group, is evidence that the cognitive instruction produced gains in literacy.

There was no difference between the cognitive group and the literacy group in literacy, although the latter had received special instruction in that domain, and there was also no difference between the cognitive and numeracy groups in numeracy. This indicates either that the control instruction in both literacy and numeracy was ineffective or that the cognitive instruction was equally effective, producing equivalent progress in *both* domains. The first interpretation is not very defensible because the comparisons cited earlier are evidence that the cognitive instruction produced progress in numeracy and literacy. It is also clear, because the literacy and numeracy groups differed from each other significantly in the hypothesised directions on the literacy and numeracy measures, that both forms of control instruction were valid.

The numeracy group was significantly better than the social studies group on numeracy, and the literacy group was significantly better on literacy, which also validated the numeracy and literacy instruction.

In sum, these results show more than that researcher involvement and extra small group attention can improve performance. The improvements shown by the numeracy and literacy groups reflect the focus of the instruction each received. That of the cognitive group shows not only improvement on the cognitive variables on which it was instructed, but also on both measures of academic attainment.

Discussion

The first important finding is that the experimental instruction produced increased competency in abstraction and that the effect lasted at least until the end of the school year. There is no reason to expect any group to decline in the years ahead since these abilities are continually strengthened in the normal course of cognitive development. The gains in ability to abstract are significant in themselves, as it is notoriously difficult to enable children to think at a level more abstract than that they have developed on their own. The learning set approach used, relying on experience with a large number of variable concrete representations of the concepts to be taught, may be an efficient and unambiguous way of simulating the interactions children have with their environments before entering school. In this research, the children who had not developed abstract levels of thought as well as their classmates were helped by the concentrated experience with situations in which the abstract thinking was necessary to produce successful understanding. Inasmuch as the instruction requires no particular training for teachers and no expensive materials, it may be an efficient way for teachers or assistants to bring children who are functioning at a low level cognitively closer to the class average. The advantage thereafter of not having to cater to students who range widely in ability to understand instruction will be recognised by any teacher.

The payoff for increasing the children's competency in abstraction was increases in early numeracy and literacy. The advantage in numeracy at least equalised those provided by control numeracy instruction, as the cognitive and numeracy groups were equivalent in numeracy and superior to the other control groups. This is a corroboration of the main finding of Pasnak et al. (2007). The present research also provides a significant extension, in that here the control instruction in numeracy was shown to be effective. This was not conclusively demonstrated in the earlier research.

The test of the effect of the instruction on literacy also demonstrates that the cognitive intervention helps in the development of early literacy, which was not convincingly demonstrated with the literacy measure employed by Pasnak et al. (2007). Thus, the advantage of the cognitive intervention is now quite clear. While the special instruction in literacy helped children with literacy, just as the special instruction in numeracy helped children with numeracy, the instruction in abstract thinking helped children in *both* spheres. It probably helped them in other areas of academic achievement as well, although no others were measured. This is presumably because instruction in the first year of formal schooling is based on a level of cognitive competency that the great majority of children have developed. There are often some children, however, who do not attain that level in a timely way. The children in the urban school system where this research was conducted contained many such.

We note that the superiority of the cognitive group on the cognitive measures was probably greater in the middle of the school year when the experimental instruction was concluded. The control children had several months to close the gap by the end of year, and presumably did so, although they did not eliminate it, because children ordinarily develop and strengthen these abilities unaided in the normal course of interactions with their environment, and these children were chronologically at the age where this process would be well under way. The superiorities in literacy and numeracy of the children receiving the cognitive instruction presumably arose from their cognitive superiority at mid-year, not from their reduced superiority at the end of the year, although the latter might be helpful in following years (Pasnak, Madden et al. 1996). These children were able to employ their strengthened cognitive abilities, now closer to those of most classmates, during the last half of the school year. This could help them to understand the teacher's instruction in all other subjects during the whole school day.

This would account for the ability of the cognitive group to perform as well on the SESAT as the children given extra lessons on early literacy and better than those who had extra sessions on numeracy or social studies. The extra literacy instruction the literacy group received – three 10-minute lessons per week – were dwarfed by the literacy instruction the classroom teachers gave all children for extended periods during the school day. While the sessions had an effect, as the children receiving them made higher literacy scores than the numeracy and social studies control groups, it was offset in the case of the children receiving the cognitive instruction. The cognitive advantage these children gained appears to have helped them understand more of the regular classroom instruction, enabling them to match the literacy children on the literacy test.

To understand how the cognitive instruction could lead to gains in numeracy and literacy, it is helpful to consider the situation of a child who is deficient in these abilities. Children who cannot easily and quickly solve oddity problems in their heads, much less with concrete objects in front of them that can be examined and compared, may not be able to quickly and easily identify and separate the relevant from the irrelevant aspects of many items and events they encounter in the classroom and elsewhere, especially when those things are described verbally and have to be considered while the speaker moves on to new considerations. Likewise, being unable to understand very simple relations between concrete objects well enough to order them sequentially along one dimension, even when there is ample opportunity for experimentation and self-correction, could be a great handicap. The child would be unable to understand the place of things in a series and unable to interrelate the things in many sequences. The situation is much worse when series are described verbally and the ability to comprehend such things instantly is assumed. Likewise, the understanding that addition and subtraction are necessary to change number and that the amount added or subtracted is crucial to answering questions concerning number, regardless of perceptual appearances, is central to first-year numeracy curricula. It is not hard to see how cognitive instruction that succeeds in strengthening such understandings can help some children, although it would not benefit the majority of children because they already understand such things. It is potentially quite important to help the children who need help, because Silliphant's (1983) research showed that kindergarten scores on measures of conservation, classification and seriation predicted academic achievement not only in kindergarten, but also for the next three years. The longitudinal study of French-Canadian children by Dudek, Strobel and Thomas (1987) showed that such 'Piagetian' measures predicted children's achievement at least through the fourth grade, and that deficiencies became associated with some negative emotional consequences, even when children were matched in psychometric IQ.

Limitations and further directions

While the deficit model offered above *may* explain, or partially explain, the effectiveness of the cognitive intervention in aiding the development of numeracy and literacy, there is no clear-cut demonstration of just what the linkages are. At this point, we have a cause-and-effect demonstration, but no direct knowledge of how the cause produces its effect. Further research is needed to specify just what the mechanisms are that lead from mastery of the oddity principle, insertions in to series, and conservation to numeracy and literacy. Alternatively, advances in theoretical models of cognition may solve this problem. At present, there is a disconnect between the empirical research and our understanding of the mediating factors that lead from the improvement in cognition to improvement in academics.

Another problem is sample specificity. The effectiveness of such instruction is presumably limited to children who are at the appropriate developmental level. Previous research indicates that it may be ineffective with children who are too advanced (Waiss and Pasnak 1993) or too laggard (Pasnak, Hansbarger et al. 1996) in cognitive development. Hence, further research programmes will be needed both to determine the cognitive mechanisms by which the cognitive intervention has its effects, and to determine the kind of children for which an educator might reasonably expect such effects.

Conclusion

What is clear from the present research is that improving children's understanding of oddity, insertions and number conservation can produce improvements in both numeracy and literacy, at least as measured in this experiment. This provides a tentative answer to the question of whether it can be worthwhile to devote instructional time to cognitive instruction. At least when the concepts taught here are taught thoroughly, the cognitive instruction appears to result in better understanding of regular classroom instruction and probably narrows the range of relevant cognitive abilities with which the teacher must deal. Delivering brief lessons three days per week early in the year to such instruction of those children who need it produces a better result than devoting the same brief sessions to instruction in academic subject matter.

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