Undergraduate and masters students' understanding about properties of air and the forms of reasoning used to explain air phenomena

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Contents

Abstract

The purposes of this study were to examine initial content knowledge about properties of air by three cohorts of undergraduate and master's students studying elementary education and to determine forms of reasoning used to explain air phenomena and the effect of an intervention on content knowledge. Subjects were assessed using a 14-question test on air phenomena before and after a lab consisting of 17 hands-on activities and six discrepant event demonstrations. The activities and demonstrations included the following concepts: air occupies space, air exerts pressure, Boyle's Law and Bernoulli's Principle. Analysis of lab journals indicated that student reasoning was focused on *what* was happening rather than *why* it was happening. A 3 *group* x 2 *time (pretest/posttest)* ANOVA with repeated measures indicated that the groups did not differ, initial understanding of the air concepts was low, and all groups improved significantly on the posttest. Instructions for activities and demonstrations are included.

Keywords: Air, understanding, reasoning, elementary science education

Introduction

Although air is all around us and is an essential part of our everyday environment, its properties are taken for granted and not consciously considered by children. The nature of air is very difficult to teach because air is colorless, odorless, and tasteless. Although children are familiar with the word "air," stationary air has little reality for them. Research studies on children's preconceptions about air (Piaget, 1972; Sere, 1982; Driver, 1983; Driver, Leach, Scott & Wood-Robinson. 1994; Borghi, Ambrosis, Massara, Grossi & Zoppi, 1988; Tytler, 1998) revealed many widely shared interpretations and explanations of phenomena and events that differ from accepted scientific explanations and sometimes become a barrier to acquiring the correct body of knowledge (Arnaudin & Mintez, 1985). Bulunuz, Jarrett, and Bulunuz (2009) found that middle school students have misconceptions about the physical properties of air. According to Wandersee, Mintzes, and Novac (1994), teachers may hold some of the same misconceptions as the children. Hashweh (1987) found that teachers' subject matter content knowledge affected their planning by embedding their misconceptions in their teaching and resulted in passing the misconceptions on to the students.

In the literature, there is a body of research on preservice and inservice teachers' misconceptions. These research studies include all aspects of science, concerning earth and space (Mant & Summers, 1993; Dal, 2009; Bulunuz & Jarrett, in press), physical sciences (Galili & Hazan, 2000; Halim & Mohd, 2002; Jarvis, Rell, & McKeon, 2003; Bayraktar, 2009), and biology and environmental phenomena (Khalid, 2003; Çibik, Diken & Darçin, 2008). However, in an extensive literature review, only one study was found that investigated the forms of reasoning preservice teachers used to explain air pressure phenomena (Leite & Afonso, 2004). In addition to air pressure phenomena, the present study explores preservice teachers' conceptions and the forms of reasoning they used to explain the following phenomena: (a) Bernoulli's Principle, i.e., flowing air exerts less pressure than stationary air; (b) the absence of air and its pressure on the Moon and in outer space; (c) the existence of lower air pressure at higher altitudes; d) the effects of air pressure on the boiling point of water; e) the effects of heating on the density of air; and (f) the pushing force of air pressure as the cause of what is commonly called *sucking*.

Research on Reasoning about Scientific Phenomena

Driver, Leach, Millar, and Scott (1996) explored the forms of reasoning used by students (9-16 years old) to explain various phenomena and developed a framework that included three main categories: (a) phenomena-based reasoning (PBR), description rather than explanation; (b) relation-based reasoning (RBR), incomplete attempt to explain; and (c) model-based reasoning (MBR), where explanations are based on conjectured models that have to be evaluated against empirical evidence. Only MBR reflects a comprehensive explanation. Driver et al. found that 9-year-olds typically used phenomena-based reasoning, 12- and 16-year-olds typically used relation-based reasoning, and only the oldest students employed much model-based reasoning. As pointed out by Leite and Afonso (2004), model-based reasoning can be either correct or incorrect from the standpoint of the science involved, since the reasoning can be based on alternative conceptions of science.

Leite and Afonso (2004) used Driver et al.'s (1996) three types of reasoning to categorize understanding about air pressure among 38 Portuguese preservice teachers. These preservice teachers had finished all their science coursework and were preparing for student teaching in the physical sciences. Leite and Afonso found that approximately 50% of their subjects used model-based reasoning to predict or explain a balloon and bottle experiment, 16% used such reasoning for a burning candle in a jar experiment, and only one person could explain an egg in bottle experiment using model-based reasoning. The dominant form of reasoning was relation-based. Leite and Afonso concluded that their subjects had difficulty relating evidence and theory and that the ability to use model-based reasoning is important for teachers who need to be able to help their students interpret physical phenomena in light of scientific theory.

Hands-on Activities and Discrepant Event Demonstrations as Conceptual Change Strategies

The need to build conceptual understanding on experience is central to the constructivist philosophy of Piaget, Vygotsky, and Dewey. Real experiences allow people to construct their own understandings in a meaningful way (Piaget, 1968; Vygotsky, 1978; Dewey, 1910/1997). The common premise for these theorists is that learning is an active process requiring physical and intellectual engagement with the learning task. Piaget (1973, p. 36) states, "Understanding always means inventing or reinventing, and every time the teacher gives a lesson instead of making the child act, he prevents the child from reinventing the answer." Demonstrations and hands-on activities create "external intrusion" (Piaget, 1968, p. 113) into current thinking and stimulates equilibration, leading to conceptual change.

According to Piaget (1973), a state of perplexity and doubt (a state he called disequilibrium) is a necessary first step in learning. According to his theory, learning takes place at all ages, as people try to equilibrate (make sense of) dissonant experiences through the processes of assimilation and accommodation. Similarly, the Theory of Cognitive Dissonance by Festinger (1957) proposes that dissonance, being psychologically uncomfortable, will motivate the person to try to reduce the dissonance. Events that do not fit one's existing understanding of events, discrepant events, function by causing dissonance between what is physically observed to occur and what one thinks should occur. Since it is impossible to change what is physically observed to have occurred, the only alternative is to begin seeking information that logically explains the occurrence. In research with primary trainee teachers, Joan (2006) found cognitive conflict useful as a strategy for promoting conceptual change and pedagogical insight about light and shadows.

Considerable research using hands-on activities for promoting conceptual understanding has been conducted on various topics with preservice teachers (Kelly, 2000; Gibson, Bernhard, Kropf, Ramirez, & Van Strat, 2001) and inservice teachers (Bulunuz & Jarrett, in press; Ebert & Elliot, 2002). According to these studies, hands-on activities and demonstrations improved conceptual understanding of various science concepts. The present study explores the impact of various hands-on activities and discrepant event demonstrations on preservice and inservice elementary teachers' conceptual understanding about properties of air.

Method

Purpose of the Research

This study has three purposes: (a) to examine the content knowledge of preservice teachers (undergraduates) and inservice teachers (masters students) on physical properties of air, (b) to assess the effects of hands-on centers and discrepant event demonstrations in clarifying incomplete understandings or misconceptions, and (c) to analyze the forms of reasoning used while observing demonstrations or engaged in hands-on experiments.

Subjects and Context

The study subjects were undergraduate and master's students majoring in elementary education at a large, urban, southern American university. They were from two undergraduate cohorts with 27 and 31 students, respectively, and a master's cohort with 21 students. Most of the undergraduates had taken a two-course biology lab sequence as their science requirement. The research was conducted in undergraduate and graduate science methods courses. While taking the course, the undergraduates were in their junior year and were in field placements two days a week. The master's group had just completed an alternative certification program with an urban focus and was in its first year of teaching in urban schools. Their program was designed for people with an undergraduate major in a field other than education, and some of the students had not enrolled in science courses since high school. Thirteen of the master's students and 44 of the undergraduates (16 from one cohort and 28 from the other) had complete data sets and were included in the study. In this study, the subjects will be referred to as preservice and inservice teachers or simply as students.

Assessment Instrument

A test on air phenomena was developed by Bulunuz in 2002, while working with middle school students' conceptions on physical properties of air, and was revised with input from the second author (a science education professor), and an environmental engineer. The test consisted of 14 items addressing conceptual understanding of the following general properties of air: that it occupies space, exerts pressure, expands when heated, and has lower pressure when flowing (Bernoulli's Principle); and knowledge of the composition of air, the relationship between altitude and air pressure, the effects of change in air pressure on the boiling temperature of water, effects of partial vacuum, and effects of no air (such as on the moon). Pretests were administered before a class session on air pressure demonstrations and hands-on activities. Posttests were administered several weeks after the session. Neither the pretest nor the posttest counted toward the students' grades. The questionnaire's content validity was established with input from a scientist and a science educator. To determine reliability of the questionnaire, a convenience sample of one undergraduate class of 22 preservice elementary teachers answered the questionnaire two times, two weeks apart. For each student, the answers to each question on the two administrations of the questionnaire were compared, and the percentage of identical answers was calculated. Across the 22 students, the mean percentage of questions answered the same both times was 78%.

Instructional Intervention with journaling

The intervention consisted of class sessions in which students engaged in 17 hands-on center activities and watched 6 discrepant event demonstrations. The sessions took most of two 2 ½ hour classes, one week apart. Most of the activities were taken from Liem (1989). They had been implemented with Turkish middle school students (Bulunuz, Jarrett, & Bulunuz, 2009) and also with adults at a convention workshop (Bulunuz, Bulunuz, Jarrett, & Hoge, 2004). The demonstrations mainly involved fire or heating and illustrated the effects of heating and/or cooling on air volume. They were done as demonstrations to model safety precautions. Some of the activities and demonstrations are described in Appendix A. The activities and demonstrations covered four physical properties of air included in the air properties test: air occupies space, air exerts pressure, Boyle's law, and the Bernoulli Principle. For each activity, students answered questions in their dialogue journals, making predictions and giving explanations of the phenomena they were observing. To ascertain what forms of reasoning were used by the students, 10 student journals were randomly selected for analysis of the reasoning used to explain the air phenomena involved in 11 of the activities. The 11 activities represented two or three activities for each of the four concepts. The authors categorized the explanations into phenomena-based reasoning (PBR), relation-based reasoning (RBR) and model-based reasoning (MBR), as defined by (Driver et al., 1996). Descriptions of the 11 activities and correct model-based explanations for each are found in Appendix B. The first author and a colleague analyzed the journal entries independently and the percent of agreement was calculated as 96%.

Results

Content Knowledge of Students on Physical Properties of Air

To determine which concepts about air the students did/did not understand, the pretest questions were categorized according to whether over 50% or under 50% of the students answered them correctly. The five items answered correctly by over 50% included general information about air, such as: the composition of air inhaled and exhaled, the absence of air and its pressure in outer space, and the expansion of air when heated. These items had an average correct response of 70%. Of the concepts included in these questions, only the expansion of heated air was a concept included in the demonstrations and activities. The nine items that fewer than 50% of the students answered correctly on the pretest included the change in air pressure with altitude change, effects of partial vacuum, and the Bernoulli Principle. On these items, the percentage of correct response was only 25%. No one correctly responded to a question that combined the Bernoulli Principle with air occupying space. Table 1 shows the percentages correct on the pretest and also includes posttest results.

Table 1: *Percentage of Correct Answers on The Pretest and Posttest Grouped by Items Greater than and Fewer than 50% Correct on the Pretest.*

No.	Concepts with at least 50% correct on the pretest	Pretest (%)	Posttest (%)
2	The composition of inhaled and exhaled air is different.	68	79
3	On the Moon surface, a trash bag will be flat and empty if moved back and forth and closed by twisting.	70	63
4	If the mouth of an astronaut was connected to a straw	79	91

	through his space suit, he could not drink liquid from a cup on the Moon.		
5	Hot air is lighter than cold air.	68	70
6	If an inflated balloon is transferred to outer space, it will burst.	59	46
		Mean=69	Mean=70.4
Concepts with fewer than 50% correct on the pretest			
1	Air pressure is the same everywhere in a room - under the table, in the closet, and so forth.	28	30
7	Our ears clog up when we drive quickly from a high mountain down to a valley.	46	49
8	Compared to sea level, the boiling point of water at the top of a mountain is lower.	35	40
9	When a balloon is placed over the mouth of a partially vacuumed bottle, the balloon will be pushed inside by atmospheric pressure.	33	79
10	Blowing under a paper between two books causes it to bend toward the table.	21	75
11	If you blow for a while through one end of a pipe, at the other end, the ping-pong ball stays over vertical end of the pipe.	44	72
12	If you blow in the neck of bottle with a paper ball in the neck, the ball moves directly outside of the bottle.	0	63
13	In a spray gun, the sprayed material comes out from the bottle because of a decrease in pressure at the end of pipe.	16	18
14	Strong windy weather often turns an umbrella inside out, because of the decrease in pressure at the convex surface of it.	5	39
		Mean=25	Mean=52

Effects of Hands-on Centers and Discrepant Event Demonstrations

In order to analyze the effect of the intervention on understanding of air, a 3 (*groups*) x 2 (*time*) ANOVA with repeated measures on time (pretest/posttest) was computed. The dependent variable was the percentage of answers correct on the pretest and posttest. The main effect time indicated an increase from pretest to posttest. F (1,54) = 65.59, $p < .001$. There were no significant differences among the groups although group differences approached significance (p = .068). There were no *time* (pre/post) X *group* (cohort) interactions, which indicated that the three student groups increased similarly from pretest to posttest.

Table 2: *Means and standard deviations of the percentages correct on the pretest and posttest on air phenomena by the undergraduates and masters students*

		Pretest		Posttest*	
Level	**N**	**M**	**SD**	**M**	**SD**
Undergraduates1	16	37.5	7.9	53.3	17.6
Masters students	13	47.0	12.7	60.2	8.9
Undergraduates2	28	43.1	12.2	62.4	14.47
Total	57	42.4	11.7	59.3	14.7

P*<.001

Forms of Reasoning used to Explain Results of Demonstrations and Activities

Students' predictions and explanations in their journals were analyzed to determine the forms of reasoning used. Table 3 lists the activities, the focus of the questions, and the category of the answers. A majority of the students used phenomena and relation-based reasoning. However, a few students on each question used correct model-based reasoning. As shown in Table 3, to explain the empty box candle snuffer, four used phenomena-based reasoning, three used model-based reasoning, and two used relation-based reasoning to answer questions. The correct model-based reasoning for the 11 activities is found in Appendix B.

Table 3: *Forms of Reasoning Used By Students to Explain Air Phenomena as They Were Engaged in Activities*

Name of the activity	Focus of the question	Category of Answer			
		PBR	RBR	MBR	No answer
Empty box candle snuffer	Air occupies space	4	2	3	1
Paper ball on the neck of a bottle	Air occupies space	-	2	-	8
Test-tube in a test tube	Gravity versus Atmospheric pressure	2	6	3	-
Inverted glass of water	Gravity versus Atmospheric pressure	6	3	1	-
Two cups on a balloon	Gravity versus Atmospheric	2	4	2	2

	pressure				
Linked syringes	Boyle's Law	5	5	0	-
Air bubbles in syringe	Boyle's Law	5	2	2	1
Cartesian diver	Boyle's Law	5	1	2	2
Leaping ping-pong ball	Bernoulli's Principle	4	5	0	1
Blowing through a straw	Bernoulli's Principle	1	6	0	1
Ping pong ball over hair dryer	Bernoulli's Principle	3	3	1	3

The following are representative quotations drawn from students' journals to illustrate the forms of reasoning used by students to explain what occurred when doing the air activities:

Phenomena-based reasoning.

Test tube in test tube:
"the smaller tube moved up into the larger tube as the water slowly dripped out. As the water dripped out, the smaller tube filled up the space. Tried it with carbonated water and saw that the small tube did not move at all."

Relation-based reasoning.

Two cups on a balloon:
"The cups are suctioned to the sides of the balloon. There is air pressure in the cups and as it gets tighter (when the balloon expands) the cups stay."

Blowing through a straw:
"Blowing through straw creates pressure and lifts water out of the straw- the air you blow goes into the vertical straw and makes water spray out."

Model-based reasoning.

Air Bubbles in a syringe:
"Putting a balloon in a syringe, covering the tip with a finger and pushing the plunger causes the balloon to shrink. As the pressure on the outside of the balloon increases, the volume of the balloon inside decreases. Starting with the syringe pushed in and then putting a finger over the tip causes the balloon to expand. Decreasing the pressure on the balloon increases the volume inside."

Discussion and Conclusion

In terms of initial understandings of properties of air, the students had many misconceptions, with a mean of only 42.4% of correct pretest answers. Some of the correct answers probably did not reflect a depth of understanding. Most of the questions that 50% or more of the participants answered correctly on the pretest are on concepts they could have memorized but not fully understood. They could not have experimented with the lack of air in space, and probably none of them had analyzed the composition of air inhaled and exhaled. These topics were not discussed in class. Therefore, it would not be expected that correct answers would increase on the posttest. In fact, on none of these questions was there a major increase from pretest to posttest; and on half of the questions, the percentage correct decreased slightly on the posttest, suggesting that the students may have guessed on both the pretest and the posttest.

For items on which most students got fewer than 50% correct on the pretest, the frequency of correct responses more than doubled on the posttest (from 25% to 52% correct). The one question that no one answered correctly on the pretest, was answered correctly by 63% on the posttest. The hands-on activities and discrepant demonstrations appeared to clarify many of the misconceptions held by the students. This finding is consistent with other research that found preservice (Kelly, 2000; Gibson et al, 2001) and inservice teachers' (Bulunuz & Jarrett, in press; Ebert & Elliot, 2002) understandings about science concepts can be improved by using hands-on activities and demonstrations. It corresponds with the observations of Borghi et al. (1998) that improvement in understanding is promoted by experimentation.

However, the analysis of reasoning used by the students in answering questions in their journals indicated that the students tended to focus on *what* was happening, using phenomena-based reasoning or relation-based reasoning, but few explained *why* it was happening using model-based reasoning. Some students tried to explain phenomena by discussing the relationships between the observable features, but these were incomplete explanations. For example, “blowing through straw creates pressure and lifts water out of straw--- the air you blow goes into vertical straw and makes water spray out.” That student was aware that blowing creates a kind of pressure but did not mention that stationary air has higher pressure than flowing air. That fewer students in this study used model-based reasoning than the students in the Leite and Afonso (2004) study may be explained by a difference in science background between the two samples. To correctly use model-based reasoning requires background knowledge the elementary school preservice and inservice teachers may not have had.

On the posttest, students were more successful on the observation questions (e.g., blowing under a paper bridge causes it to bend toward the table) than on the interpretation/ explanation questions (e.g., in a spray gun, the sprayed material comes out from the bottle because of a decrease in pressure at the end of the pipe). Given the limited explanations in their journals, some of the students may have observed what was occurring without understanding why it was occurring. According to epistemological reasoning theory (Driver et al., 1996), understanding is different from correct observation. In order to explain scientific concepts, students and teachers should demonstrate a high level of epistemological (model-based) reasoning (MBR). Teachers cannot teach for understanding unless they understand. To increase understanding, more time may have been needed for investigation and reflection. In the two sessions on air, there was little time for questions and discussion that could have promoted deeper understanding.

This study adapted a survey, first developed for middle school students, for use with preservice and inservice teachers. Ten journals were analyzed for a glimpse into the reasoning used by the participants in explaining the phenomena they observed through demonstrations and activities. The findings are intriguing in suggesting connections between understanding and reasoning. Further research on this topic could be strengthened by the addition of interviews to probe student understanding and the analysis of the reasoning used in all the journals. If all journals were to be analyzed for reasoning, the type of reasoning used could be correlated with answers on the posttest.

The findings of this study suggest ways in which both the survey instrument and the activities and demonstrations could be improved. This study employed an instrument on air phenomena that has potential for future studies. However the present instrument included questions beyond the possibility of experimentation (e.g., lack of air on the moon). It was useful in assessing initial understanding but some of the questions were not appropriate for a pretest/posttest analysis. To assess the effectiveness of demonstrations and activities in conceptual change, the assessment instrument should be limited to phenomena appropriate for demonstrations and activities. A lesson learned about demonstrations and activities was that more time was needed, with opportunity to discuss, reflect and perhaps do additional reading. More time would have helped students build deeper understandings about air properties and would have better modeled how to teach these topics to elementary school students.

In order to help children develop a scientific understanding about air, teachers must have clear understandings about properties of air. However, this study found that both the preservice and the inservice teachers held many initial misconceptions on the physical properties of air. The lack of research with preservice and inservice elementary teachers on these concepts suggests that properties of air are not generally covered in science methods classes. Given that the understanding of many phenomena including weather, airplane flight, cooking at various altitudes and tire pressure require an understanding of the properties of air, we recommend inclusion of activities on air phenomena in teacher education programs. With revisions to the assessment instrument, future research can better probe the effectiveness of such activities on teacher understanding. However, understanding accepted theory on air properties is not sufficient. Teachers should be explicitly introduced to the three types of reasoning with a focus on helping them become more effective model-based reasoners. Personal understanding and reasoning ability are important building blocks for teachers who will provide appropriate experiences, ask probing questions and guide their young students toward scientific understanding about air properties and other difficult concepts.

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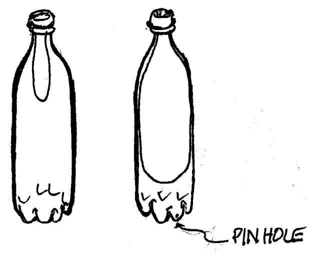
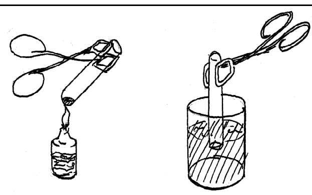
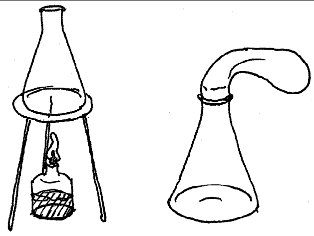
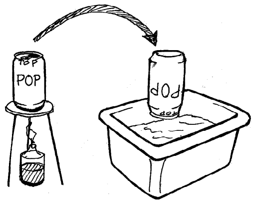
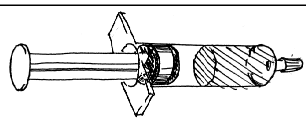
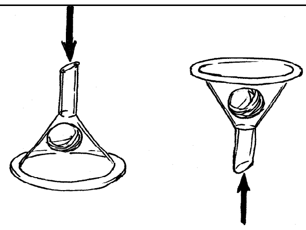
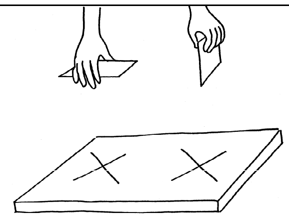
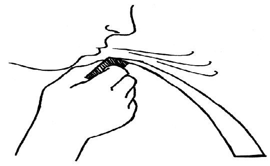
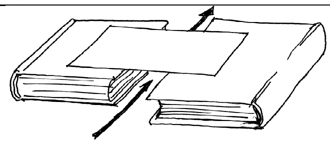
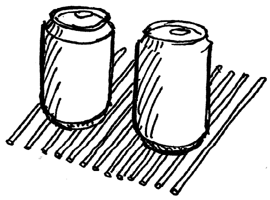
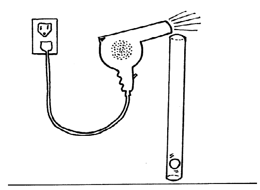
Appendix A

Demonstrations and Hands-on Activities that were Included in Class but that were not Analyzed for type of reasoning

Demonstrations	Property of air
Air Occupies Space	
Mystery bottles: Insert the air pump tube into the balloons and try to blow them up one at a time. You will need to push the tube in fairly far and pinch your hand around it to prevent air from escaping. Do the two balloons react differently? Can you explain why? Can you figure out a way to keep the one balloon blown up when the air tube is removed? **Materials:** Air pump, balloons, two-soda bottle (one with a tiny, hidden pin hole)	
Air Exerts Pressure	
The mysterious hot test tube: Fill a jar with colored water. Put a little water in a test tube and boil it vigorously. Then invert this test tube immediately in the colored water. What happened? What is in the test tube besides the water before heating? What happens to water when it is boiled? **Materials:** A test tube and test tube holder, a jar, an alcohol burner or other source of heater, food coloring.	

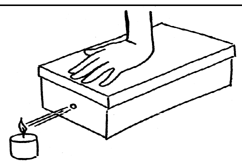
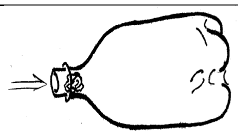
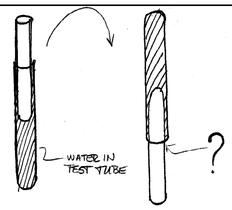
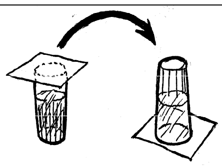
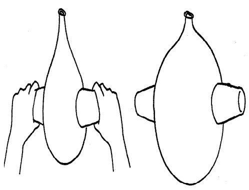
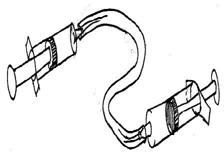
The balloon and the flask: Put a little water in a flask and heat it to boil vigorously for a while. Take the flask off the fire and immediately place the balloon with the mouth over the flask's mouth. Let it cool slowly at room temperature. Watch what happens to the balloon. What is in the flask besides the water? What is the steam doing to the air in the flask? Why did the balloon do what it did? **Materials:** A flask, a balloon, plate or burner & stand.	
Heated soda pop can: Put a little water in an empty coke can and heat it to boil vigorously for two minutes. Take the can with boiling water off the heat and invert immediately in a cold-water container. Watch what happens. Try to explain the changes in the can. **Materials:** Soda pop can, hot plate or burner, stands, and pot holder or glove to protect hands.	
Boyle's Law: Relationship between volume & the pressure of a confined gas	
Water in a syringe: Fill a syringe one-third full of colored warm water, then put the cap on it. Now, pull the piston. What happened? Try to explain your observation**.** **Materials:** A syringe, warm water, and food coloring.	
Bernoulli's Principle: The faster the flow of a fluid (air), the lower the pressure it exerts	
A discrepant funnel: "How can I pick up the ball with the funnel without sucking through it? I may not touch the ball" Pick up the funnel by the stem; place it over the ball and blow through the stem, lift the funnel while blowing. What happens when we stop blowing? Is it possible to blow the ball out of the funnel? Where is the air moving fastest when we blow the ball out of the funnel? What is the flowing air creating that stationary air doesn't? **Materials:** One long stem funnel, one ping-pong ball.	
Hands-on Center Activities	**Property of Air**
Air Occupies Sapce	
The air catcher: Take the garbage bag, open its mouth, and move the bag with two hands back and forth. Then quickly close the mouth of the bag with a twisting motion. What was filling the bag? Would the material in the bag be the same if you blew into it? **Materials:** Plastic garbage bags.	
Bernoulli Principle	

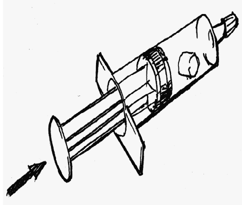
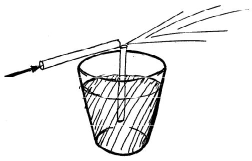
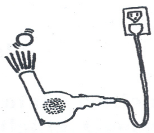
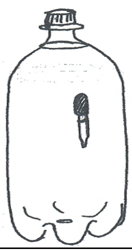
Cards over a target: Hold a playing card horizontally about a meter (yard) over a target, which can be a sheet of paper, notebook or a box. Then let it drop on to the target. Observe what happens. Now, hold the playing card vertically at the same height and drop it straight down onto the target. Do the cards get into/onto the target or drift away? Why? **Materials:** Playing cards, box.	
Blowing over a strip of paper: Make a fold at one end of the paper strip. Hold the strip near the chin and blow over it. What do you observe? What will happen if you blow against the underside of the paper? **Materials:** Strip of paper about 15x3cm.	
Blowing under a paper bridge: Place a sheet of paper between two books. What will happen if you blow hard under it? What is different about flowing air compared to stationary air have? **Materials:** A sheet of paper, and books or folders.	
Two soda pop cans on straws: Spread the straws parallel to each other on the table and leave about 1/2 cm gap between them. Place the two cans upright about 2 cm from each other on the straws. Now, blow hard in between the cans. What happened? What will happen if you blow more gently? What will happen if you place the cans different distances apart, such as 5, 10, 15, and 20 cm away from each other, and then blow? **Materials:** Two empty soda cans, two dozen drinking straws	
Ping-Pong ball and a fluorescent tube protector: Hold tube slightly up from the floor. Drop the ping pong ball into the tube. Turn hair dryer on high and blow across the top of the tube. Experiment with angles. Observe what happens. **Materials:** Hair dryer (1875 watt), ping-pong ball, and clear plastic tube (sold in hardware store as a protective cover for a fluorescent tube).	

Illustrations by Christopher Jarrett and Karen Kimble

Appendix B

Activities Analyzed for Reasoning Method with Correct Model-based Reasoning Included

Activity	Question		Elements of correct Model-Based Reasoning
The empty box candle snuffer	Explain the snuffing of a candle with a sudden hit to the box top.		There is air in the box and it occupies space. With a hit to the box, the volume of the box decreases and air is forced out from the box hole snuffing the candle
A paper ball in the neck of bottle	Explain what happens when you blow hard into the neck of bottle.		The air in the bottle occupies space, air passes quickly into the bottle faster than the ball and then the extra air pressure pushes the ball out.
Test-tube in test tube	Explain why the small test-tube moves upwards against gravity.		The gravity and atmospheric pressure both act on the small test-tube when they are up side down. The dripping water creates a partial vacuum and atmospheric pressure pushes the small test tube upwards against gravity.
The inverted glass of water	Explain what happens to the paper card when a glass of water is inverted.		The atmospheric forces acting upward on the paper card is greater than the downward gravitational forces.
Two cups on a balloon	Explain what happens if the open ends of two cup placed on opposite sides of the balloon while it is inflating		The volume of the gas inside the cup increases and its pressure decreases as the curve of the balloon flattens. The atmospheric pressure acting on the outside of the cups balances the gravitational forces on the cups.
Linked syringes	Explain what happens when the plunger of one syringe is pushed and pulled.		When the plunger is pushed in, confined air moves to the second syringe. When a plunger is pulled out, the gas volume of that syringe increases the pressure decreases. The other plunger is pushed by atmospheric pressure.

Marshmallow and small balloon in a syringe	Explain what happens when the plunger is pulled out or pushed into the syringe while the nozzle is blocked with your finger		Push the plunger in, the pressure of the confined gas increases and the gas pressure inside the marshmallow and balloon increases so they shrink. When the plunger is pulled out, the pressure of the confined gas in the syringe decreases and the marshmallow and balloon expands.
Leaping ping-pong ball	Explain what happens when you blow at a small angle into the cup with the ping-pong ball		The blow angle over the first cup creates flows of air across and in that cup. The flowing air has less pressure than stationary air, so the ping-pong ball is lifted and moved within this air current. It "jumps" to the other cup.
Blowing through a straw	Explain what happens when you blow through the horizontal straw		The flowing air has less pressure than stationary air. The pressure decreases over the top of the vertical straw. The water is pushed up by atmospheric pressure on the water surface and sprayed out of the vertical tube.
The ping-pong ball over hair dryer	Explain what will happen when you place a ping-pong ball over a hair dryer		The forces of the moving air balances gravity to keep the ball suspended. The lower pressure of moving air compared to the pressure of the stationary air keeps the ball from moving side ways.
Cartesian diver	Squeeze the bottle and watch what happens to the dropper. Release your hand. What happens? Can you explain why this happens?		When the bottle is squeezed, the air in the dropper is squeezed in and more water gets into the dropper. This makes the dropper heavier or denser than water and it sinks.

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