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Middle School Students' Conceptions on Physical Properties of Air

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ABSTRACT

This paper includes two studies on understanding of physical properties of air, both conducted in Turkish middle schools. In the first study, 6th, 7th, and 8th graders in public and private schools were compared on their understanding of Boyle's Law and the Bernoulli Principle as well as the following: that air occupies space, has weight, exerts pressure, and rises when heated. No difference was found between the schools. The purpose of the second study was to investigate the effects of an intervention on private middle school students' conceptions of the same properties of air. The intervention consisted of three 40-minute sessions with discrepant event demonstrations and hands-on activities. The private school students completed a questionnaire both before and after the sessions. The pre- and post-test data, analyzed by three grade levels (a 2 x 3 ANOVA), indicated that at all grades the students significantly increased their understanding of properties of air. A time x grade level interaction indicated that the 8th graders improved more than the other students. Implications are discussed.

Keywords: Air; Conceptions; Misconceptions; Elementary Science Education.

INTRODUCTION

Air is all around us and is an essential part of our everyday environment. Children have a lot of experiences with air before they are taught about it in schools; they live in air, feel wind and drafts and they inhale and exhale and use devices operating with air, for example, tire-pumps, balls, electric fans, air conditioners, vacuum cleaners, sprayers, etc. However, since air is invisible, its properties are taken for granted or not consciously considered by children before they are taught about air in school. The nature of air is very difficult to understand for children because it is colorless, odorless and tasteless. Although children are familiar with the word "air," stationary air has little reality for them.

Children's naïve beliefs about air were studied by Piaget (1972) and described in his book The Child's Conception of Physical Causality. Since Piaget's work, many research studies have been conducted on children's conceptions about physical properties of air, such as whether or not air exists, occupies space, has weight, or exerts pressure. Borghi, Ambrosis, Massara, Grossi, and Zoppi (1988) indicate that children's knowledge about air is mostly pre-causal, which means that the child resorts to descriptive, finalistic, or dynamic elements (e.g., air is sky, air is wind, or air is involved with breathing). Sere (1986) reports following ideas that children have: (a) they can produce air by flapping, (b) it is necessary to hold an open bottle in a stream of air to fill it with air, and (c) they cannot transport air (do not believe that they can carry air from one place to another). Children refer to the fact that hot air rises, but never refer to cold air sinking. Many children think that air changes form when heated; that is, with the increase in temperature, air becomes "gas." Sere (1982) indicates that most of the children only know that air is in motion and most of them acknowledge that air pushes and exerts force, but only when it is heated or during movement, in the direction of this movement. She concludes that this interpretation is the result of using daily experience like the blowing of wind. Understanding formed only from the experience of wind makes the concept of air pressure difficult to grasp in experiments with pressure reduction in a closed container. Children in her study used the word "suction force" or "pulling forces" to interpret the experiment. They had difficulty in imagining atmospheric pressure without movement so they attributed the state of equilibrium to the absence of forces. Tytler (1998) points out the difficulty of understanding atmospheric pressure using presuppositions based in perceptual features. Hsiao-Ching (2002) found that three fourths of 9th graders believed that air could not be compressed. In a cross-age study, Brook and Driver (as cited in Driver, 1994) found that an explanation of the notion of vacuum, which 'sucks' or 'pulls' in terms of differences in pressure of the air inside and outside the device, was used progressively during secondary years.

According to Sere (1982), to interpret experiments concerning the physical properties of air, children generally use frameworks relating force, movement, and equilibrium and mechanical dimensions. She suggests that to understand and interpret even simple experiments on air, children must use fundamental physical dimensions such as quantity, volume, mass, pressure and temperature, to describe air. She also noted that children recognize air pressure by its movement. Therefore, observable movement needs to be established to convince children that air pressure exists even when it is stationary.

Students come to school with ideas about the natural world that may or may not be correct. Prior knowledge of individuals might be correct, partially correct, or incorrect with a misconception. Many researchers state that misconceptions play a crucial role in learning by interfering with scientific understanding (Hewson, 1992; Trundle, 1999). It is expected that individuals with misconceptions have difficulty in learning new concepts because of the negative or blocking effect of their incorrect knowledge. It may be particularly difficult for children to understand scientific concepts that are difficult to visualize (Callison & Wright, 1993).

The theoretical framework for this study is based on the constructivist theories of Piaget and Vygotsky. These theories, in explaining how concepts are developed, also propose ways in which concepts might be changed. According to Piaget (1970), an individual constructs knowledge by using current ideas and theories while interacting with the physical environment. The interaction between an individual and a material will aid learners in building and learning various concepts about natural phenomena. In concept formation, Piaget explains two interrelated processes: organization, and adaptation (Piaget, 1970). People organize their ideas to make logical connections between them. Piaget defines the term adaptation by using two other terms: assimilation and accommodation (Piaget, 1970). In the process of "assimilation," an individual must act on the objects or materials in the environment. Because of this action, the individual incorporates the new concept into the existing one. If the new way of thinking does not fit his present way of thinking, the individual experiences a state of "disequilibrium." One might experience disequilibrium when an unexpected thing occurs in life. At that point, two things can happen: another person might help us to clarify the conflict by giving more information, or we might act further on the same material to resolve the unexpected situation ourselves. Piaget calls this "accommodation;" i.e., the adjustment of existing ideas to new experiences. After accommodation, an individual is expected to reach the state of "equilibrium," that is the final stage of adjustments of concepts (Piaget, 1970).

Like Piaget, Vygotsky (1978) argues that children start to form concepts long before they attend school. Through play, most the children first begin to sort, classify, and count before preschool or pre-kindergarten, forming initial science and maths concepts. One of the most important constructs in Vygotsky's theory is the Zone of Proximal Development. He defines this concept as the distance between the most difficult task a child can do by himself and the most difficult task a child can do with other people's help. Vygotsky uses the term "scaffolding" to describe the assistance a teacher or peer gives to a child (Vygotsky, 1978). Like a scaffold used by a housepainter working on a house, teachers or peers can help a child to learn new concepts and form his understandings by giving supporting information. But, if that assistance does not match the actual mental level of the child, learning does not occur.

Various studies have noted that traditional methods involving primarily lecture are not successful in changing misconceptions (Marinopoulos & Stavridou, 2002; Weaver, 1998). Using hands-on activities for conceptual change in science has become very popular in the last four decades. To clarify students' conceptual understanding, researchers have explored the effects of hands-on activities and science experiments for different age groups, including elementary school students (Baser & Cataoglu, 2005; Dalton & Morocco, 1997; Marinopoulos & Stavridou, 2002; Pyle & Akins-Moffatt, 1999; Thomson & Logue, 2006; Weaver, 1998), middle school students (Alexopoulou & Driver, 1996; Ertepinar & Geban, 1996), and high school students (Ben-zvi-Assarf & Orion, 2005; Nakiboglu & Tekin, 2006). Costa (2003) reported that hands-on activities were the most effective way of acquiring scientific knowledge for most children and adolescents. In her cross-age study, Weaver (1998) investigated the successes of hands-on activities and experiments with fourth, eighth and tenth grade students, reporting that students found hands-on activities very valuable. However, Weaver also concluded that simply presenting hands-on activities or demonstrations was not sufficient for conceptual change. She stated that hands-on activities and demonstrations could promote conceptual change when combined with discussion and reflection.

The usefulness of simple materials and discrepant events in challenging students' understandings fits with Piaget's ideas of equilibration (Piaget, 1964/1993). Familiarity, which can promote assimilation, coupled with incongruity, promoting disequilibrium, can be a powerful combination. Brandwein (1968) states that the use of simple materials in the experiment enhances children's recognition of the concepts involved. Also, research has shown that students find science topics more interesting when they are relevant to daily life or experience (Weaver, 1998). In addition, hands-on activities make students more active learners in science classrooms (Cetin, 2003).

The purposes of the present research are twofold: (a) to explore middle school students' conceptual understanding about physical properties of air and the practical effects of air and its pressure and (b) to determine the effect of discrepant event demonstrations and hands-on activities on such understanding. Practical applications of air and air pressure to be studied include: the Bernoulli Principle and its application to sprayers and airplanes, the relationship between altitude and atmospheric pressure, the effect of atmospheric pressure on the boiling point of liquids, the absence of air and pressure in outer space and its effect on space travel. The research involved two separate studies, a comparison between private and public school students on understanding of air concepts and a pre-post analysis of understanding of individual air properties concepts among private school students.

The following question guided Study One:

1. Do private and public middle school students differ in knowledge about physical properties of air?

Study Two employed a sample of private school students to answer the second and third research questions:

2. What aspects about air do the students understand, and what aspects do they find confusing?

3. Does understanding about properties of air increase after discrepant event demonstrations and hands-on activities?

In the following method and results sections, Study One and Study Two are presented separately. Although both studies used the same questionnaire, the participants, and analyses were different in the two studies. However, in the discussion section, the two studies were combined in order to examine new insights and implications drawn from both studies.

Study One

Method

The purpose of Study One was to compare students in private and public schools on their knowledge of the physical properties of air in order to determine whether knowledge and misconceptions were consistent across age or influenced by differences in school and related home environments.

Participants

The participants were 36 sixth-graders, 34 seventh-graders, and 36 eighth-graders from a public school and 21 sixth-graders, 18 seventh-graders, and 22 eighth-graders from a private school. There are many differences between these two schools. The private middle school has a better educational setting than the public school in terms of physical environment, budget, library, and class size (approximately 20 students per class). The private middle school students either have achieved high test scores, winning them scholarships, or come from families able to pay for private schooling. In public school, students are generally from lower income families, and class size ranges between 36 to 40 students.

Questionnaire

Participants filled out a questionnaire, designed by the first author, consisting of questions addressing understanding of the composition of air and the following general properties of air: that it occupies space, exerts pressure, expands when heated, and has lower pressure when flowing (Bernoulli Principle). In addition, there were questions on the: relation between altitude and air pressure, effects of change in air pressure on boiling, effects of partial vacuum, effects of no air (such as on the moon), and nature of atmospheric pressure. 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 public school class of 24 seventh graders answered the questionnaire two times, a week 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 24 students, the mean percentage of questions answered the same both times was 72.4%. See the Appendix for the questionnaire.

Results

To determine whether the private middle school and public middle school students differed in number of questions correct on the questionnaire, independent samples t-tests were computed using percentage correct as the dependent variable. Table 1 presents the means and standard deviations by school. An independent t-test analysis indicates that the two schools are not statistically different, $t\ (165) = .82$, $p = .41$. In fact, the percentage correct by the private school students was only very slightly higher than the percentage correct by the public school students as shown in Table 1.

Table 1. *Means and Standard Deviations of Percentage Correct by School*

Group	N	M	SD
Private school	61	38.60	1.50
Public School	106	37.00	1.20

Study Two

Method

The purposes of the second study were: (a) to determine the aspects of air that middle school students understand and the aspects they find confusing and (b) to investigate the effects of discrepant event demonstrations and hands-on activities on middle school students' conceptions of the same properties of air described above.

Participants

Participants were the private school students from Study One: 21 sixth-graders, 18 seventh-graders, and 22 eighth-graders.

Questionnaires

Participants were administered the questionnaire described above as a pretest before an air pressure lab and again several months later as a posttest.

Air Pressure Lab Sessions

The lab sessions consisted of 20 activities, 13 demonstrations, and seven hands-on activities, covering many of the concepts in the survey. These sessions were completed in three 40-minute class periods. The first author conducted the 13 demonstrations, some requiring specialized laboratory equipment such as an alcohol burner, test tubes, a beaker, a flask, and a glass funnel. These demonstration sessions also involved class discussion in which students were encouraged to express their understandings and ask questions. The hands-on activities were investigated in learning stations set up in the laboratory. In small groups, the students rotated through stations where the seven activities were set up. Each station had instructions for doing the activity and students could discuss the activities as they experimented. To encourage conceptual change through hands-on learning stations, the first author moved from group to group, promoting discussion. Most of the stations employed simple materials which can be found at homes and schools or which can be purchased cheaply or obtained free; e.g., plastic bags, cups, shoe boxes, syringes, balloons, plastic bottles, and ping pong balls. The experiments related to the properties of air such as "air occupies space," "air exerts pressure," "the Bernoulli Principle" (fast moving air has lower pressure than slow moving air), and "Boyle's Law" on the relationship between volume and the pressure of a confined gas. At the end of the rotation through the learning stations, the first author led a discussion of what the students did and what they learned.

Results

To determine which concepts about air the students did/did not understand, the survey questions were categorized according to whether over 50% or under 50% of the students answered them correctly. The six items that over 50% of the students responded correctly , included general knowledge about air such as a comparison of composition of exhaled air and inhaled air, the expansion of air when heated, the effects of air pressure change with altitude, and the absence of air and its pressure in outer space. These items had an average of 64% correct response. These items are shown in Table 2.

Table 2. *The Questions that more than Half of the Students responded correctly on the Pretest with Posttest Comparison*

Question Number	Concepts	Pretest Percentage of correct answers	Posttest Percentage of correct answers
2	The composition of inhaled and exhaled air	69	77
3	Is there air on the moon?	65	90
4	Is there any air pressure on the moon surface?	74	80
5	Air expands when heated.	52	75
7	The relationship between altitude and air pressure	67	79
8	The relationship between altitude and boiling point of water	57	69

The eight items that fewer than 50% of the students responded correctly included air pressure being the same everywhere in a room, absence of pressure in the outer space, effects of partial vacuum, and the Bernoulli Principle. These items with the percentages correct on the pretest and posttest are found in Table 3.

Table 3. *The Questions that fewer than Half of the Students got Correct on the Pretest with Posttest Comparison*

No	Concepts	Pretest Frequency (%)	Posttest Frequency (%)
1	Air pressure is the same everywhere in a room	36	41
6	If an ordinary balloon is inflated and transported into the outer space, it will burst.	13	59
9	If a partial vacuum is created in a flask closed with a balloon, the balloon blow up inside the flask	18	28
10	Blowing under a paper bridge causes it to bend toward the table	19	95
11	If you blow for a while through one end of a pipe, at the other end, the ping-pong ball stays over the pipe.	19	87
12	If you blow a paper ball in the neck of bottle, it moves directly outside of the bottle	5	75
13	In a spray gun, the sprayed material comes out from the bottle because of decrease in pressure at the end of pipe.	23	36
14	Strong wind weather, often turns an umbrella inside out, because of the pressure drop at the top of it.	5	15

In order to analyze the effect of the demonstrations and hands-on activities on correct answers by grade level, a 2 (*time*) x 3 (*grades*) ANOVA with repeated measure on *time* (pretest/posttest) was computed. The dependent variable was the percentage of questions answered correctly on the air properties questionnaire.

Table 4. *Mean Percentages Correct and Standard Deviations before and after Instruction*

		Pretest		Posttest	
Grades	**N**	**M**	**SD**	**M**	**SD**
Six	21	40.13	9.16	64.28	14.81
Seven	18	30.55	12.44	53.17	11.54
Eight	22	39.61	10.51	82.46	13.17
Total	61	37.12	11.35	67.56	17.86

The results showed three significant effects (see table 5 for the Analysis of Variance summary). Discussion of the main effect for *grade level* is less meaningful because of the time X grade level interaction. The main effect was for *time*, which indicated an increase from pretest to posttest, $F(1, 58)= 272.52$, $p < .001$. Interaction 3 (*grade level*) X 2 (*time*) shows that the amount of change from pretest to posttest depended, in part, on whether the students were sixth, seventh, or eighth-graders, $F(2,58)= 13.42$, $p < .001$. The simple effect analysis showed that all grade levels improved their scores on the posttest. For sixth-grade $F(1,58)= 61.7$, $p < .001$; seventh- grade $F(1,58)= 46.4$, $p < .001$; and eighth grade $F(1,58)= 203.7$, $p < .001$. The interaction occurred because the eighth-graders improved more than the other students.

Table 5. *Summary for Split Plot Repeated Measures Analysis of Variance*

Source	***DF***	***MS***	***F***	***p***
Grade level	2	3640.03	18.87	.001
Error 1	58	192.82		
Time (Pre/posttest score)	1	27024.02	272.51	.001
Time X Grade level	2	1331.06	13.42	.001
Error 2	58	99.16		

DISCUSSION AND CONCLUSION

Findings of the study indicate that middle school students from both public and private schools hold many misconceptions on physical properties of air, similar to those found in previous studies with various age groups (Borchi et al., 1988; Piaget, 1930/1972; Sere, 1982, 1986). Comparing the private and public middle school students it can be seen that both groups had the same level of misconceptions. Both groups received less than 39% correct and the low standard deviation for both groups indicates that there was not much variability in correct answers. Although air properties are included in the middle school curriculum, these findings suggest that this topic may not have been taught prior to the research. Alternative explanations may be that this topic was covered in both schools by expository teaching that, according to Marinopoulos and Stavridou (2002) and Weaver (1998), is not sufficient for building understanding. The present study is unique in comparing public and private school students on this issue, but interpretation is limited since little is known about the previous teaching of air concepts in either school. Further research comparing private and public schools should study how and when concepts on air properties are taught, in order to better understand the roles of: (a) age in the development of concrete operational versus formal operational thinking on air properties and (b) teaching method (expository versus discrepant event learning through demonstrations and hands-on activities)

As shown in Tables 2 and 3, the percentage of students answering correctly increased after the lab experience. On the pretest, many students were confused about the physical properties of air, especially the concepts related to the Bernoulli Principle, which states that the faster the flow of air, the lower the pressure it exerts. This is not surprising since children's daily experiences with wind seem to contradict this principle. For instance when the wind blows, it pushes and carries everything in its blowing direction. During the intervention, students observed several hands-on experiments and demonstrations related to the Bernoulli Principle. Therefore, on the posttest, the greatest improvement was on questions related to this principle. For example, students' correct responses increased from 19% to 95% on question 10. This high achievement on the posttest can be explained by the effectiveness of using various kinds of discrepant events in the intervention. Exposing children to a sequence of appropriate experiments and collaboration with their classmates leads them to give up pre-causal explanations and resort to more accurate ones (Borghi et al., 1988; Cetin 2003). The students were surprised and motivated when they observed that their prior knowledge could not explain the events in the experiments. In addition to observing demonstrations and participating in the hands-on activities, reflection and classroom discussions may also have played an important role in the students' conceptual growth. If the students had just observed demonstrations, their misconceptions may have never become apparent to them and conflicted with their previous understanding. As concluded by Weaver (1998), personal understandings may require reflection on their own predictions or explanations as well as the challenge of trying to explain concepts to others.

The finding that the private school students increased their understanding of properties of air after the lab sessions suggests that the hands-on activities and demonstrations contributed to development of conceptual understanding. This corresponds to research findings (Alexopoulou & Driver, 1996; Baser & Cataoglu, 2005; Ertepinar & Geban, 1996; Thomson & Logue, 2006; Weaver, 1998) that students' naïve conceptions can be improved through active participation in hands-on activities and demonstrations and collaboration with teachers and peers. In terms of Piagetian theory (Piaget, 1970), the demonstrations and hands-on activities were familiar enough to allow for assimilation but discrepant enough to cause the students to experience disequilibrium. A factor contributing to assimilation may have been the use of readily available and inexpensive materials, such as soda bottles, straws, candles, and garbage bags, with which the students were familiar in their daily lives. The use of simple materials in discrepant events can be extremely effective in challenging students' understandings (Brandwein, 1968). The disequilibrium experienced, according to Piagetian theory, caused the students to accommodate their thinking to the new experience and build their conceptual understanding to fit their new understandings. Collaboration with the teacher and peers may have been helpful in scaffolding students as they sought to make sense out of the phenomena (Vygotsky, 1978).

The students improved most on the questions requiring an understanding of the Bernoulli Principle. Many of these questions on the Bernoulli Principle related directly to the hands-on experiences. On the other hand, increases in correct answers were less dramatic on questions dealing with other aspects of air, that it exhibits the following characteristics: exerts pressure, changes in composition when exhaled, rises when heated, and does not exist in outer space. For these items on the questionnaire, students did not have hands-on experiments or demonstrations. That the composition of air changes when exhaled was not covered at all in the activities or discussions. On the other concepts, students were supposed to extend and infer their understandings from the experiments, but increases in correct answers to these items averaged only an average of 10% from pretest to posttest. The low level of improvement on these items is consistent with the findings of Brandwein (1968). He found that student improvement particularly depends on the experiments done by children themselves. However, application of hands-on lab experiences to explain other real life problems or events requires a higher level of thinking. For example, students did a hands-on activity on boiling warm water in a medical syringe by decreasing pressure. However, about 30% of the students answered incorrectly the question about the relationship between altitude and the boiling point of the water. In Turkish elementary and middle schools, science is often instructed from textbooks, and much emphasis is placed on testing leading to memorization of science concepts, facts and principles, without application to real life problems. Such memorization may interfere with higher-level thinking and the confidence to apply knowledge to new situations. Other instructional strategies such as concept mapping, using analogies, and computer simulations may support higher-level thinking and be especially useful in building conceptual understanding where experimentation is impossible.

Improvement on the posttest, corresponding particularly to questions covered directly by demonstrations and activities, suggests that students need to understand the concepts by doing various inquiry-based hands-on activities. However, that some of the middle school students still held misconceptions after the instructional intervention suggests that a combination of methods designed to create discrepant experiences and to encourage transfer of knowledge to new situations might be useful.

Other research has examined children's understanding of physical properties of air; i.e., whether it exists if it is not moving (Sere, 1982), whether it occupies space and has pressure (Borghi, Ambrosis, Massara, Grossi & Zoppi 1988; Tytler, 1998). This study is unique in that it examined some properties of air not covered in other studies; e.g., absence of air and its pressure in outer space, Boyle's Law, and the Bernoulli Principle. It also allowed for examination of concepts taught through demonstrations and hands-on experiences as well as concepts that required extension of knowledge to new situations. That many students developed understandings of the concepts included in the demonstrations and activities but had limited ability to generalize those concepts to other situations suggests the need for more assistance to be able to generalize their new experiences with new phenomena. That aid could be in the forms of added research on the questions, conversations, demonstrations, and perhaps readings.

REFERENCES

Alexopoulou, E., & Driver, R. (1996). Small-group discussion in physics: peer interaction modes in pairs and fours. *Journal of Research in Science Teaching, 33*(10), 1099-1114.

Baser, C., & Catlioglu, E. (2005). Effect of Conceptual Change oriented instruction on remediation of students' misconceptions related to heat and temperature concepts. *H.U. Journal of Education, 29,* 43-52.

Ben-zvi-Assarf, O, & Orion, N. (2005). A study of junior high students' perceptions of water cycle. *Journal of Geoscience Education, 53* (4), 366-373.

Borghi, L., De Ambrosis,, A., Massara, C. I., Grossi, M. G., & Zoppi, D. (1988). Knowledge of Air: A study of children aged between 6 and 8 years. *International Journal of Science Education, 10* (2), 179-188.

Brandwein, P. F. (1968). *The method of intelligence*. Presentation at the National Science Teacher Associations Convention, Toronto.

Callison, P.L., & Wright, E.L. (1993, April). *The effect of teaching strategies using models on preservice elementary teachers' conceptions about earth-sun-moon relationships*. Paper presented at annual meeting of the National Association for Research in Science Teaching, Atlanta, Georgia.

Cetin, G. (2003). *The effect of conceptual change instruction on understanding of ecology concepts*. Unpublished Doctoral Dissertation, Middle East Technical University, Ankara, Turkey.

Costa, M.F. (2003). Hands-on Science. European Commission under the Socrates Project, Retrieved from, http://www.isoc.siu.no/isocii.nsf/projectlist/110157.

Dalton, B., & Morocco, C.C. (1997). Supported inquiry science: Teaching for conceptual change in urban and suburban science classrooms, *Journal of Learning Disabilities, 30* (6), 670-684.

Ertepinar, H., & Geban, O.(1996). Effect of instruction supplied with the investigative-oriented laboratory approach on achievement in a science course. *Educational Research, 38* (3), 333-341.

Hewson, P.W. (1992, June). *Conceptual change in science teaching and teacher education,* Paper presented at a meeting of the Research and Curriculum Development in Science Teaching, Madrid, Spain.

Hsiao-Ching, S. (2002). Concept of higher hierarchical level require more dual situated learning events for conceptual change: a study of air and buoyancy. *International Journal of Science Education, 24* (9), 981-996.

Marinopoulos, D., & Stavridou, H. (2002).The influence of a collaborative learning environment on primary students' conceptions about acid rain. *Educational Research, 37*(1), 18-24.

Nakiboglu, C., & Tekin, B. B. (2006). Identifying students' misconceptions about nuclear chemistry. A Study of Turkish High School students. *Journal of chemical Education. 83* (11), 1712-1718.

Piaget, J. (1972). *The Child's Conception of Physical Causality*. Totowa, NJ: Littlefield Adams & Co.

Piaget, J. (1970). Piaget's theory, *Manual of Child Psychology*, In P.H. Mussen (Ed.) Third Edition, Vol. 1, New York: John Wiley & Sons, Inc.

Piaget, J. (1964/1993). Development and learning. In M. Gauvain and M. Cole (Eds.), *Readings on the Development of Children* (pp. 25-33). New York: Scientific American Books.

Pyle, E. J., & Akins-Moffatt, J. (1999). The effects of visually-enhanced instructional environments on students' conceptual growth. East Lansing, MI: National Center for Research on Teacher Learning, ERIC Document Reproduction Service No. ED EJ651157.

Sere, M. (1982). A study of some frameworks used by pupils aged 11 to 13 years in the interpretation of air pressure. *European Journal of Science Education, 4*(3), 299-309.

Sere, M. (1986). Children's conceptions of the gaseous state, prior to teaching. *European Journal of Science Education, 8*(4), 413-425.

Thompson, F. & Logue, S. (2006). An exploration of common student misconceptions in science. *International Education Journal, 7*(4), 553-559.

Trundle, K. C. (1999). *Elementary preservice teachers' conceptual understandings of the cause of moon phases*, Unpublished doctoral dissertation**,** The University of Tennessee**,** Tennessee.

Tytler, R. (1998). Children's conceptions of air pressure: Exploring the nature of conceptual change. *International Journal of Science Education*. *20*(8), 929-958.

Vygotsky, L.S. (1978). *Mind in Society*, In M. Cole, V. J. Steiner, S. Scribner, & E. Souberman (Eds.), Cambridge, MA: Harvard University Press.

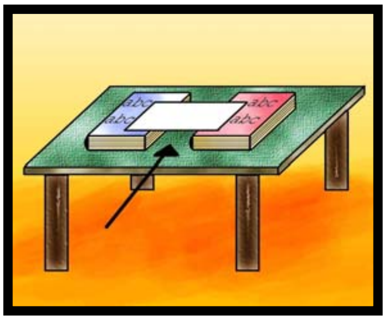
Weaver, G.C. (1998). Strategies in K-12 science instruction to promote conceptual change. *Science Education*, *82*, 455-472.

Appendix

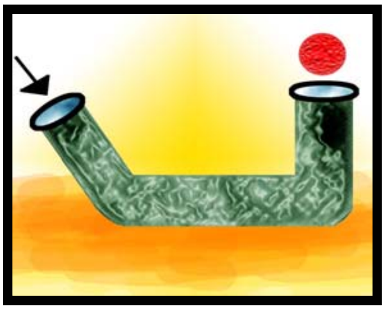
Air Properties Questionnaire

The following questions are related to properties of air and the Bernoulli Principle. There are 13 multiple choice questions and 1 essay question. Thank you!

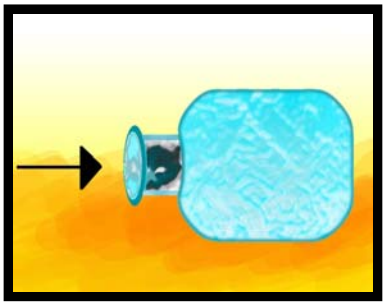
1. Do you think air pressure is the same everywhere in a room? Under the table, in the closet, etc?
   a. The same X b. Different
2. You have two bags. Suppose first one is inflated by moving the bag back and forth (like wanting to catch a bug in the bag) then the mouth of the bag is closed with a twisting motion. The second one is inflated by blowing. Would the material in these two bags be the same?
   a. Yes, the same b. No, different X
3. Suppose a trash bag is moved back and forth on the Moon, then the mouth of the bag is closed with a twisting motion. What will happen to the bag?
   a. Inflate b. Burst c. Flat and empty X
4. If the mouth of an astronaut were connected to a straw through his space suit to an open cup with liquid on the Moon surface, would he be able to drink liquid by sucking through the straw?
   a) Yes, he would b) No, he would not X
5. Two open paper bags are hung upside down on the ends of a smooth rod. The paper bags are in balance. Suppose a burning match is held under the one of bags. What will happen?
   a) The bag over the flame moves up X
   b) The bag over the flame moves down
   c) Nothing changes
6. Imagine an ordinary balloon is inflated on the surface of Earth and is magically transported into outer space. What do you think will happen to it?
   a) Expand b) Burst X c) Shrink
7. Suppose you drive quickly down a high mountain to a valley. Your ears will be clog up. What is the reason for it?
   a) Increase in air pressure X b) Decrease in air pressure d) Change in temperature
8. Compared to sea level, the boiling point of water at the top of a mountain is
   a) Higher b) The same c) Lower X
9. Suppose we heat a little water in a bottle and boil it vigorously for two minutes. What will happen if we immediately place a balloon over the mouth of the bottle and then let it cool slowly?
   a) The balloon goes inside the glass X
   b) The balloon expands
   c) Nothing changes



10. In the figure, a paper is placed on two books. What will happen if we blow between the two books?
    a) The paper bends toward the table X
    b) The paper flies over books
    c) Nothing changes.



11. In the figure, there is a ping-pong ball on the pipe. What will happen if we blow for a while through the pipe?
    a) First, the ball rises, then falls off
    b) The ball stays over the pipe X
    c) The ball falls off immediately



12. In the figure, three is a paper ball in the neck of the bottle. What will happen if we blow through the mouth of bottle?
    a) First the paper ball goes in, then it moves out
    b) It goes in and stays in the bottle.
    c) It moves directly outside of the bottle X

13. In the figure, there is a spray gun. What causes the sprayed material to come out from the bottle?
    a) Decrease in pressure at the end of pipe X
    b) Increase in pressure at the end of pipe
    c) Increase in pressure inside the bottle

14. In strong, windy weather, often an umbrella turns inside out. What might be the reason for this event?

-----*Rapidly moving (lower pressure) air moving over the top of the umbrella causes the more stationary (higher pressure) air under the umbrella to push the umbrella outward.*