DOCUMENT RESUME

ED 344 775 SE 052 858

AUTHOR	Norman, John T.; Taddonio, Thomas E.
TITLE	An Exploratory Study of the Effectiveness of a Play-Based Center Approach for Learning Chemistry in an Early Childhood Program.
PUB DATE	Apr 90
NOTE	25p.; Paper presented at the Annual Meeting of the National Association for Research on Science Teaching, (Atlanta, GA, April 8-11, 1990). Print marginally legible.
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150) -- Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Affective Behavior; *Chemistry; *Curiosity; Language Acquisition; *Learning Centers (Classroom); Learning Theories; Nonverbal Communication; Play; *Preschool Education; *Science Activities; Science Education; Spatial Ability; Verbal Communication

ABSTRACT

The purpose of this study was to evaluate the effectiveness of seven chemistry learning centers for use in an ongoing preschool education program. The seven centers piloted were: (1) Observing Color Changes; (2) Making Bubbles; (3) Using a Thermometer; (4) Balancing; (5) Classifying Colors; (6) Cooking; and (7) Sink or Float. All of the centers piloted were designed for use in a play-based early childhood program, since this was the approach already being used for other content areas in the test site. The goals of this play-based center approach for preschool chemistry were delineated and involved socioemotional, cognitive, and language goals of learning. The average time each student spent at each of the chemistry learning centers was determined from videotapes and was thought to be a measure of one of the socioemotional goals dealing with student curiosity. The class average ratings for the socioemotional goals of autonomy, persistence, cooperation, enthusiasm, and curiosity were determined from the ratings given to each individual student based on teacher notes and videotapes. Cognitive data for classifying, ordering/seriation, spatial relationships, and temporal relationships is also provided. In addition, centers were evaluated with respect to how they encouraged students to identify problems and come up with their own ideas. Language goals were evaluated in a 10-minute span with respect to average number of: questions asked by students; words spoken by students in direct response to the teacher; words spoken by students in response to other students; words of student initiated conversation with teacher; words of student initiated verbalization to other students; and total words per students. Also, total different words verbalized per student was averaged. It was found that all chemistry centers were successful and appropriate for the preschool child with regard to cognitive, socioemotional, and language goals. However, there were important differences between the centers with respect to how well each met delineated goals. Preschool students demonstrated various metacomponents of intelligence when non-verbal as well as verbal data were analyzed. Certain aspects of both Piagetian as well as Vygotsky's theories were supported in this study. The objectives, materials, and procedures for each activity are provided. (45 references) (KR)

AN EXPLORATORY STUDY OF THE EFFECTIVENESS OF A PLAY-BASED CENTER APPROACH FOR LEARNING CHEMISTRY IN AN EARLY CHILDHOOD PROGRAM

John T. Norman
Thomas E. Taddonio
Science Teacher Education
Wayne State University
Detroit, Michigan 48202

Paper prepared for the annual meeting of the National Association for Research on Science Teaching, April 8-11, 1990, Atlanta, Georgia.

AN EXPLORATORY STUDY OF THE EFFECTIVENESS OF A PLAY-BASED CENTER APPROACH FOR LEARNING CHEMISTRY IN AN EARLY CHILDHOOD PROGRAM

There has been some controversy in recent years about the appropriateness of chemistry experiences and content for the early elementary school child (Steiner, 1984 and Bent, 1985).

Purpose

Therefore, the purpose of this exploratory study was to evaluate the effectiveness of seven chemistry learning centers for use in an ongoing preschool education program. The seven centers piloted were: Observing Color Changes, Making Bubbles, Using a Thermometer, Balancing, Classifying Odors, Cooking, and Sink or Float. All of the centers piloted were designed for use in a play-based early childhood program, since this was the approach already being used for other content areas in the test site.

Play-based Approach

The play-based approach allows young children to make their own decisions about what they want to do and to learn at a particular center. Children are given the opportunity to develop their curiosity and to learn concepts and language through their physical interaction with the materials at the center and their verbal interactions with other students and their teachers. Such an approach to learning is based on developmental theorists such as Piaget (Piaget, 1962, 1973) and Vygotsky (cited in Genishi, 1988; Vygotsky, 1986) where experience with objects and people is fundamental to the development of understanding.

Goals

The goals of this play-based center approach for preschool chemistry were delineated and involved socioemotional, cognitive, and language goals of learning.

The socioemotional goals were to encourage students to:

1. become more autonomous
2. respect feelings and rights of others
3. become more curious and pursue curiosities; have confidence in own ability to figure things out

The cognitive goals were to encourage students to:

1. identify problems and come up with their own ideas
2. note relationships between objects and events; note similarities and differences; and learn to classify or group
3. order or seriate - mainly qualitatively (big/little, more/less, cold/hot, heavy/light)
4. learn spatial relations, mostly concepts of position (in/out, to/from, high/low, near/far)
5. learn temporal relations; to be able to sequence events in a chronological order

The language goals included:

1. to encourage increased verbalization with respect to both word variety and length of responses
2. to encourage students to ask questions
3. to encourage student initiated talk as well as talk

in response to other people's questions or comments

Description of Chemistry Learning Centers

For each of the seven pre-school chemistry learning centers, a set of anticipated outcomes were developed along with a listing of materials and a description of the procedures for involving students.

Observing Color Changes Center

Anticipated Outcomes:

1. To be able to identify and name a colored object by comparing it with a different kind of object that has the same color.
2. To be able to name an observed change in color after observing such a change.
3. To note the relationship between objects and events in color changes.

Materials:

Congo red dyed squares of cotton cloth (place 1/8 teaspoon of Congo red indicator in 1 liter of water and immerse cotton cloth. Allow cloth to dry overnight.)
Baking soda solution
Citric acid solution
Red Food coloring
Clear plastic cups
Spoons and trays

Activity:

When squares of Congo red dyed cloth are dipped into an acid solution (citric acid solution) they will change from a red to a blue color. When a blue cloth is placed in a more basic solution (baking soda solution) it will change back to a red color.

Initially two clear plastic cups were placed on a tray with one having a citric acid solution and the other a baking soda solution. Students were given one of the Congo red dyed cloths and encouraged to dip the cloth into the solution to see what happened.

Subsequent extensions included adding a third container of red solution (red food color in citric acid solution) and providing slices of foods for students to rub their cloth on to observe color changes.

Bubble Center

Anticipated Outcomes:

1. To learn how to produce bubbles in different ways.
2. To be able to differentiate large bubbles from small bubbles.
3. To recognize the relationship between the size of the bubble and the shape of the object used to produce the bubble.

Materials:

Bubble solution (Add 1 cup of liquid dish soap to 1 gallon of water. Add 1 teaspoon of glycerin if desired.)
Assorted bubble makers (wire loops of various sizes and shapes, canning jar caps, plastic golf tubes cut 5" long, straws, scissor handles, and cookie cutters.)
Trays and sponges
Margarine containers (or other containers for soap solution)

Activity:

Students could dip a potential "bubble maker" into the soap solution and either blow into it or shake out a bubble. Different sizes of bubbles would come from these objects and a teacher would ask the students to note if these were large or small. Also, students were asked to predict the size and/or shape of a bubble for a particular bubble maker. Students could experiment with different methods of making bubbles. Extensions included having students find which object/method produced the largest bubbles. Also, bubbles could be blown by placing a thin layer of bubble solution on the tray and sticking the straw into it and blowing. Perhaps students would be interested in methods of keeping bubbles airborne as long as possible.

<u>Balancing Center</u>

Anticipated Outcomes:

1. To recognize how to use the balance as a means of measuring "heavy/light" (mass designation ignored here).
2. To recognize that the size or shape of an object does not always determine its heaviness.
3. To be able to differentiate the relative "heaviness" of two objects using a balance.
4. To be able to relate "heaviness" as measured on the balance with "heaviness" as measured by lifting an object by hand.

Materials:

Large elementary balance (available from Delta as part of ESS equipment)
Objects of different sizes, shapes, and densities (e.g. wood blocks of different sizes, cotton balls, play dough or clay, box of salt, roll of tape)
Rice Krispies cereal, sand, and 35mm containers

Activity:

At "circle time" the concepts of heavy and light were explored by lifting such objects as cotton and wood. Then the balance was introduced as another means of measuring this.

At the learning center students were encouraged to place various wooden blocks of different sizes on the balance to see which was "heavier." Later, many different objects were added for students to compare. Students were often asked by the teacher which object was "heavier" and how they knew this. Also. they were asked to predict which object was heavier on the balance after lifting them by hand. On the second day, granular materials such as sand and cereal were introduced for students to compare when poured into film containers.

<u>Classifying Odors Center</u>

Anticipated Outcome:

To become aware of the sense of smell and how to distinguish different smells by their odors.

Materials:

7 - identical dark 35mm film containers with a tiny hole in the top
7 - pieces of common foods having different odors - onion, banana, strawberry, peanut butter, garlic, mint, and coffee

Activity:

Different pieces of food having a distinctive odor were placed in each of seven dark film containers and capped. Children were asked to see if they could identify the food by its distinctive chemical odor. Later, students were allowed to open each of the containers to see what was inside. Responses were charted for odors they found favorable or unfavorable.

Sink or Float Water Table Center

Anticipated Outcome:

To be able to classify objects as to whether they sink or float when placed in a liquid.

Materials:

Clean plastic shoe box half filled with water
Items to put in water (e.g. leaf, rock, nail, toothpick, crayon, and grass)
Individual data sheets

Activity:

Children were encouraged to drop various objects in water and to note whether they "sink" or "float." Data were entered into a chart (used names and pictures) by checking in the appropriate column for "sink" or "float."

Cooking Center

Anticipated Outcomes:

1. To introduce the skill of measuring solids and liquids using a standard measuring cup.
2. To be able to sequence the events (in chronological order) of making instant pudding.

Materials:

Measuring cup (2 cup size)
Bowl for mixing pudding
Instant pudding mix
Milk
Cups, bowls, and spoons for serving pudding

Activity:

Students were introduced to the purpose of this center in the circle time which was to make pudding. The use of the measuring cup was demonstrated at this time. Students then measured and mixed pudding as instructed on the package. While waiting for the final product, the students were asked if they could remember the necessary steps taken (in chronological order) to make the pudding.

Using A Thermometer Center

Anticipated Outcomes:

1. To learn how to use a thermometer for measuring hot/cold substances.
2. To recognize the relationship on the thermometer between the relative height of the liquid in the tube and the "hotness" or "coldness" of substances.

Materials:

Small thermometers with color coding on side (red decorating tape 40-110° C, yellow 20-40°C, green 0-20°C, and blue below 0°C. Thermometers had a metal backing and were made by AS & E for elementary science.

Containers of water, each of different temperature (use warm and ice water).

Large thermometer chart with color coding in place of numbers, and a movable red line made from sewing elastic into a loop with one half behind chart) to demonstrate different temperatures on a real thermometer.

Activity:

Students were asked to place their hands in warm and cold water and to note which was the warmest. The thermometer chart was then introduced to show the rise and fall of the red liquid in the thermometer to indicate warm and cold. Then students were encouraged to put their thermometers in each water container and note the color in the liquid in the tube. They were asked to show this on the thermometer chart. Children were asked to predict how hot the various liquids would feel after they had measured them using a real thermometer (but not touching them with their fingers). As an extension, students were encouraged to mix solutions and to measure temperatures.

Method

The learning centers consisted of a delimited table in a room with a particular set of materials to encourage student curiosity. Furthermore, there was an anticipated strategy for actively involving the students with these materials. This strategy involved a set of anticipated outcomes, procedures for involving students actively with these materials, and provisions for individual differences and extensions of the activities. There were other non-science learning centers in the room that a student could choose to spend their time rather than the chemistry center.

The teacher would introduce the new chemistry center in the circle time, making sure to review needed concepts that were within the individual experience of the preschool child (Sternberg, 1988), such as colors or names of objects. Students were then allowed to choose which of about five or six learning centers they wanted to initially begin their play. Only one of these centers was the chemistry center. Students could leave each center when they wanted and other students could come to the chemistry center as long as there were no more than four students at a time. An adult was present at the chemistry center most of the time to help students and to monitor progress.

Each center was videotaped for about a sixty minute period and significant verbal and non-verbal student behaviors were noted by the teacher. Subsequently, a complete transcript was made of each tape. The written transcripts, the teacher's notes, and the videotapes were then coded to see how well the particular center met the aforementioned goals. Furthermore, the learning centers were evaluated with respect to Smith's (1987) ten criteria for developmental appropriateness of preschool experience. Additional interpretations were made to better understand how these pre-school children's thought processes compared to theory (Ericsson & Simon, 1984).

The centers were piloted in a preschool class consisting of fifteen developmentally delayed students of four and five years of age. Most of these students had delayed speech.

The two hypotheses tested were:

1. The seven play-based chemistry centers will not differ in their favorable impact on preschool student's socioemotional, cognitive, and language skills.
2. The seven play-based chemistry centers will be developmentally appropriate for preschool students.

Results and Discussion

The average time each student spent at each of the chemistry learning centers was determined from videotapes and was thought to be a measure of the one of the socioemotional goals dealing with student curiosity. These data are shown in Table I and demonstrate that all centers were found to be interesting with " Observing Color Changes" attracting students for the longest time.

The class average ratings for the socioemotional goals of autonomy, persistence, cooperation, enthusiasm and curiosity were determined from the ratings given to each individual student based on teacher notes and the videotapes. These findings can be found in Table II and made use of non-verbal as well as verbal data. The overall average across all five of the socioemotional goals favored the "Observing Color Changes", "Bubbles", and "Classifying Odors" centers. However, on individual socioemotional goals there were important differences. For example, the "Balancing" and the "Bubbles" centers seemed to encourage more autonomy. One of the students who talked the least demonstrated the most curiosity and persistence.

The cognitive data for classifying, ordering/seriation, spatial relationships, and temporal relationships are displayed in Table III. In addition, centers were evaluated with respect to how they encouraged students to identify problems and come up with their own ideas. Since all centers did not attempt to emphasize all cognitive goals, an evaluation was made to see if one or more cognitive goals were met with a rating of "3" (out of 5) or higher. All seven of the centers were successful in at least meeting one of the cognitive goals.

Language goals were evaluated with respect to: 1) average number of questions asked by students per 10 minutes; 2) average number of words spoken by students in direct response to the teacher per 10 minutes; 3) average number of words spoken by students in response to other students per 10 minutes; 4) average number of words of student initiated conversation with teacher per 10 minutes; 5) average number of words of student initiated verbalization to other students per 10 minutes; 6) average number of total words per student per 10 minutes; and 7) average number of total different words verbalized per student. The data in Table IV indicate that the "Observing Color Change", "Cooking", and "Balancing" centers were most effective with regard to total words and different words generated. All centers were successful in generating a rich variety of student talk.

The ten developmental appropriateness criteria from Smith (1987) were evaluated for each center and can be found in Table V. The total scores across all ten of these criteria indicate that the most developmental appropriate centers were the "Bubbles", "Observing Color Changes", "Sink or Float", and "Balancing". Some of these criteria overlap other categories evaluated in previous tables, but were thought to be an indicator of the validity of the other analyses.

The importance of videotaping and individual monitoring of each center became very important for evaluating each center and for better understanding preschool student thinking since many preschoolers are not highly verbal. These non-verbal records were also considered along with verbal records when coding and when evaluating the accomplishment of the goals and the developmental appropriateness criteria. The importance of this non-verbal record can be illustrated with student X whom his teachers described as completely non-verbal on most days. While at the "Observing Color Changes Center", student X seemed very interested in changing the color of the cloth by dipping it into the various solutions. He didn't ask questions or talk to anyone but the teacher felt that he probably understood what caused the cloth to change colors because of his methodical actions. When various fruit were later brought to the Center for students to rub their cloth on, student X didn't do what was expected. Instead, he began to cut out grapefruit sections with a wooden tongue depressor and discovered a two-step process for dying the inside of the grapefruit rind blue. When the teacher at the table tried to interest him in rubbing the cloth on the fruit, he persisted in his previous behavior. Finally, the teacher asked asked him why he didn't dye the grapefruit in a one-step process that seemed easier to do. Student X shook is head back and forth as if to say "no." Later when prodded further about this, he proceeded to test the teacher's hypothesis by trying the one-step process. When the rind failed to become dyed blue, he looked at the teacher and said "see!" This was the only word student X spoke that day. Another discovery he made was that grapes burst when left in the water.

Student X demonstrated several metacomponents of intelligence (Sternberg, 1988) since he was able to recognize problems, generate steps and workable strategies to solve problems, and to allocate mental and physical resources to solve problems. These non-verbal metacomponents of intelligence were also noted in other students at the other chemistry centers. Thus, certain metacomponents of intelligent thinking, according to Sterndberg's Theory of "The Triarchic Mind" (1988) were observed in these preschool children while at the chemistry centers.

Students also seemed to enjoy talking to the adult at the Center and seemed able to learn from the guidance they received. This supports Vygotsky's contention that instruction is one of the principal sources of a schoolchild's concepts and, in fact, is also an influential force in directing their evolution (Vygotsky, 1986). An example of this was found in the notes of an observer at the "Balancing Center." Here student Y did not seem to understand how one could use the balance to determine the relative "heaviness" of two objects. When asked to determine which of two objects was "heavier" she would simply place only one of the objects on the left pan of the balance pan and nothing on the right pan. She did not understand how "heaviness" (ignore mass distinction) of an object must be compared simultaneously with another object on the balance. She tried hard to understand but always was wrong. On the next day, she asked the teacher to explain it to her again but still she couldn't figure it out. Later in the period she tried it again and suddenly understood. She was very excited and repeatedly demonstrated her new understanding to her teacher.

Most of the goals and objectives for learning at the preschool chemistry centers were based on Piagetian Theory (Piaget, 1962, 1973). These goals and objectives were generally met in this study and thus seem to support Piaget's descriptions of the capabilities of student thinking at this level.

Conclusions

All chemistry centers were found to be successful and appropriate for the preschool child with regard to cognitive, socioemotional, and language goals. However, there were important differences between the centers with respect to how well each met delineated goals. Overall, the findings indicate that those centers that were the most developmentally appropriate and that best meet the goals for encouraging cognitive, socioemotional, and language growth were the "Observing Color Changes", "Bubbles", and "Balancing" centers. The least appropriate and effective centers with regard to the goals were the "Thermometer" and "Classifying Odors" centers.

Preschool students demonstrated various metacomponents of intelligence when non-verbal as well as verbal data were analyzed. Certain aspects of both Piagetian as well as Vygotsky's theories were supported in this study.

TABLE I
Average Time Per Student Spent at Each of Seven Preschool Chemistry Play-based Learning Centers

CENTER NAME	AVERAGE TIME PER STUDENT AT CENTER (MINUTES)
Classifying Odors	7.5
Bubbles	8.4
Sink or Float	9.1
Balancing	10.7
Cooking	11.6
Thermometer	13.0
Observing Color Changes	14.7

TABLE II
Socioemotional Goal Ratings for Each of Seven Preschool Chemistry Play-based Learning Centers Expressed as Class Averages

CENTER NAME	[a]SOCIOEMOTIONAL GOALS A	P	CO	E	CU	OVERALL
Cooking	[b]1.0	4.2	5.0	4.5	4.0	3.7
Bubbles	4.4	4.0	4.3	3.8	4.0	4.1
Balancing	4.5	4.5	3.7	3.0	3.3	3.8
Sink or Float	3.0	4.0	4.4	3.4	4.0	3.8
Thermometer	2.0	2.6	4.9	2.9	2.6	3.0
Classifying Odors	3.0	4.3	4.9	4.0	4.4	4.1
Observing Color Changes	4.2	3.8	4.7	3.8	4.2	4.1

[a]Socioemotional Goal Key
A = Autonomy
P = Persistence
CO = Cooperation
E = Enthusiasm
CU = Curiosity
[b]Ratings Based on 1(low) to 5(high)

TABLE III
Cognitive Goal Ratings for Each of Seven Preschool Chemistry Play-based Learning Centers Expressed As Class Averages

CENTER NAME	[a]COGNITIVE GOAL CR	OS	SR	TR
Cooking	[b]*	*	*	[c]3.7
Bubbles	3.8	4.3	*	*
Balancing	3.7	3.7	*	*
Sink or Float	3.7	3.9	3.9	*
Thermometer	2.6	*	3.9	*
Classifying Odors	4.7	*	*	*
Observing Color Changes	3.5	3.0	*	3.5

[a]Cognitive Goal Key
CL = Classifying
OS = Ordering and Seriation
SR = Spatial Relationships
TR = Temporal Relationships
[b]* = no data
[c]Ratings Based on 1 (low) to 5 (high)

TABLE IV
Language Category Scores for Each of Seven
Preschool Chemistry Play-based Centers

CENTER NAME	[a]LANGUAGE CATEGORY SQ	SRT	SRS	SIT	SIS	TW	DW
Cooking	1.7	43.6	1.2	39.8	1.8	86.4	44.6
Bubbles	1.3	9.0	1.8	21.3	29.7	61.8	19.2
Balancing	1.4	57.0	0.0	32.7	3.3	93.0	38.7
Sink or Float	1.6	21.3	0.0	34.9	3.4	59.6	18.4
Thermometer	0.6	32.3	0.0	29.0	1.1	62.4	33.5
Classifying Odors	1.3	42.8	0.3	25.3	1.0	80.3	28.2
Observing Color Changes	2.3	19.2	0.5	74.3	2.7	96.7	32.1

[a]Language Category Key
- SQ = Average Number of Questions Asked By Students Per 10 minutes
- SRT = Average Number of Words Spoken by Students in Response to Teacher Per 10 Minutes
- SRS = Average Number of Words Spoken by Students in Response to Other Students per 10 Minutes
- SIT = Average Number of Words of Student Initiated Conversation with Teacher Per 10 Minutes
- SIS = Average Number of Words of Student Initiated Verbalization to Other Students Per 10 Minutes
- TW = Average Number of Total Words Per Student per 10 Minutes
- DW = Average Number of Total Different Words Verbalized Per Student

TABLE V
Developmental Appropriateness Ratings for Each of the Seven Preschool Chemistry Play-based Learning Centers

CENTER NAME	[a]DEVELOPMENTAL APPROPRIATENESS CRITERIA A	B	C	D	E	F	G	H	I	J	TO
Cooking	[b]2	3	1	4	5	3	2	4	4	5	33
Bubbles	5	4	5	5	5	5	4	5	5	4	47
Balancing	4	3	3	5	5	5	3	3	3	4	38
Sink or Float	3	4	4	5	5	5	5	4	4	3	42
Thermometer	2	3	1	3	5	4	1	3	3	4	29
Classifying Odors	3	4	2	3	3	4	3	4	5	2	33
Observing Color Changes	4	4	4	5	5	5	5	5	5	3	45

[a]Developmental Appropriateness Criteria Key as Developed by Smith (1987)

A = Children Will Naturally Gravitate to for Play
B = Provide Opportunities for Development of Perceptual Abilities
C = Encourage Self Directed Problem Solving and Experimentation
D = Children Can Act Upon-Cause to Move-Or Encourage Observations of Change
E = Provide Opportunities to Extend Children's Learning
F = Allow for Additional Materials to be Added Gradually
G = Allow for Differences in Ability, Development, and Learning\Style
H = Allow Children to Freely Interact with Other Children and Adults
I = Encourage Children to Observe, Compare, Classify, Predict, or Communicate
J = Allow for Integration of Other Curriculum Areas
TO = Total Scores across All Criteria

[b]Ratings Based on a 1 (low) to 5 (high) for Criteria A-J

References

Abraham, M. R. (1976). The effect of grouping on verbal interaction during science inquiries. Journal of Research in Science Teaching, 13, 127-135.

American Association for Advancement of Science. (1967). Science - A Process Approach (Part A). Lexington, MA: Ginn.

Beaty, J. J. (1986). Observing Development of the Young Child. Columbus, OH: Charles E. Merrill.

Benham, N. B., Hostica, A., Payne, J. D., & Yeotis, C. (1982). Making concepts in science and mathematics visible and viable in the early childhood curriculum. School Science and Mathematics, 82, 45-66.

Bent, H. B. (1985). Let's keep chemistry out of kindergarten. Journal of Chemical Education, 62(12), 1071.

Bettelheim, B. (1987, March). The importance of play. The Atlantic Monthly, pp. 35-46.

Brown, S. E. (1981). Bubbles Rainbows and Worms: Science Experiments for Pre-school Children. Mt.Ranier, MD: Gryphon House.

Caplan, F., & Caplan, T. (1974). The Power of Play. New York: Anchor Books.

Cliatt, M. P., Shaw, J. M., & Sherwood, J. M. (1980). Effects of training on the divergent-thinking abilities of kindergarten children. Child Development, 51, 1061-1064.

Darlington, R. B. (1980). Preschool programs and later school competence of children from low-income families. Science, 208, 202-204.

Darlington, R. B. (1981). Response to article: Duration of preschool effects on later school competence. Science, 213, 1145-1146.

Day, B. (1983). Early Childhood Education: Creative Learning Activities. New York: Macmillan.

Elkind, D. (1986, May). Formal education and early childhood education: An essential difference. Phi Delta Kappan, pp. 631-636.

Ericsson, K. A., & Simon, H. A. (1984). Protocol Analysis: Verbal Reports as Data. Cambridge, MA: MIT Press.

Genishi, C. (1988). Children's language: Learning words from experience. Young Children, 44, 16-23.

Gordon, I. J., Guinagh, B., & Jester, R. E. (1972). Child Learning Through Child Play: Learning Activities for Two and Three Year Olds. New York: St. Martin's Press.

Heath, P. A., & Heath, P. (1982). The effect of teacher intervention on object manipulation in young children. Journal of Research in Science Teaching, 19, 577-585.

Hendrick, J. (1986). Total Learning: Curriculum for the Young Child. Columbus, OH: Charles E. Merrill.

Henniger, M. L. (1987). Learning mathematics and science through play. Childhood Education, 63, 167-171.

Howe, A. C. (1975). A rationale for science in early childhood education. Science Education, 59(1), 95-101.

Horn, J. M. (1981). Duration of preschool effects on later school competence. Science, 213, 1145-1146.

Huff, P., & Languis, M. (1973). The effects of the use of SAPA on the oral communication skills of disadvantaged kindergarten children. Journal of Research in Science Teaching, 10, 165-173.

Iatridis, M. (1981). Teaching science to preschoolers. Science and Children, 19(2), 25-27.

Johnson, J. E., Christie, J. F., & Yawkey, T. D. (1987). Play and Early Childhood Development. Glenview, IL: Scott Foresman.

Kamii, C., & DeVries, R. (1978). Physical Knowledge in Preschool Education: Implications of Piaget's Theory. Englewood Cliffs, NJ: Prentice-Hall.

Landreth, C. (1972). Preschool Learning and Teaching. New York: University Press of America.

Lary-Dopyera, M., & Dopyera, J. (1987). Becoming a Teacher of Young Children. New York: Random House.

Meyers, B. K., & Maurer, K. (1987). Teaching with less talking: Learning centers in the kindergarten. Young Children, July, 20-27.

Mills, B. C. (1972). Understanding the Young Child and His Curriculum: Selected Readings. New York: Macmillan.

National Association for the Education of Young Children. (1986). Position statement on developmentally appropriate practice in programs for 4- and 5-year-olds. Young Children, 41(6), 20-27.

Norman, M. J., Byrne, S., & Norman, J. T. (1987, July). A play-based center approach to learning chemistry in elementary education. Paper presented at the Ninth International Conference on Chemical Education, Sao Paulo, Brasil.

Paley, V. G. (1986). Mollie is Three: Growing Up in School. Chicago: University of Chicago.

Pepler, D. J., & Ross, H. S. (1981). The effects of play on convergent and divergent problem solving. Child Development, 55, 1202-1210.

Piaget, J. (1973). To Understand Is to Invent: The Future of Education. New York: Grossman.

Piaget, J. (1962). Play, Dreams and Imitation in Childhood. New York: W. W. Norton.

Poppe, C. A., & Van Matre, N. V. (1985). Science Learning Centers for the Primary Grades. New York: Center for Applied Research in Education.

Rambush, N. M. (1962). Learning How to Learn: An American Approach to Montessori. Baltimore: Helicon.

Severeide, R. C., & Pizzini, E. L. (1984). What research says: The role of play in science. Science and Children, 21(8), 58-61.

Smith, R. F. (1981). Early childhood science education: A piagetian perspective. Young Children, 36, 3-9.

Smith, R. F. (1987). Theoretical framework for preschool science experiences. Young Children, Jan., 34-40.

Spodek, B. (1985). Teaching in the Early Years. Englewood Cliffs, NJ: Prentice-Hall.

Steiner, R. (1984). Chemistry in the kindergarten classroom. Journal of Chemical Education, 61(11), 1013-1014.

Sternberg, R. J. (1988). The Triarchic Mind. New York: Penguin Books.

Thier, H. D., Karplus, R., Knott, Lawson, C. A., & Montgomery, M. (1979). Beginnings. Science Curriculum Improvement Study. Chicago: Rand McNally.

Tipps, S. (1982). Making better guesses: A goal in early childhood education. School Science and Mathematics, 82, 29-

Vygotsky, L. (1986). Thought and Language. Cambridge, MA: MIT Press.

Weikert, D. P., Rodgers, L., & Adcock, C. (1971). The Cognitively Oriented Curriculum: A Framework for Preschool Teachers. Urbana, IL: University of Illinois.