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ABSTRACT

This study examined the effects of hands-on instruction on young children's understanding of an aspect of flight, specifically Bernoulli's principle. First, 137 public school children, ages 5 through 8 years, were interviewed about their understanding of how an airplane flies. Two weeks later, the subjects participated in two hands-on instructional activities that demonstrated Bernoulli's principle of flowing fluids (which creates lift). Three weeks after the instructional activities the subjects were interviewed again about their understanding of flight. The study found that although no children, pre- or post-intervention, demonstrated a complete understanding of Bernoulli's principle or flight, significant numbers of children progressed from a level of no understanding to some understanding or some vocabulary knowledge. Overall, 29 percent of the subjects evidenced a change in their level of understanding following instruction. The youngest children evidenced the largest percentage of change in responses, whereas the oldest students demonstrated the smallest percentage of change. Contains eight references. (MDM)

Bernoulli's Principle:
The Effects of Instruction on
Young Children's Understanding of Flight

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Running Head: Bernoulli's Principle

An understanding of how young children acquire abstract concepts depends in part on an understanding of the role played by instruction in the acquisition process. The question of whether to introduce abstract concepts, and what type of instruction is most appropriate, is critical to the design of curriculum and classroom practices for young children, particularly with respect to content areas such as science and math. Constructivist views of children's cognitive development suggest that a hands-on approach to instruction is better suited to young children's understanding of abstract concepts. The research reported in this paper examined children's acquisition of abstract concepts using hands-on instructional activities related to concepts of flight.

Piaget believed that acquisition of concrete operations was primarily a maturational phenomenon and that instruction had little effect upon its development. However, subsequent research has suggested that early intervention can affect the rate at which cognitive development occurs (Campbell & Ramey, 1990). Specifically, research has demonstrated the ability of hands-on instruction to increase children's understanding of abstract concepts (Borghi, 1988; Cohen, 1992).

Studies which have contrasted differing types of instructional activities support the value of hands-on or manipulative activities over more traditional or abstract kinds of instruction (Cohen, 1992; Meyer, 1992). Other research demonstrates the effectiveness of hands-on experiences in children's acquisition of abstract concepts inherent in subject matter such as science and mathematics (Kotar, 1988; Kyle, 1988; Zvonkin, 1992). Further studies indicate that the use of hands-on instruction facilitates the cognitive development of economically disadvantaged young children (Campbell & Ramey, 1990).

The present investigation reports findings from a study of the effect of hands-on instruction on young children's understanding of an aspect of flight, specifically, Bernoulli's principle. Results illustrate quantitative changes in children's level of understanding of flight as well as qualitative changes in their concepts of flight after experiencing hands-on instruction.

Methods

Participants

The sample was composed of 137 public school children, 67 females and 70 males, ranging in age from five to eight (see Table 1). The subjects were randomly selected from an urban elementary school designated as a Chapter 1 school. Data were collected by a team of interviewers consisting of 30 undergraduate students enrolled in a five course early childhood education block at a large urban public university.

Table 1. Subjects by Age and Gender

Age	Frequency	Percentage	Females	Males
5	41	30%	20	21
6	46	34%	26	20
7	35	26%	16	19
8	15	10%	5	10
Total	137	100%	67	70

Training of interviewers

Training consisted of two, 3 hour sessions. In the first session the interviewers were trained to conduct the two hands-on science activities which they presented to the children. In the second session focused on strategies for presentation, vocabulary and questioning as well as practice carrying out the activities.

Procedures

An interviewer individually interviewed five subjects and asked the question, "How does something as heavy as an airplane stay in the air?" and their responses were recorded. Two weeks after the initial interview, all subjects participated in the two instructional activities. These instructional activities were taught in the students' regular classroom by pairs of interviewers working with the whole class.

The two instructional activities presented by the interviewers followed a prescribed lesson format. Both activities were designed to demonstrate Bernoulli's principle of flowing fluids. A fluid is any substance, solid, liquid, or gas that flows. For example, the faster the air flows over a surface the lower the air pressure above the surface. The greater the difference between the lower air pressure above the surface and the higher air pressure below the surface, the greater the weight that can be lifted. The first activity uses paper strips to demonstrate creating areas of high and low air pressure resulting in lift. The second activity also demonstrates this pressure difference by using an index card folded in the shape of an airplane wing.

Twenty-one days after both instructional activities were completed, all subjects were again interviewed individually and asked the identical question, "How does something as heavy as an airplane stay in the air?"

Data Collection

Data collection consisted of responses to the airplane question during the first interview and responses to the same question during a second interview. Collected data were entered into a database by the primary researchers. Responses to the first and second interviews were coded by the primary researchers using two different methods.

Both coding methods consisted of assigning children's responses to categories determined by the researchers using constant comparison methods. One of the methods categorized the children's interview responses based upon the actual words from the responses (hereafter referred to as "response coding"). The second method consisted of coding children's interview responses by degree of understanding and vocabulary related to Bernoulli's principle (hereafter referred to as "understanding coding"). All data were coded individually by four of the primary researchers. Discrepancies in codings were discussed until consensus was reached.

From the children's responses to the first interview the following categories emerged and were used for one of the codings:

Code	Category	Response Example
0	null	no response, don't know
1	wings	"it flies with its wings"
2	driving	"somebody driving the plane"
3	motor	"it can't fly without a motor"
4	air	"the air" or "the wind"
5	simile	"it flies like a bird"
6	parts	"wheels, buttons, tail, brake"
7	idiosyncratic	"heavy boxes"
8	propeller	refers to propeller only
9	flies	"it just flies"
10	combination	more than one category in response

The children's interview responses were also coded according to their degree of understanding and vocabulary with respect to Bernoulli's principle. This understanding and vocabulary was based in part on the concepts presented in the instructional activities. The categories that emerged in this coding were:

Code	Category	Response Example
1	no understanding or vocabulary	"it just starts flying"
2	some understanding, no vocabulary	"the air makes it stay up"
3	some understanding, some vocabulary	"gravity and pressure in the air"
4	understanding and vocabulary	(no responses this category)
5	null response	no answer

Data Analysis

Data from both the response coding and the understanding coding were compared for differences in the frequency of categories of codes between the pre-instruction and post-instruction interviews. Additionally, both pre-instruction and post-instruction data for both the response coding and understanding coding were analyzed using a chi square test which compared the pre-instruction codings (expected responses) with the post-instruction codings (observed responses). Cross tabulations were also conducted which examined changes in both codings by age group. Statistical analyses were performed using the SPSS-Windows program.

Results

Frequencies - Both Codings

Preliminary results indicate marked changes in the percentages of codings in both response and understanding following the instruction. Table 2 illustrates these changes for the response coding and Table 3 presents the same data for the understanding coding.

Table 2. Frequency of Response Codings

Code	Category	Frequency Pre-Instr	Frequency Post-Instr.	Percent Change
0	null	8	4	-50%
1	wings	24	27	13%
2	driving	11	4	-64%
3	motor	2	3	50%
4	air	16	23	44%
5	simile	11	2	-82%
6	parts	12	7	-42%
7	idiosyncratic	18	5	-72%
8	propeller	6	11	83%
9	flies	9	2	-78%
10	combination	20	49	145%

Categories which showed a marked decrease from pre- to post-instruction included: null, driving, simile, parts, idiosyncratic, and flies. Categories which showed a marked increase from pre- to post-instruction included: air, propeller and combination. Overall, 69% of the subjects demonstrated a change in response from the first to the second interview.

Table 3. Frequency of Understanding Codings

Code	Category	Frequency Pre-Instr	Frequency Post-Instr	Percent Change
1	no understanding or vocabulary	114	83	-27%
2	some understanding, no vocabulary	21	50	138%
3	some understanding some vocabulary	1	2	100%
4	understanding and vocabulary	0	0	0

Results here also indicate a marked change in several categories following instruction. In Category 1 (no understanding) there was a decrease of 27%; there was an increase of 138% in Category 2 (some understanding but no vocabulary); there was a 100% increase in Category 3 (some understanding and some vocabulary). It should be noted that there were no codings of Category 4 in either set of interviews. Overall, 29% of the subjects evidenced a change in level of understanding following instruction.

Results of Chi Square

Data for both the response and understanding codings were analyzed using a chi square. For the response codings, the frequency of responses in each category from the pre-instructional interview were used as the expected values. These values were then compared with the frequency of responses in each category from the post-instructional interview (the observed responses). Because of the level of degrees of freedom, the analytical procedures required collapsing categories where frequencies fell below five. Then codings in Category 3 (motor) were collapsed into Category 6 (parts of the plane). Results of this analysis yielded a statistically significant difference between the two sets of responses (see Table 4).

Table 4. Chi Square Analysis - Response Coding

Category	Observed	Expected	Residual
0	4	8	-4.00
1	27	24	3.00
2	4	11	-7.00
4	23	16	7.00
5	2	11	-9.00
6	10	14	-4.00
7	5	18	-13.00
8	11	6	5.00
9	2	9	-7.00
10	49	20	29.00

Chi-Square	D.F.	Significance
79.4485	9	.0000

For the understanding codings, the frequency of codings in each category from the pre-instruction interview were used as the expected values. These values were then compared with the frequency of codings in each category from the post-instructional interview. Because of the level of degrees of freedom, the analytical procedures required collapsing categories where frequencies fell below five. In order to run the analysis, codings in the "some understanding and no vocabulary" and the "some understanding and some vocabulary" categories were collapsed into Category 2; codings in the "no understanding" and the "null response" categories were collapsed into Category 1. Results yielded a statistically significant difference between the two codings (see Table 5).

Table 5. Chi-Square Analysis of Understanding Codings

Category	Observed	Expected	Residual
1	85	115	-30.00
2	52	22	30.00

Chi-Square	D.F.	Significance
48.7352	1	.0000

Cross Tabulations

After the chi square analysis was completed, cross tabulations were calculated according to the age of the subjects for both the response coding and the understanding coding. In both cases, the cross tabulation compared and analyzed the changes in frequencies of codings from pre- to post-instruction interviews by age group. Both pre- and post-instructional cross tabulations were also calculated to compare global changes in responses.

Results of the analysis of changes in frequencies in the response coding by age are provided in the following two tables.

Insert Table 6

Insert Table 7

Changes in the frequencies of response codings by category exhibited different patterns for each age group. Five-year-olds in the study, for example, evidenced marked changes in four categories, with large decreases in codings in the "idiosyncratic" and "flies" categories, and large increases in the "propeller" and "combination" categories. Six-year-olds evidenced marked changes in five categories, with large decreases in the "driving," "idiosyncratic" and "simile" categories, and large increases in the "wings" and "combination" categories. Seven-year-olds evidenced marked changes in only three categories, with decreases in the "wings" and "simile" categories and a large increase in the "combination" category. Eight-year-olds evidenced marked change in only one category - "combination" - and also showed the least diverse responses in both pre- and post-instructional codings. In fact, for this age group, there were few codings in categories such as "null," "simile," "idiosyncratic" and "it just flies." Based upon the results of this cross tabulation, subjects' response codings were then categorized dichotomously as to whether or not there was a change in each subject's response from pre- to post-instruction interview. This additional data was then analyzed using a cross tabulation by age group. The following table illustrates the results of this analysis.

Table 8. Changes in Response Codings by Subject Age

Age	Subjects	Change in Response	No Change in Response	Percent Change
5	41	33	8	80%
6	46	32	14	70%
7	35	21	14	60%
8	15	9	6	64%

Five-year-olds evidenced the largest percentage of changes in response codings from pre- to post-instructional codings, with 33 subjects (80%) giving a different category of response in the post-instructional coding. Eight-year-olds evidenced the smallest percentage of changes in response codings post-instruction although the percentage of subjects giving a different category of response was still marked (64%).

Results of the analysis of changes in frequencies in the understanding coding are provided in Table 9. Note that the codings are based upon the collapsed categories used in the chi square analysis.

Table 9. Participant's Age by Understanding Coding Pre- and Post-Instruction Interviews

	No Understanding Coding			Some Understanding Coding		
Age	Pre-	Post-	%Change	Pre-	Post-	%Change
5	38	28	-26%	3	13	333%
6	49	28	-28%	7	18	157%
7	28	21	-25%	7	14	100%
8	10	8	-20%	5	7	40%

Changes in the frequencies of understanding codings by category also exhibited similar patterns for each age group, although differences in the degree of change are consistent across age level. All age groups evidenced a marked decrease in codings in the "no understanding" category from pre- to post-instructional interviews. The degree of decrease was similar across age groups although it was lowest for eight-year-olds. All age groups evidenced a marked increase in codings in the "some understanding" category from pre- to post-instructional interviews. With this category, the degree of increase was largest for five-year-olds (333%) and became comparatively smaller in each succeeding age group with eight-year-olds showing an increase of 40%.

Based upon the results of this cross tabulation, subjects' understanding codings were then categorized dichotomously as to whether or not there was a change in each subjects's response from pre- to post-instructional interview. These additional data were then analyzed using a cross tabulation by age group (see Table 10).

Table 10. Changes in Understanding Codings by Subject Age

Age	Subjects	Change in Responses	No Change in Responses	Percent Change
5	41	13	28	32%
6	46	15	31	33%
7	35	8	27	23%
8	15	4	11	29%

In comparison with changes evidenced in the response codings, far fewer subjects across all ages evidenced a change in understanding codings from pre- to post-instructional interviews. Percentages of changes by age group are similar, with 32% of five-year-olds changing from no understanding to some understanding, and 29% of eight-year-olds changing from no understanding to some understanding.

Discussion

Findings from this research support the power of hands-on instruction to favorably affect children's understanding of abstract principles. Significant changes were demonstrated in both the quality of children's concepts about flight as well as the overall developmental level of those concepts. In terms of their response to the question, "How does something as heavy as an airplane stay in the air?", some children did focus on singular aspects of flight such as the wings or the air or the propeller. However, a large number of children in the first interview were unable to provide any reasonable explanation and either focused on the idiosyncratic ("a robot, God, giant human") or simply responded that it "just flies." Still others attempted to explain flight by referring to other objects that fly, including birds, helicopters, rockets, and even Dumbo. After the instruction, the second set of interview responses showed a marked change in the response categories. Very few children gave a null or idiosyncratic response; responses in the "it just flies" and the simile category also dropped dramatically. Responses in the combination category, where children referred to some aspect of flight, increased the most. These changes indicate that instruction does result in qualitative changes in children's understanding of concepts of flight. Further, results suggest that these changes are occurring at a microlevel of understanding.

Results of the response coding indicate that eight-year-olds had smaller numbers of change. This could possibly be attributed to the eight-year-old's more sophisticated framework of understanding. Unlike the younger subjects, they may not be acquiring new concepts, but simply integrating the new information into their existing frameworks. Further research is necessary to determine the constructs of these frameworks. How are they acquired? What factors affect their acquisition?

Instruction also appears to effect positive change in children's level of understanding and vocabulary of abstract concepts. In the understanding coding, significant numbers of children progressed from a level of no understanding to some level of understanding and/or vocabulary. Further, there was a dramatic decrease in children in the null response category from the first to the second interview. It should be noted, however, that no responses in the full understanding category were coded either before or <u>after</u> instruction. This finding supports the notion that hands-on instruction with young children can produce limited or microlevel changes in their understanding of abstract concepts, and that overall developmental level of students sets limits on the changes that instruction, especially on abstract topics, can produce.

Results of this research support the ability of hands-on instructional activities to increase children's understanding and vocabulary of abstract concepts. Findings support prior research which demonstrates that understanding and vocabulary of science concepts can be altered, at least at a microlevel, by hands-on instructional strategies (Borghi, 1988; Cohen, 1992). Findings suggest that further research needs to explore factors such as length of instruction and the degree of effectiveness of hands-on instruction when compared with instruction received by a control group.

The findings of this research strengthen what we know about teaching techniques and appropriate curriculum for young children. Hands-on instruction allows children to construct knowledge about abstract concepts. However, construction of knowledge takes time and cannot be rushed.

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Table 6. Participant's Age by Response Coding Pre-Instruction Interviews

Code	Age 5	Age 6	Age 7	Age 8	Total
0	3	4	1	0	8
1	6	3	12	3	24
2	4	5	0	2	11
3	0	1	1	0	2
4	2	7	4	3	16
5	3	4	4	0	11
6	3	6	3	0	12
7	8	7	3	0	18
8	1	2	2	1	6
9	7	1	1	0	9
10	4	6	4	6	20
TOTAL	**41**	**46**	**35**	**15**	**137**

Table 7. Participant's Age by Response Coding Post-Instruction Interviews

Code	Age 5	Age 6	Age 7	Age 8	Total
0	0	2	2	0	4
1	9	10	7	1	27
2	2	1	0	1	4
3	1	2	0	0	3
4	5	10	7	1	23
5	1	1	0	0	2
6	3	2	2	0	7
7	3	2	0	0	5
8	5	3	3	0	11
9	2	0	0	0	2
10	10	13	14	12	49
TOTAL	**41**	**46**	**35**	**15**	**137**