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ACQUIRING CONCEPTS ABOUT THE STRUCTURE AND BEHAVIOUR OF AIR: PRODUCTIVE PROCESS OR UNDESIRABLE OUTCOME?

PAPER SUBMITTED FOR THE THIRD INTERNATIONAL SEMINAR ON MISCONCEPTIONS AND EDUCATIONAL STRATEGIES IN SCIENCE AND MATHEMATICS

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ABSTRACT

The ability of children to apply scientific concepts to 'everyday' phenomena appears to emerge late in secondary schooling. These acquired concepts, however, must often take their place beside personal beliefs about the world which remain intact despite the numerous cognitive challenges faced by students. One issue confronting classroom practitioners is whether they can facilitate the acquisition of scientific perspectives from within the students' constructs by taking full account of the social and cultural factors which may be significant determinants of concept acquisition.

This study is a preliminary investigation of concept acquisition across age groups. A questionnaire based on the structure and behaviour of air was used to obtain a 'snapshot' of students' ideas in the eight to seventeen age range. The results suggest that formally useful concepts which are introduced early in school curricula may not necessarily be personally useful for many students. Some of the implications for teaching are considered in the light of the crucial role teachers play in helping students to resolve the gulf separating their ideas from the scientific paradigm.

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INTRODUCTION

A great deal of attention in recent years has been given to empirical indicators of students' ideas about specific topics in the science curriculum (Erickson, 1979, 1980; Osborne and Freyberg, 1985; Bar, 1989; Finegold and Trumper, 1989; Shapiro, 1989; Anderson, 1990). Each focuses on what Driver and Oldham (Driver and Oldham, 1986) refer to as a reconsideration of perspectives on teaching and learning which takes into account students' prior ideas on the topic. The reasons for giving such attention to students' ideas are further articulated by Tobin (Tobin, 1990) and Cleminson (Cleminson, 1990) who express concern for the mismatch between teaching methods and student learning.

Piaget is acknowledged as having given impetus to the emergence of current constructivist theories of learning, such as generative learning (Osborne and Freyberg, 1985), in which knowledge is acquired as the learner organises experiences in terms of pre-existing mental structures. Such mental structures cannot always be reworked easily, and this may require the teacher to make a shift in teaching style. This shift might be seen as with a move away from a Piagetian approach to learning which requires the determination of a student's specific operational stage to develop instructional materials, in favour of an approach which determines the extent of the learner's pre-existing knowledge, skills, attitudes, values and personal experiences.

The importance of identifying students' pre-existing knowledge is considered essential by Dreyfus, Jungwirth and Eliovitch (1990) if active reconstruction and reshaping of ideas is to be achieved. A major feature of students' pre-existing knowledge which needs special attention is the intuitiveness of the ideas or alternative frameworks brought to the formal learning context (Gil-Perez and Carrascosa, 1990; Driver and Oldham, 1986). These ideas can be used positively to promote conceptual change (Jungwirth and Eliovitch, 1990), but, if ignored by the teacher, may lead to learning difficulties.

Whether such ideas are innate, learned from experience, or due to strategic inattention, they are acquired early (Macnamara, 1982; Pope & Gilbert, 1983) and have been shown to persist over periods of time, often quite resistant to change (Clough et al, 1987; Bar, 1989).

One of the challenges facing teachers is to ensure that replacement of existing beliefs and ideas is achieved using scientific concepts which the learner finds intelligible, plausible and fruitful. For example, many students find it difficult to accept that air exists with a vacuum between the particles (Osborne and Freyberg, 1985). New concepts may develop only when attributes of the phenomenon under investigation are clearly understood by the learner and are seen to be consistent with their observations and needs.

Gender equity in secondary education has been identified as another area of mismatch for building scientific knowledge based on students' beliefs and experiences. Science has been described as a masculine discipline which ignores girls' backgrounds and needs (Byrne, 1978; Kelly, 1987; Head, 1985, 1988; Sjoberg, 1988,1989). Any attempt to make science an equitable undertaking necessitates the use of terms such as "girl-friendly science", "feminine science" and "feminist science". The reasons for the under-participation of girls in science when the decision to study science becomes a matter of choice may not be that girls cannot learn science, but that the collection of attitudes which clothes science is either unattractive or unappealing to them (Byrne, 1978). Science is clearly influenced by gender culture.

Whether because of experience gaps (Piburn and Baker, 1989), a loss of confidence (Doherty, 1987) or the way ego-identity is attained (Head, 1988), girls may not necessarily be individually responsible for their lack of achievement in science related subjects (Sjoberg and Imsen, 1988).

The role of the organiser may be significant in creating meaningful and relevant learning experiences for both boys and girls. Byrne (1978) and Kahle (1988) draw attention to a subtle "numbers game" problem arising from the imbalance of male and female teachers in primary and secondary schools. The majority of primary teachers are women, many of whom may lack relevant training in science education. Equal numbers of girls and boys may participate in science lessons, but they may gain experiences in unequal ways.

According to Sjoberg and Imsen (1988), girls are more likely to have experiences in activities associated with the household, biology, health and caring, whereas boys' activities reflect physical concepts, mechanical interests and their application. The discrepancy becomes more apparent with progression through the secondary grades of schooling.

Whereas girls in New South Wales make up 52% of Higher School Certificate candidates, girls make up only 40% of the top students in the HSC Examination. Only one third of students in top science and mathematics classes in the State are girls (ABC TV, Four Corners, 29th June 1992).

The purpose of this study was to undertake a preliminary investigation of the impact of formal teaching on student's personal views. Topics focussing on air are included in formal curricula or school studies in both primary and secondary schools. Children are encouraged to develop sensible and coherent explanations of personal observations from a very early age.

METHODOLOGY

A 19 item multiple choice questionnaire (Appendix 1) was devised to elicit student responses to their conceptions of air. The final instrument resulted from a three stage development and review programme. ie.

Preliminary student interviews;
Pilot instrument development, testing and review, and
Survey instrument refinement.

The resulting survey instrument was then administered to the respondents. Responses were analysed and evaluated.

Preliminary student interviews

A structured interview schedule was developed to elicit student's ideas about air. Audio-taped interviews were individually conducted with 3 girls and 3 boys to represent the upper, middle and lower ability cohorts with respect to performance in science. The pupils were selected from year 8 classes (13/14 year olds) from single sex schools. A year 6 (12 year old) boy from a co-educational school was also interviewed to determine the congruence of language and constructs. All respondents had no recent formal teaching in the area. Probing of responses provided explanation and justification for beliefs. Pupil responses were analysed to find common constructs and familiar terminology with respect to air.

The analyses revealed that the students' responses generated three main categories for further investigation. These areas were:

a) Students' personal experience of air;
b) Students' perceptions of the organisation and structure of air; and
c) Students' perceptions of the properties and behaviour of air.

Categories 'b' and 'c' provided the opportunity to probe separately the extent of students' particulate and kinetic ideas about air.

Pilot instrument development, testing and review

A pilot questionnaire encompassing the range of ideas expressed during student interviews was developed across the three identified categories. The pilot survey was couched in terms and language frequently used by the pupils at interview.

The survey instrument was trailed across a sample of 20 persons spanning tertiary to infant education levels. The respondents provided additional feedback on the readability and comprehensibility of the survey instrument. Together with responses, these comments provided valuable additional feedback to enhance the validity and reliability of the final instrument.

Survey instrument administration and response analysis

An across the grades response was obtained by administering the revised questionnaire to a sample of 347 students - 203 females and 144 males, ranging from grade 3 to grade 12. The students were selected from 9 different schools and included New South Wales state and independent schools; male, female and co-educational schools; K-6, K-12 and 7-12 schools. One male and one female student from each of the teacher selected cohorts of upper, middle and lower sections of their class were selected to complete the questionnaire.

Female teachers were associated with 161 students from 26 different classes, and male teachers with 186 students from 29 classes. However, attempts to control for teacher and other environmental variance was considered beyond the scope of this preliminary study.

The responses were analysed using the SPSSX statistical package using cross tabs subprogramme and Excel graphics routine to map conceptual understandings of students across grades.

QUESTIONNAIRE ANALYSIS

a) Personal experience with Air

Initial interviews and trials have demonstrated that children develop strong personal views about air from a very young age. Prior personal experiences have played an important role in the formation of students' ideas. Questions 1 and 3 sought to elucidate children's perceptions of air through word associations.

Student responses to questions 1 and 3 have indicated a familiarity with air which is based on their immediate personal experiences and may demonstrate a gender dependence. (Figures 1 and 2).

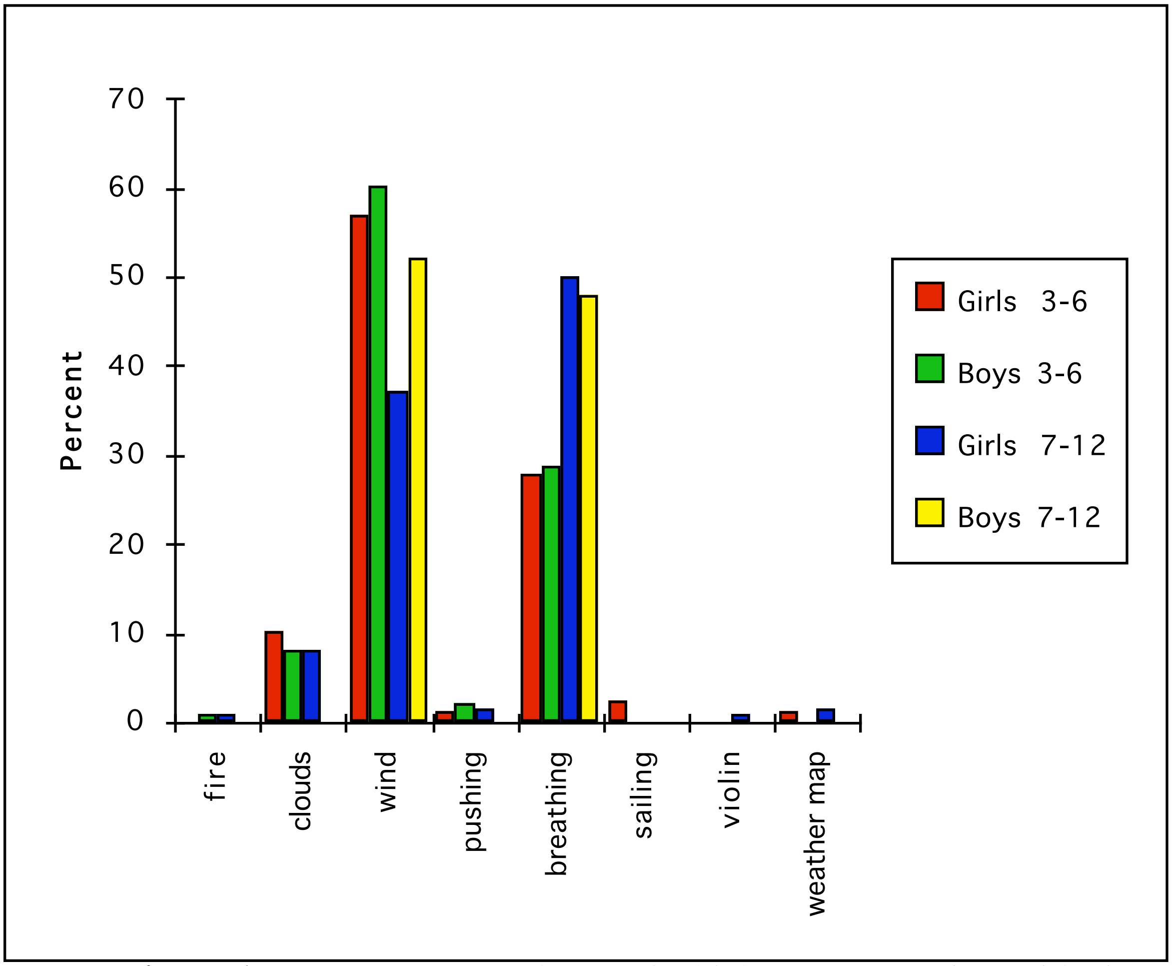

Figure 1. QUESTION 1: The word which I most associate with air. Student grade groups by gender.

In Figure 1 the preferred responses were *wind* (50.1%), *breathing* (38.6%) and *clouds* (7.5%).

Primary children (grades 3-6) demonstrated a preference for the option, *wind*.

Secondary students (grades 7-12) showed a marked shift towards *breathing* (49.0%) as a preferred response with secondary boys maintaining a clear preference for *wind* (57.0%).

Primary grade students and boys were clearly more likely than girls to respond to the *wind* option. Their physical sense experiences may have been influential in determining the selection of *wind* more than the other options. In contrast, the increased selection of *breathing* by the secondary students emphasises their growing recognition of the importance of air for the person as a result of widening experiences.

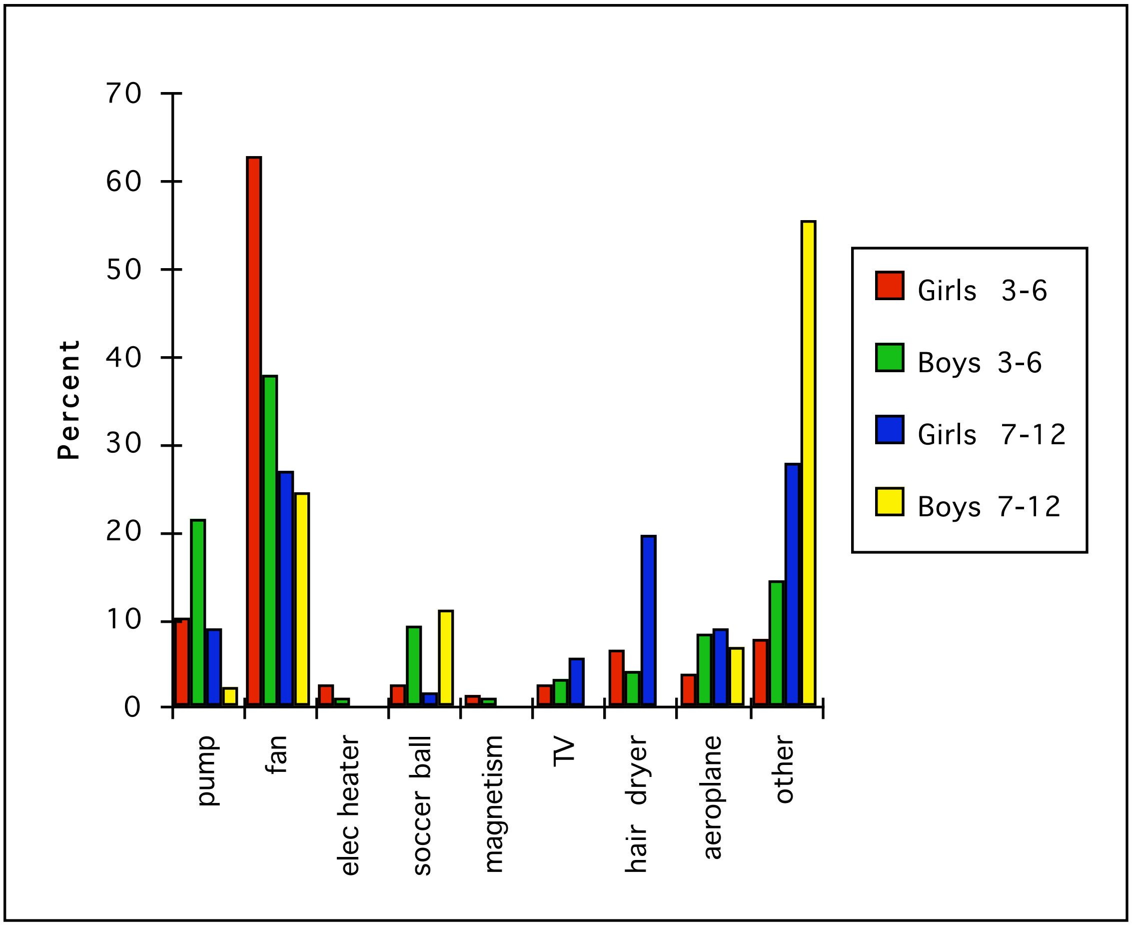

Figure 2. QUESTION 3: The most familiar use of air.
Student grade groups by gender.

Responses to the use of air (Question 3) have demonstrated both gender bias and age dependence. (Figure 2).

the *fan* (37.9%) was clearly the preferred option for all student groups, but especially for grades 3-6 girls.

grades 7-12 girls also preferred the stereotypical choices of *hairdryer* and *TV*.

boys showed a preference for the gender dependent, and societally determined choices, of *pump* (grades 3-6), and *soccer ball* (grades 3-12).

The strong *other* category, identified as *breathing* by almost all of these respondents, predominated in grades 7-12.

Discussion

All students responded to their personal familiarity with air and its uses in a manner which is sometimes gender specific. These uses reflect an egocentric shift towards *breathing* with increase in age.

Males were more likely to respond to the sense option, *wind,* and secondary pupils more likely to associate air with *breathing* , selections which reflect the importance of air for the individual and which signify tangible signs of interactions with the immediate environment.

The preference of grades 7-12 girls for hair-*dryers* and *TV*, grades 3-6 boys towards *pump* and grades 3-12 boys towards *soccer ball*, reflects general societal use of these technologies for the particular gender and age categories. When viewed in the context of all sample responses, the average for boys selecting *wind* was consistently above the sample average, whereas for the option *breathing*, girls selected above the sample average .

b) Organisation and Structure of Air

Questions 2, 4, 6, 7, 10, 17 and 18 were selected to probe students' views on the organisation and structure of air.

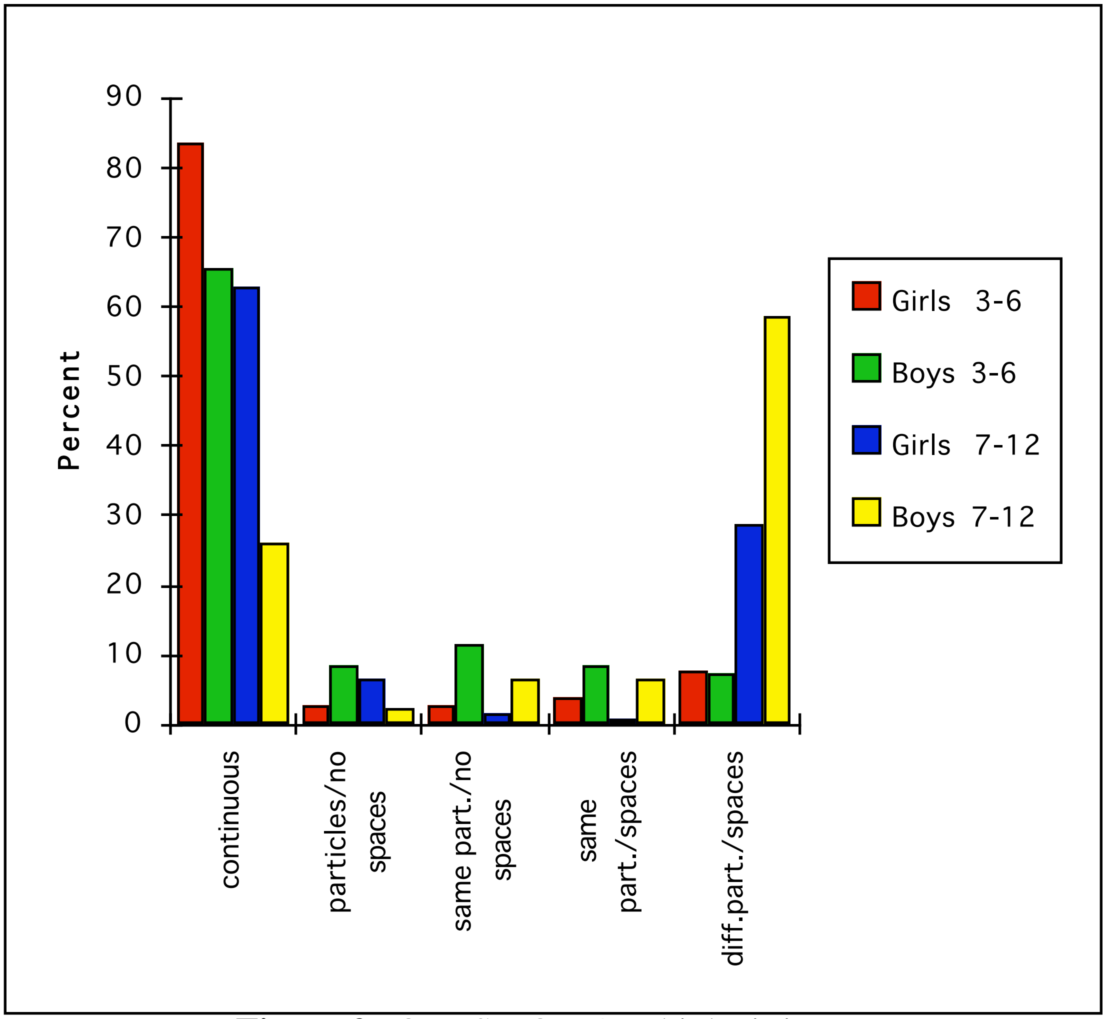

Figure 3. QUESTION 4: I think air is... Student grade groups by gender.

Question 4 sought to distinguish those students who viewed air as non-particulate and continuous or "everywhere" (Brook and Driver, 1988) from those who adopted a particulate view of air (Figure 3).

a majority of primary grade children hold air to be continuous:

girls 84.4%
boys 66.3%

many secondary students retain a continuous concept of air:

girls 62.3% grades 7 - 10
boys 28.3% grade 7 only.

Questions 2, 17 and 18 introduced the concept that air might contain a number of components.

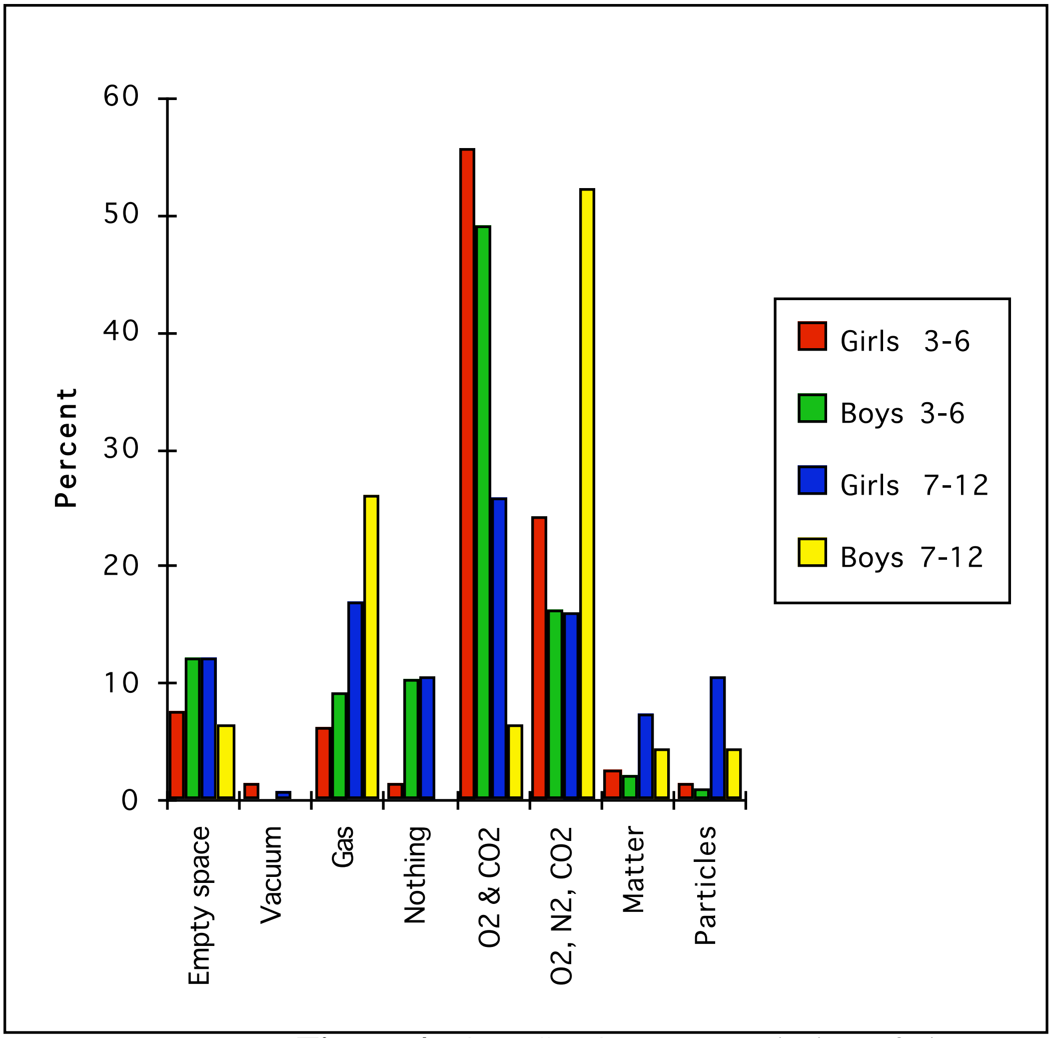

Figure 4. QUESTION 2: Description of air.
Student grade groups by gender.

In contrast to the high non-particulate response rate to question 4, question 2 (Figure 4) has shown a relatively low response of 35.7% for this trait compared with those options which include mixtures of components (64.3%). In question 2.

the most popular response for all students was *oxygen and carbon dioxide* (36.6%) :

primary respondents 52.4%
secondary students 32.3%.

oxygen, nitrogen and carbon dioxide became the preferred response for:

boys, grades 7 - 12
girls, grades 11 -12.

Séré (1985) found that only some 12 year old students and half 16 year old students recognise air as a mixture of gases. In the present study, 42.3% of grade 9 (14 year old) and 95.6% of grade 10 students viewed air in this way.

Questions 17 and 18 (Figures 5 and 6) sought student's views on the main component of inhaled and exhaled air.

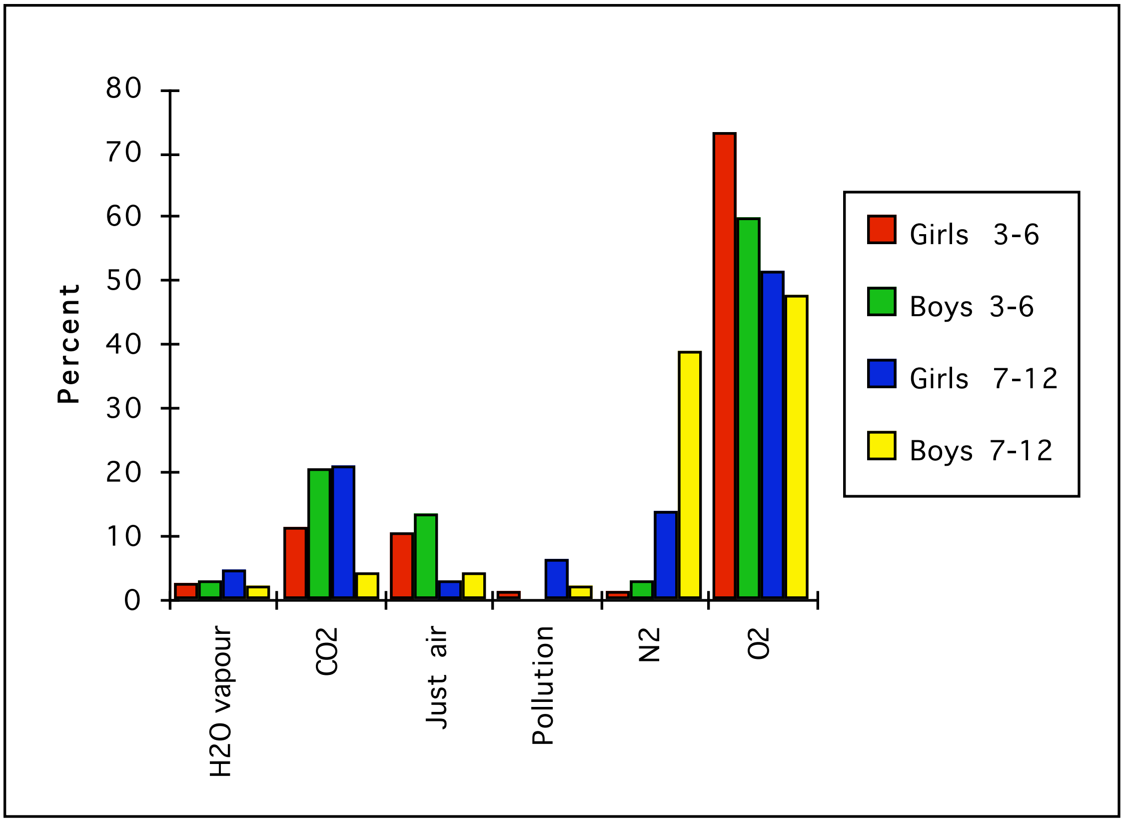

Figure 5. QUESTION 17: The main component of inhaled air. Student grade groups by gender.

58.5% of all pupils identified *oxygen* as the main component of inhaled air with 16.4% response to *carbon dioxide* and 11.2% for *nitrogen*.

In contrast, for the main component of exhaled air, the options favoured were *carbon dioxide* (65.6%), *oxygen* (12.1%) and *nitrogen* (10.3%).

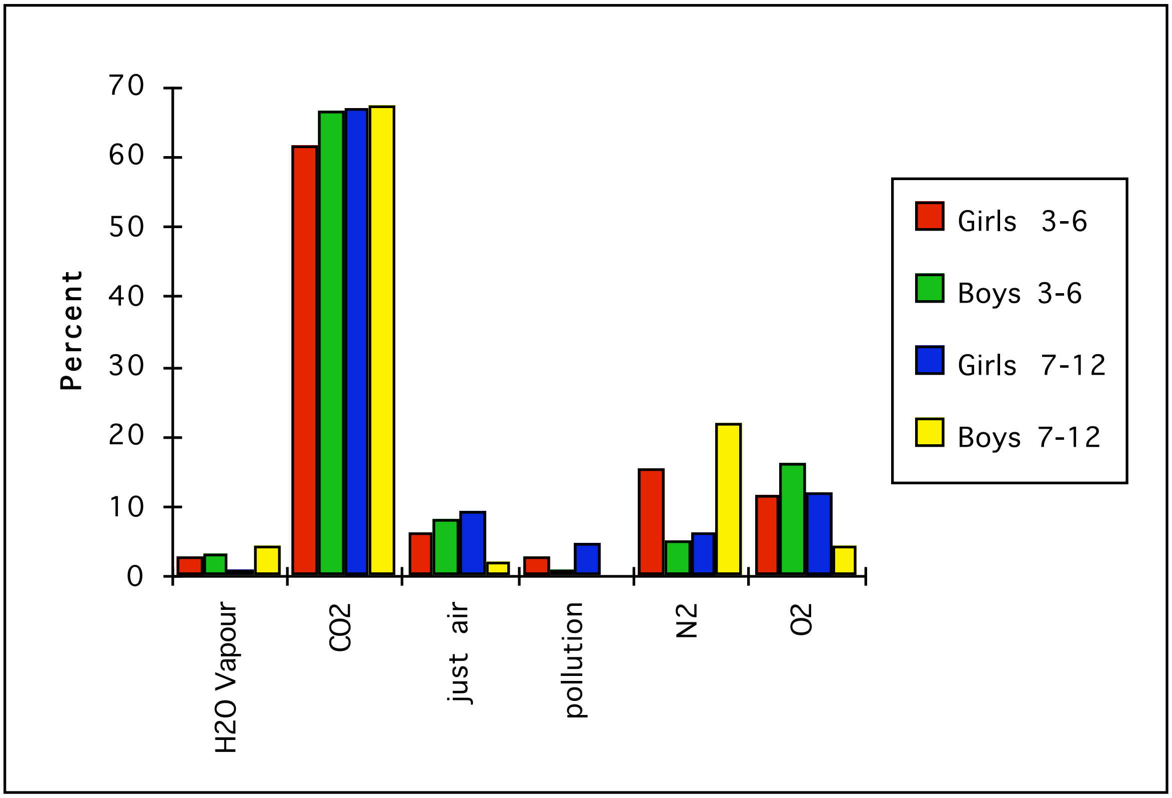

Figure 6. QUESTION 18: The main component of exhaled air.
Student grade groups by gender.

Séré (1985) has reported that some 5 year old children associate air with breathing whilst some 8 year olds can recognise a difference between inhaled and exhaled air. The present study demonstrates that children enter grade 3 with a strong view that we breathe in oxygen (60.0%) and breathe out carbon dioxide (43.3%). It was not until grades 10, 11 and 12 (boys) that boys identified nitrogen as the major component of inhaled air. Girls in all grades maintained their strong belief in oxygen being the major component of inhaled air.

In contrast, preference for carbon dioxide as the main component of exhaled air, was maintained by all students, grades 3 - 12.

Questions 6, 7 and 10 provided different contexts for students to apply their ideas about air.

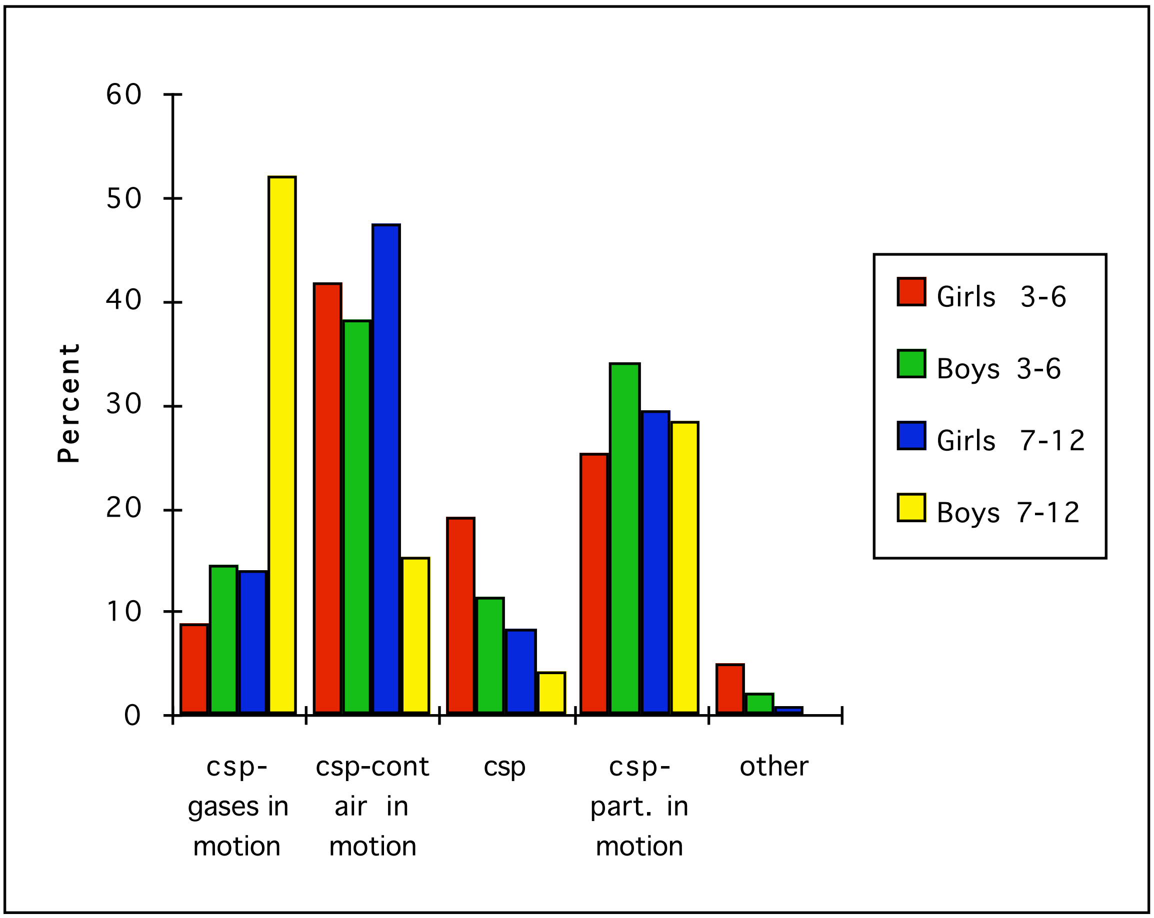

Figure 7. QUESTION 6: Perceptions of air in a cupboard. Student grade groups by gender.

A consideration of the presence of air around plates in a cupboard has revealed a strong preference for non-particulate responses from (Figure 7):

all primary students, and
secondary girls

The strongest response for a multi-component view of air (gases or particles) was observed from boys. This response is particularly evident in grades 11 and 12 boys (82.4% with the more general option of gases predominating) and to a lesser extent in grades 11 and 12 girls.

Little discrimination is shown in question 7, (Figure 8) with the main response identifying *air and water particles* existing between the *very small dirt particles in the soil* (64.8%). Secondary students (76.2%) and in particular boys (84.8%) showed a greater preference for this option than primary children (57.3%).

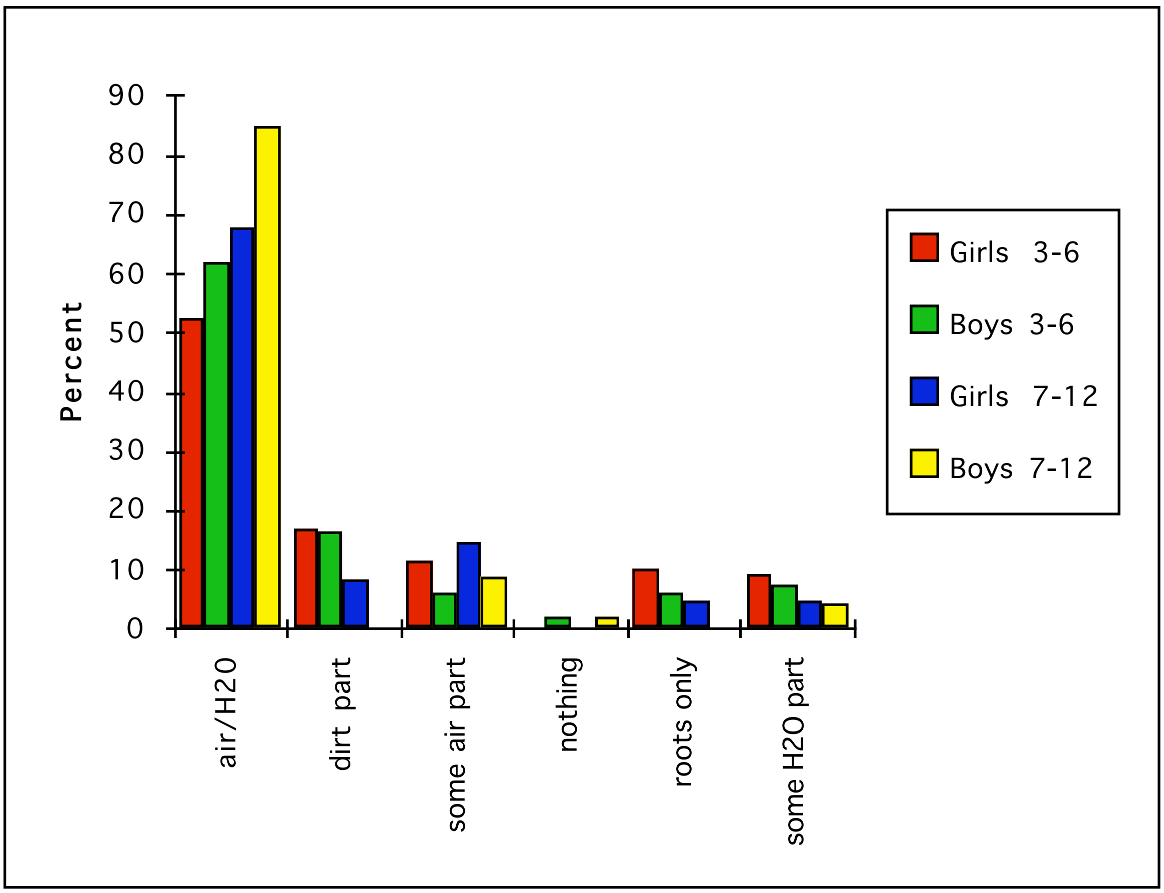

Figure 8. QUESTION 7: What exists between dirt particles. Student grade groups by gender.

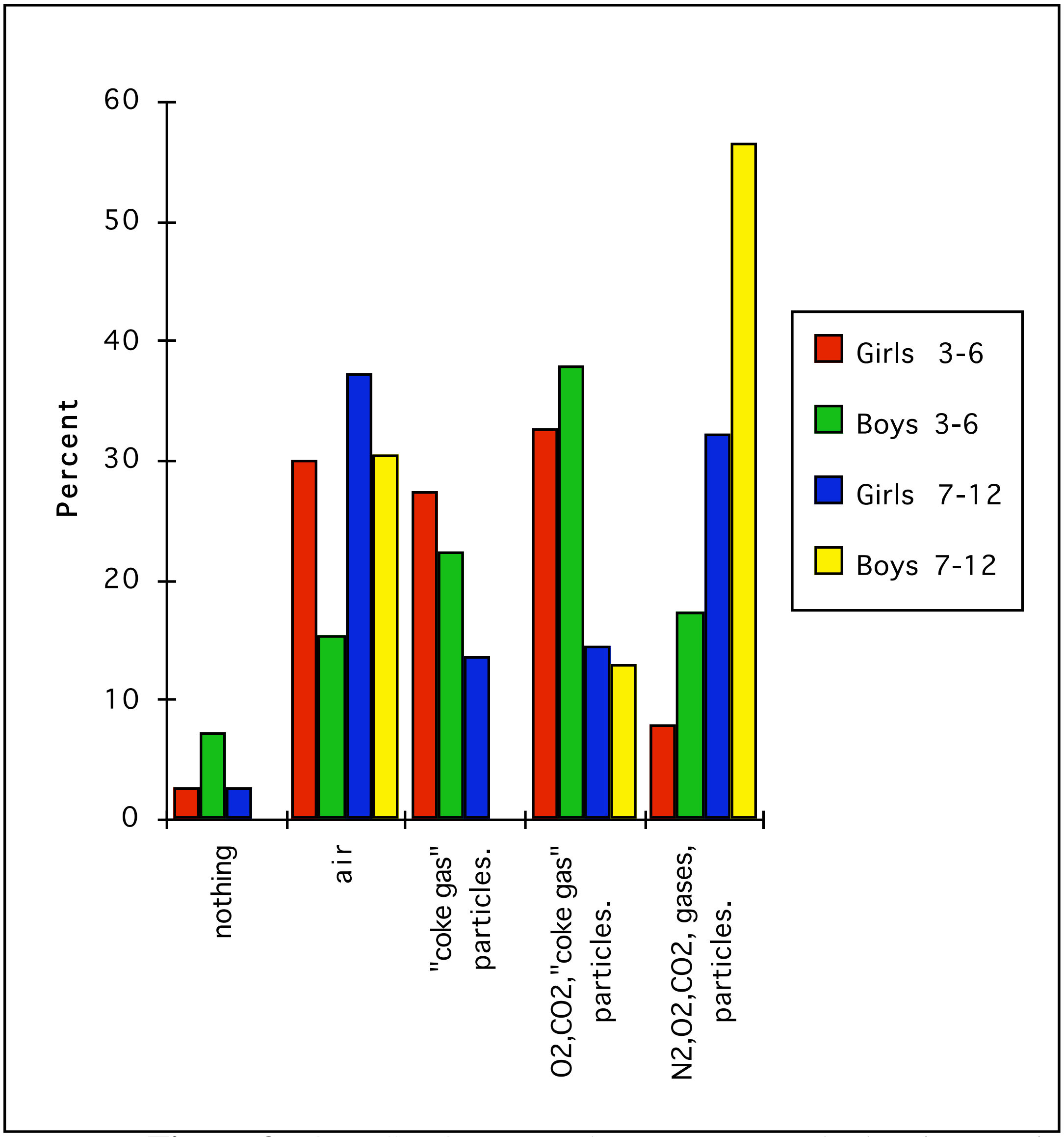

Figure 9. QUESTION 10: What an empty coke bottle contains. Student grade groups by gender.

Question 10 (Figure 9) demonstrated a distinct spread across the non-mixture options *air* and *coke gas,* and the mixture options *oxygen, carbon dioxide, coke gas* and *nitrogen, oxygen, carbon dioxide, water vapour and other gases*.

Girls' responses in this question again highlighted their belief in the continuous nature of air (55.0%). In keeping with previous findings, only secondary grade 12 girls demonstrated a strong preference for air as a mixture.

Boys' preference for a multi-component option (grades 4-12) was again demonstrated in this question, with the more inclusive option favoured by secondary boys (56.5%).

Discussion

It is evident that most primary and secondary students recognise that air contains oxygen and carbon dioxide and that these gases are associated with breathing. Although the majority of boys in grades 10 to 12 and girls in year 12 recognise the particulate nature and behaviour of air, little credence is given by primary and most secondary students to the concept that air consists of a multi-component mixture of discrete gases.

For the majority of students the mismatch associated with the continuous-particulate nature of air would seem to remain unresolved throughout schooling.

c) Properties and Behaviour of Air

Questions 5, 8, 9, 11, 12, 13, 14, 15, 16, and 19 required students to focus on the properties of air and the way they perceived air to behave.

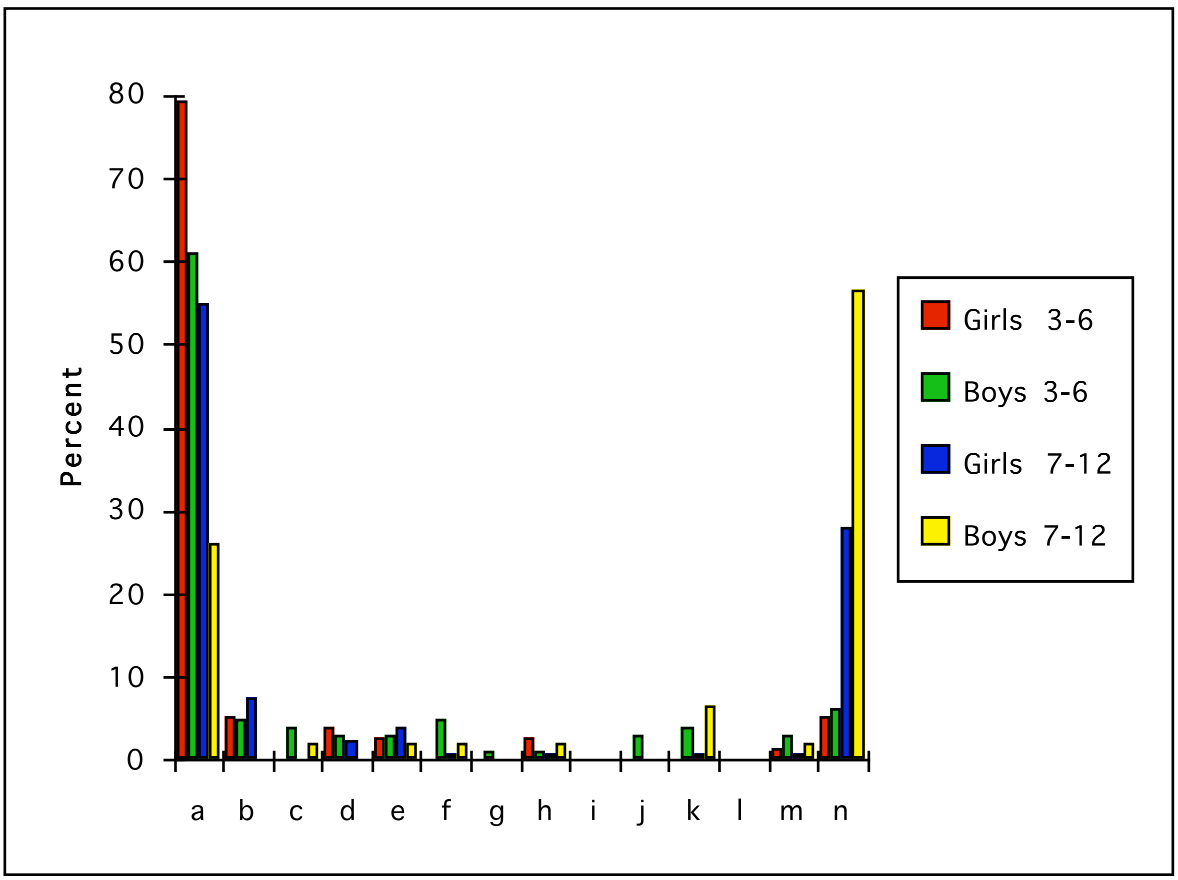

Figure 10. QUESTION 5: How air moves.
Student grade groups by gender.

Whilst most students in grades 3 to 12 considered air to move uniformly, (Question 5, Figure 10) a trend towards an independently moving particulate view was observable in secondary students, and particularly for boys:

uniformly	*separately*
boys grades 3-12 (50.7%)	boys grades 3-12 (43.2%)
girls grades 3-12 (65.0%)	girls grades 3-12 (31.0%)

In question 8, students were asked to consider what they would expect to be inside a lunch box after it was closed (Figure 11).

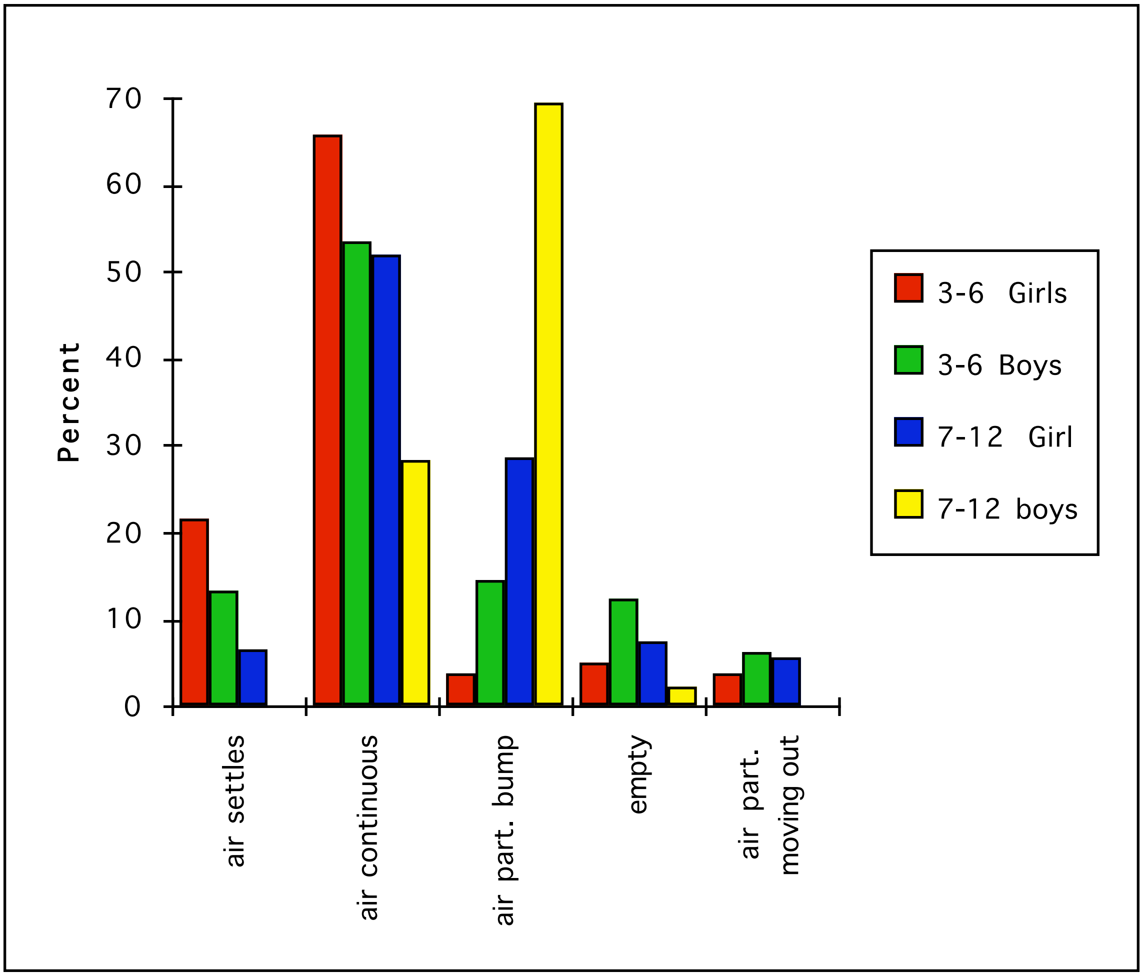

Figure 11. QUESTION 8: When the lunch box is closed. Student grade groups by gender.

Responses to question 8 indicated a non-particulate view of air was held by:

most primary children	(90.3%)
most girls, grades 7-12	(57.4%).

In each case the boys whose response reflected a continuous, non-kinetic view of air, were lower than the average for the group.

In contrast, a kinetic particulate view of air was held by

most boys, grades 8 - 12
most girls, grade 12.

Questions 9 and 11 (9/11) (eg Figure 12) provide students with the opportunity to demonstrate familiarity with kinetic and particulate ideas. Both questions illustrate considerable variance across choices with the most popular option in each case reflecting respondent's demonstration of conservation principles, i.e., with the same number of particles remaining in each bottle before and after treatments.

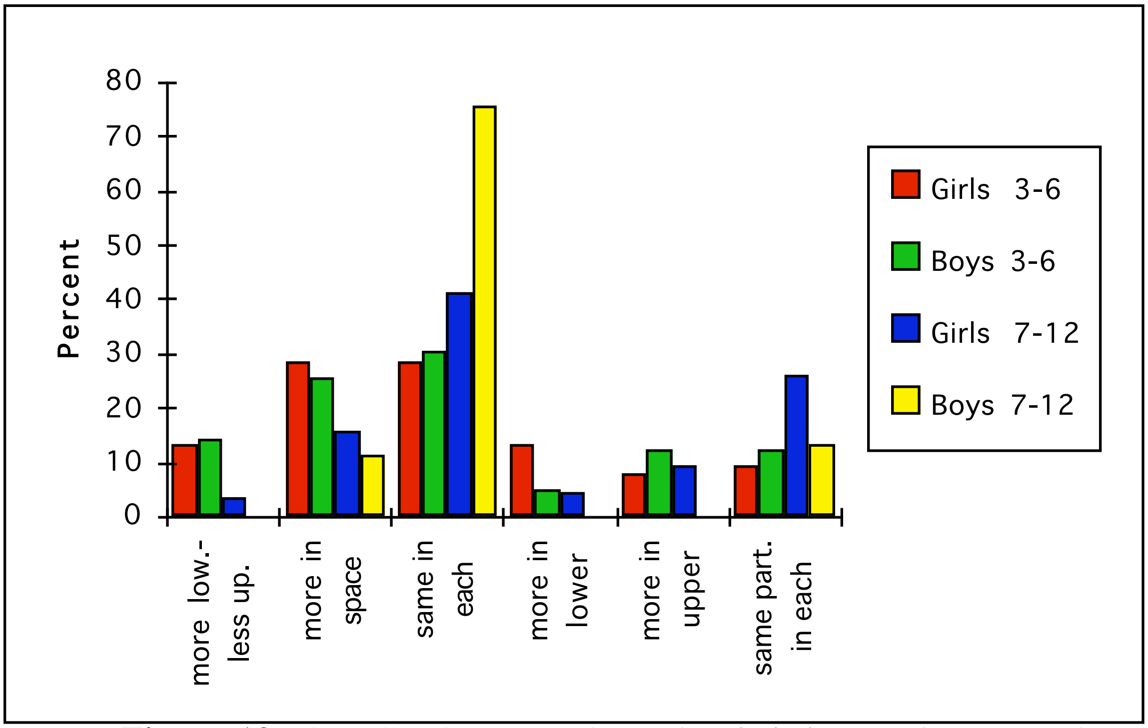

Figure 12. QUESTION 11: When a bottle is inverted over another. Student grade groups by gender.

This conservation principle was recognised by

boys, grades 4-12
girls, grades 7-12

Responses which represented a continuous view of air were strongly favoured by both boys and girls, grades 3-6 (53.0%).

Both secondary boys and girls demonstrated a clear preference for options which combine particulate and kinetic ideas. However, grade 7-12 boys' response is significantly higher (71.7% / 75.6%) than that for the grade 7-12 girls (51.7% / 41.4%) in both questions.

Although girls demonstrated a preference for the particulate-kinetic response, item 'd', for grades 4-12, the view only became dominant for females in grades 7-12.

In question 11, option ‘f’ expressed conservation in terms of numbers of particles. 25.9% of secondary girls and 13.3% of secondary boys favoured this option. However, only girls in grade 12 saw it as the preferred option.

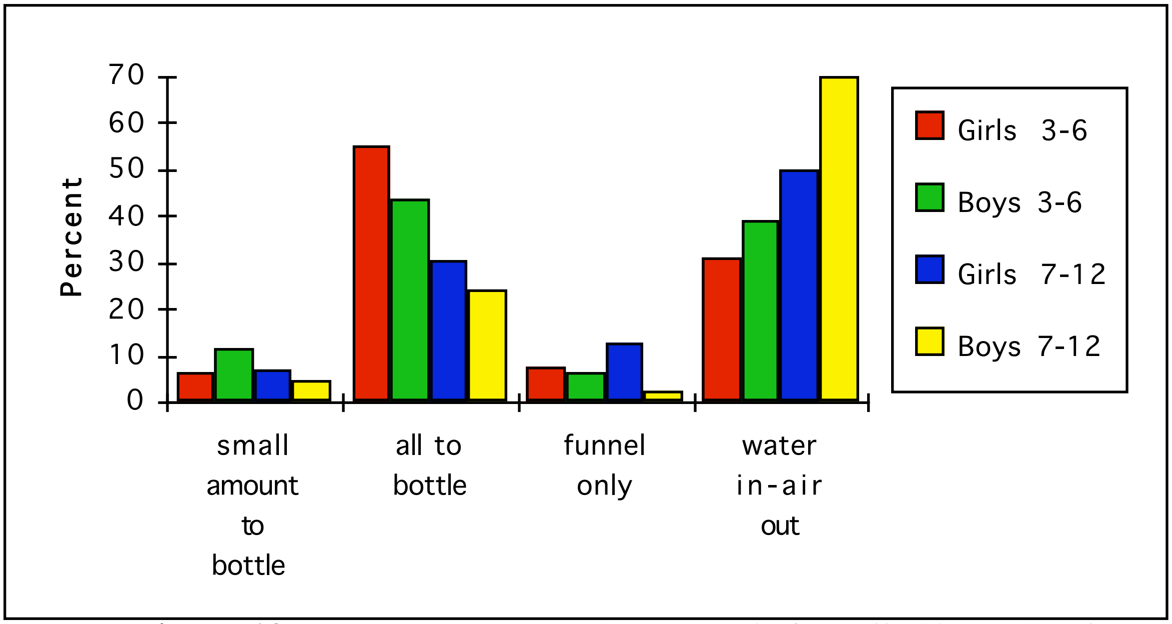

Figure 13. QUESTION 12: When water is funnelled into a bottle. Student grade groups by gender.

Responses to question 12 (Figure 13) were bipolar on options ‘b’ and ‘d’ indicating that almost all students believe the water will be transferred from the jug to the bottle. It was considered that respondents selecting option ‘d’ demonstrated a more detailed understanding of the conservation problem.

Responses were more discriminating when viewed across grade groupings, 3-6 and 7-12, primary grade students displaying preference for the more intuitive option, ‘b’, with secondary students favouring item ‘d’.

It is interesting to note that few respondents (8.3%) recognised item ‘c’, *the water will fill the funnel only* , as a pressure comprehension question because they did not appreciate the implications of the statement: *the funnel makes an airtight seal with the bottle*. Selection of option ‘c’ would require a counter-intuitive response, unless students were operating at the necessary conceptual level or could recall participation in the performance of such an activity.

Question 19 (Figure 14) sought to elucidate respondents' understandings of the effects of atmospheric pressure in a problem mode and has drawn considerable variance across most options.

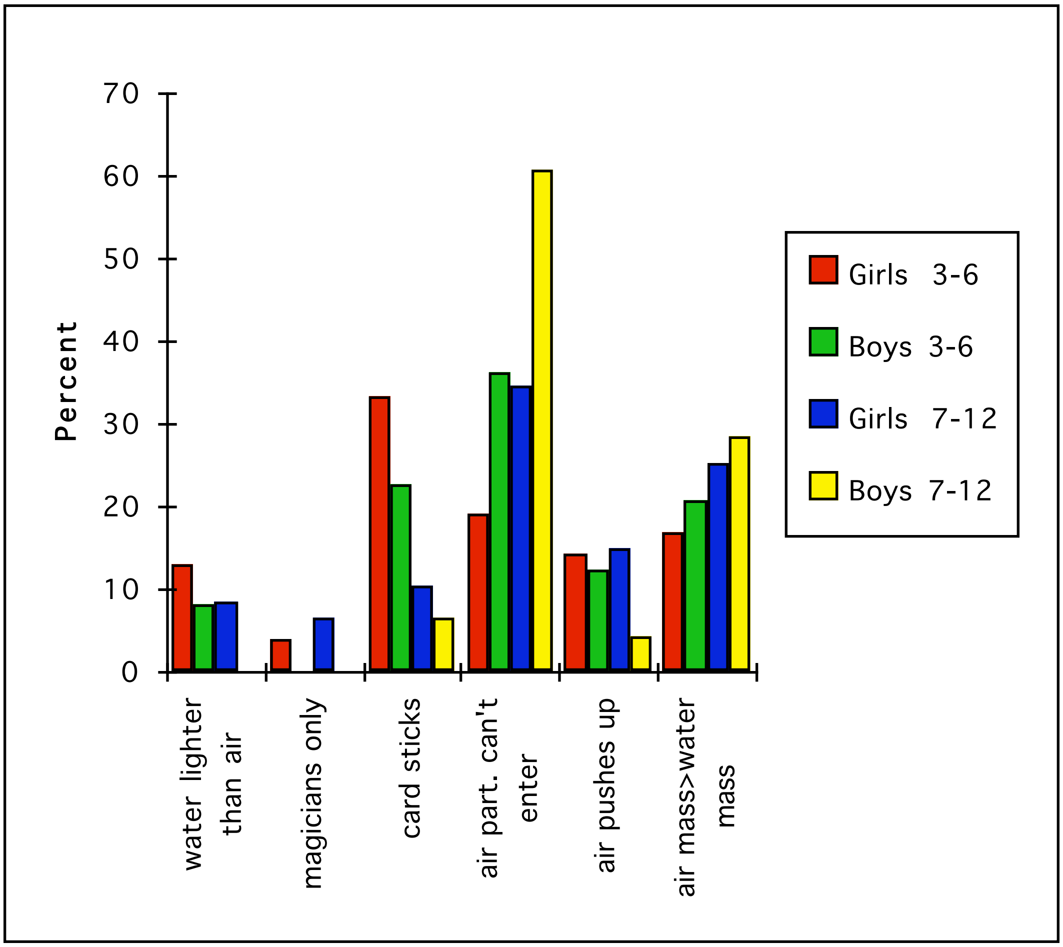

Figure 14. QUESTION 19: Upturned glass of water.
Student grade groups by gender.

The preferred student response, item 'd', (35.1%): *air particles cannot get inside the glass to replace the water,* was selected by almost twice the number of boys compared with girls. The item sought conservation and atmospheric pressure effects and was preferred by

boys, grades 4-12
girls, grades 8-12

The view that *the card sticks to the glass*, item 'c', preferred by 27.4% of primary aged children, is less favoured by the secondary cohort.

The particulate model option, item ‘f’, was also based upon atmospheric pressure effects and drew 22.3% of overall response with more interest evident in grades 10-12 for both boys and girls. This response was still below that of the more intuitive conservation response, item, but below that of option ‘c’.

Questions 13, 14, 15 and 16 were selected to probe the students understandings of the effects of temperature changes on air.

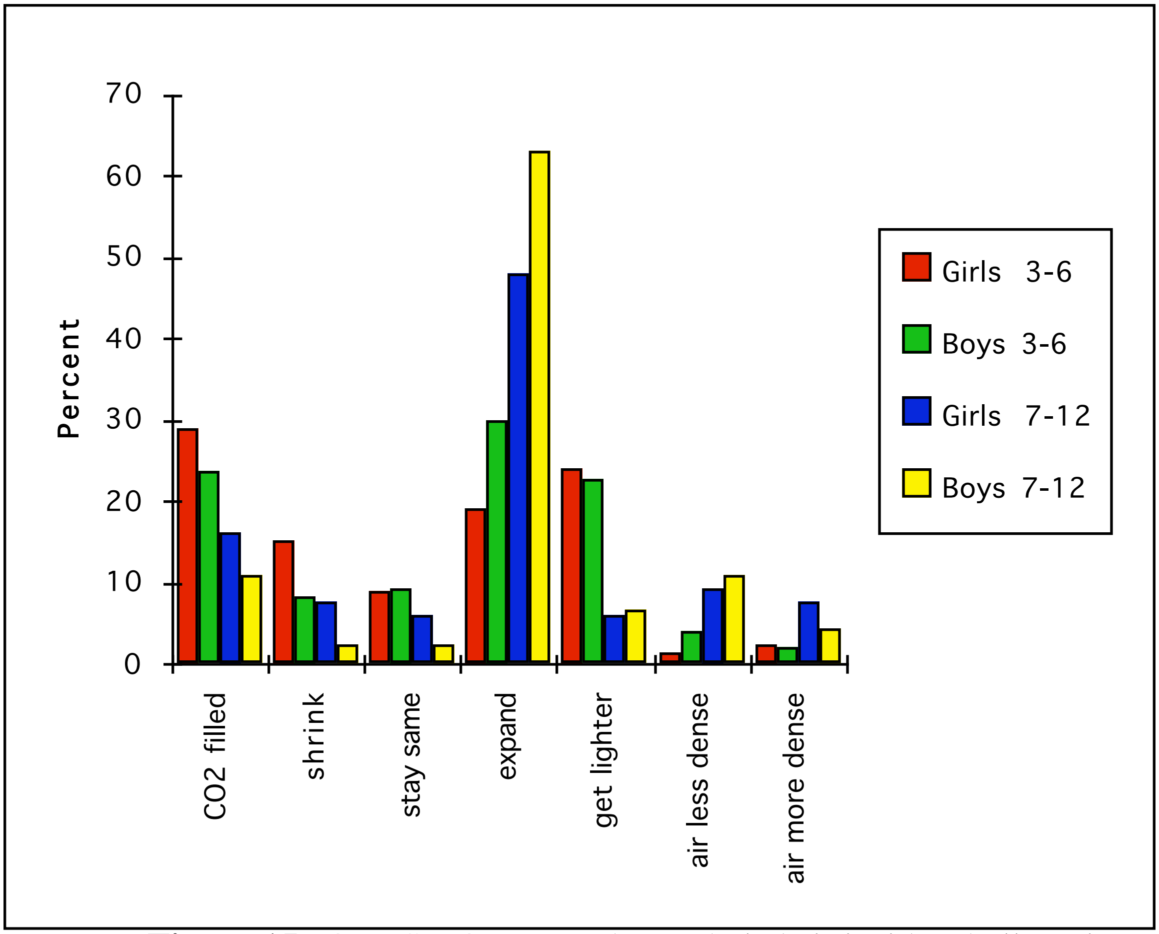

Figure 15. QUESTION 14: When exhaled air inside a balloon is heated.
Student grade groups by gender.

Questions 13 and 14 (eg Figure 15) consider the effect of heat on non-enclosed air and on air restricted within a balloon. Both questions recorded considerable variance across options indicating the wide range of views held by students. However, considerable similarity in students' constructs was evident across both questions:

the balloon containing the air will expand (question 14) (38.1%)
the air will expand and rise (question 13) (33.9%)

The air expansion option (question 14) was strongly preferred by:

both boys (grades 4-12) and girls (grades 6-12)
secondary boys (63.0%)

secondary girls (47.9%)

The concept that air has negative mass has previously been reported by Séré (1985) in his study with 11 and 13 year olds and by Miller, Robinson and Driver (1985) with some 15 year olds who still hold air to be "weightless" or to "make things lighter". The present study (option 'e') confirms this belief to be held by almost 25% of primary school students but was not exhibited by secondary students.

In contrast, responses to question 13 were less definite, although the air expansion and rise option was again supported by:

girls, grades 3-6 with particle expansion preference (question 13)
grades 7-12
boys, grades 3-6.

Secondary boys (grades 7-12) have selected the alternative kinetic particulate option in which the particles were viewed as *pushing apart*. (62.2%). Secondary girls, however, did not exhibit the same strength of conviction (25.2%).

20.5% of variance (question 14, item ‘a’) suggests a heated balloon will be *filled with carbon dioxide gas*. This response was spread over both primary and secondary students being stronger from the primary years (26.1%) and secondary girls (16.0%) more so than from secondary boys (10.9%). This response is in stark contrast to the strongly held view that expired air consists of carbon dioxide (question 18) and highlights the context specific nature of many responses.

It is apparent that primary students and secondary girls are more likely than secondary boys to suggest air / air particles will expand and rise on heating. Primary students may also suggest the heat will make *air lighter* causing it to rise. 15% of students (mainly primary) also believe a balloon would be “lighter” reflecting the popular belief that all inflated balloons will rise into the air on their own accord.

In contrast, a small number of students (8.8%), mainly primary students and secondary girls, believe the inflated balloon would sink.

Question 15 (Figure 16) again demonstrated variability among respondents with each alternative realising more than 10% variance.

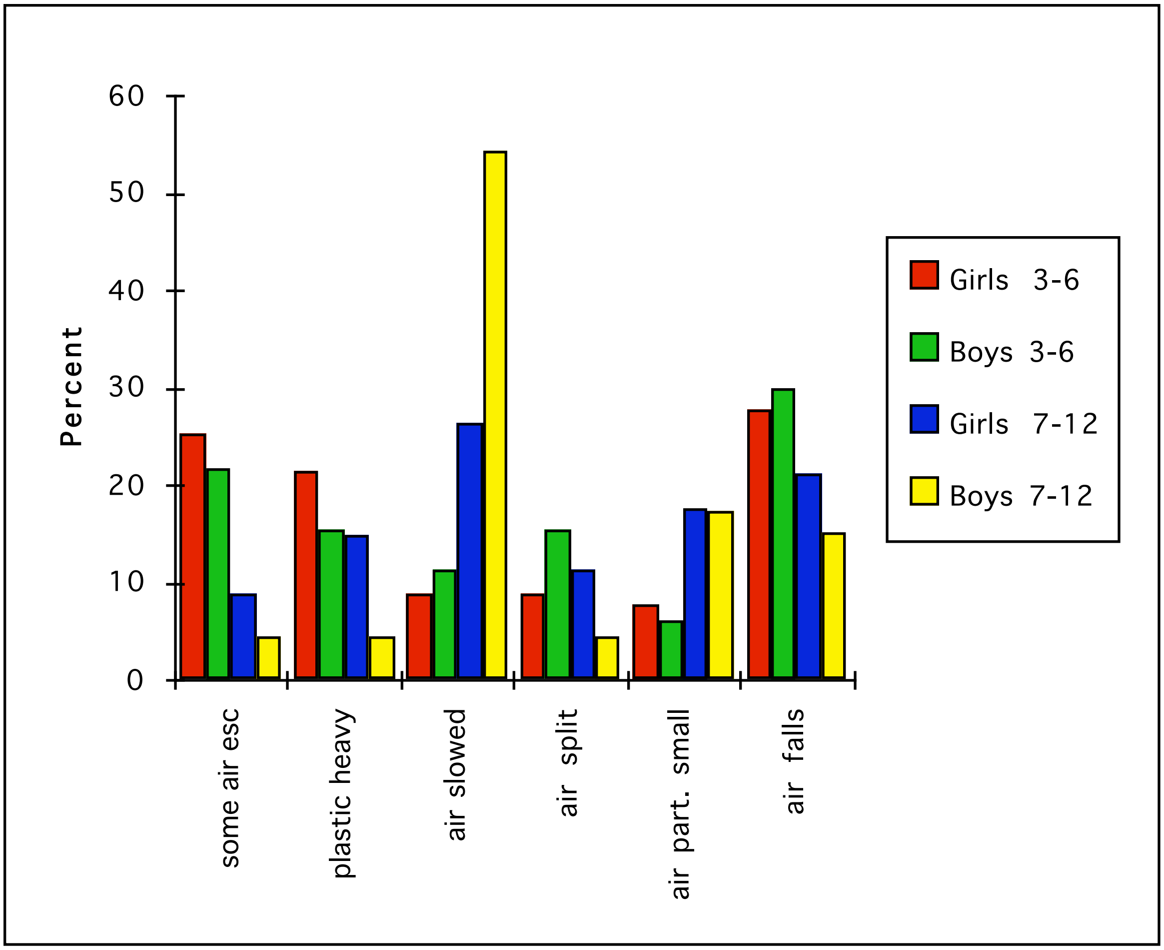

Figure 16. QUESTION 15: When a glass sealed with plastic wrap is cooled.
Student grade groups by gender.

The strongest response was for the non-particulate option, 'f', *when air cools it falls so that the plastic falls as well* (24.4%). This response was particularly favoured by the younger students and girls

girls, grades 3-8
primary boys, grades 3-6

This again demonstrated the consistent, non-particulate response set for these groupings.

The second most favoured response, option ‘c’, *the air particle slowed down,* was preferred by secondary students

secondary boys (54.3%)
secondary girls (26.3%)

and was the predominant response for

boys, grades 7-12
girls, grades 9-12.

The non-particulate option (item ‘a’): *some air escaped* (15.8%) was favoured principally by primary students with item ‘b’: *the plastic became heavy and dropped* showing support across both primary and secondary respondents.

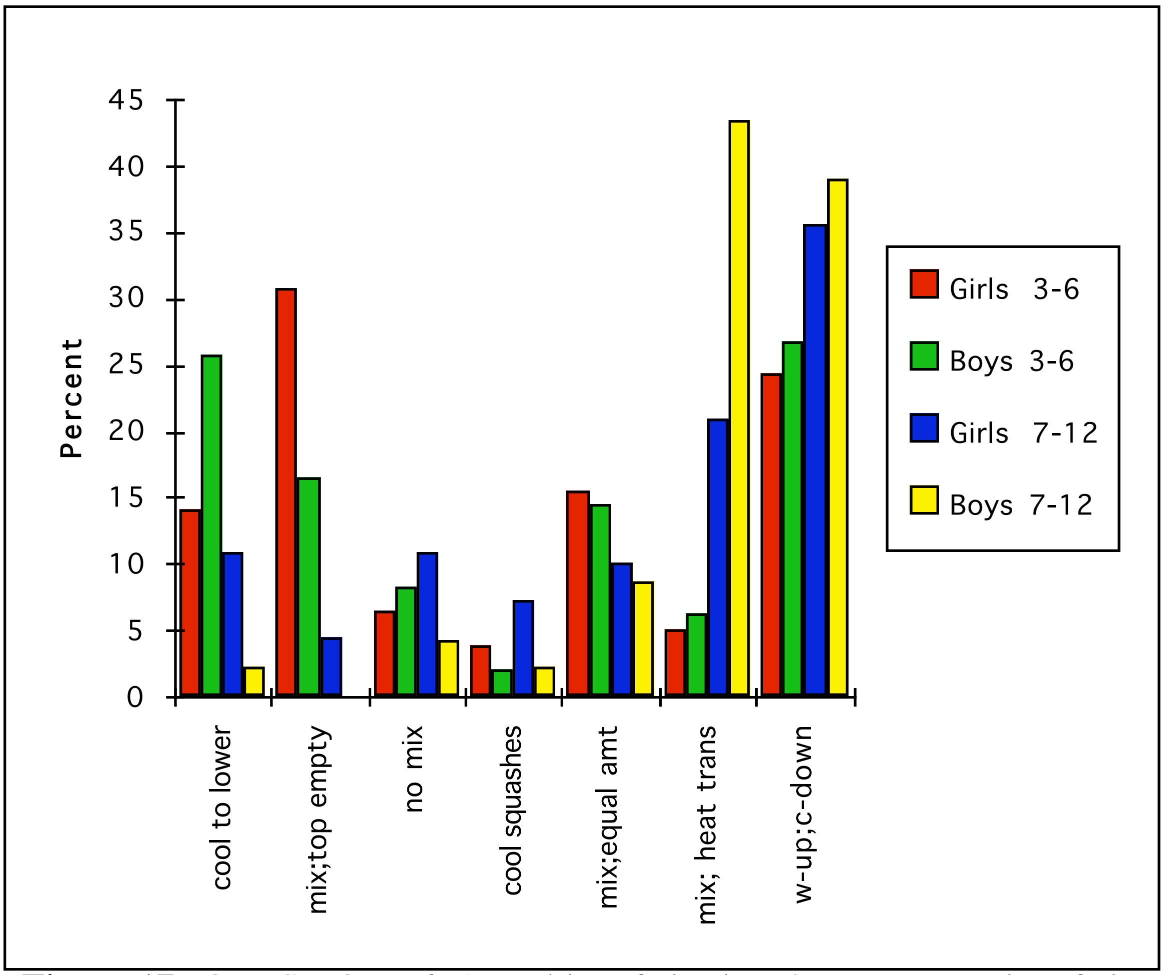

Figure 17. QUESTION 16: A cool jar of air placed over a warm jar of air. Student grade groups by gender.

Responses to question 16 (Figure 17) exhibited strong variance over all options with each item recording more than 10% of variance. The most popular response, item 'g', *The warm air would rise into the upper jar, pushing the cold air down into the lower jar* gained 30.8% response and showed little discrimination over students, primary, secondary or gender based groupings.

Similarly, little discrimination was observed for options ‘c’, ‘d’, or ‘e’ between primary and secondary groupings although:

secondary boys favoured item ‘f’, *the particles of air would mix. Some heat would be transferred from the warm air particles to the cool air particles.*

in item ‘a’ *the cool air would fall into the lower jar* was selected principally by boys who were in primary grades; and

in item ‘b’, *the air from the two jars would mix, leaving some empty space at the top,* showed to be the most popular response for primary girls (30.8%)

An examination of the raw data indicates that the items focusing on particle ideas (‘f’) and kinetic ideas (‘g’) of air were favoured by boys, grades 10-12, whilst item ‘g’ was favoured by girls only in grades 10-12.

Discussion

The concept of conservation is reflected within the range of questions included within this section, and the responses have indicated that most students can demonstrate an intuitive application depending on the context and complexity of the problem. That air is “continuous” yet made up from a mixture of gases is very strongly held by many students throughout schooling. It would appear only to be seriously challenged in the senior years of schooling, particularly amongst the boys. Although kinetic principles are not generally incorporated into responses before year 10, the particulate nature of air is more readily accepted and applied by boys more than by girls.

Furthermore, when presented with an unfamiliar situation requiring the application of a number of ideas (eg question 14) students appear to be able to re-evaluate their personal ideas, readily replacing a strongly held and seemingly contradictory belief in order to develop a meaningful problem response.

VALIDITY OF RESULTS

Although the pilot questionnaire was developed to reflect the language, terminology and constructs of year 8 pupils the pilot questionnaire was found readable, comprehensible and acceptable to the twenty tertiary to infant students and adult non-student respondents to whom it was administered. Reading assistance was available for younger respondents, but in practice none were found to require it. Subsequent discussion with respondents generally reinforced the appropriateness of the language and cognitive demand of the questions and the provision of a sufficient range of responses to allow ownership of one or more of the options offered. Probing reflected the consistency of individual selections with personal understandings The limited number of options provided for any question was raised as an issue only once. These comments, limited to a small number of questions, were made by a second year tertiary science student who may be considered to fall outside the target population.

RELIABILITY OF RESULTS

Reliability of the sample was sought through the selection of similar numbers of students in classes across the state and independent schools; single sex and co-educational schools selected for this study. The 347 students selected to ensure upper, middle and lower performance cohorts with respect to science performance were reliably sampled.

Responses to the refined survey instrument were found to be consistent across questions, across similar grades, and within gender groupings. For example, question 5 which was dependent upon responses from question 4, was found to be consistent to within a fraction of a percent. Questions 9 and 11 which mapped across similar content stimuli demonstrated very similar response sets. Responses of boys and girls were consistent through grades to their gender groupings.

DISCUSSION

Children hold definite views on the structure and behaviour of air from a very early age. These views reflect the children's personal associations with air and are reinforced by its visible and tangible effects as well as societal uses of associated technology and terminology. Some of these views differ from those formally taught in schools and appear to persist even after formal teaching.

Many views are gender and age specific, reflecting societal use of and conditioning for particular technologies. Because the children have found success from the application of their personal constructs, their views are often strongly held even when challenged by alternative scientific viewpoints in the formal setting, remaining unchanged throughout schooling, eg, Osborne and Freyberg, 1985. For example, the popular belief that we inhale oxygen and exhale carbon dioxide was well established by grade 3. This belief concerning inhaled air was only challenged by boys from grade 10 onwards and by girls in grade 12. Beliefs about exhaled air remained in tact regardless of student grade or student gender. Senior students failed to reflect conservation with respect to the proportion of nitrogen in inhaled and exhaled air.

Brook and Driver (1989) have also reported that 8 year olds recognise air to be involved in breathing. Their research further showed that these students recognised a difference between inhaled and exhaled air but that it was not until age 12 that it became a majority view.

The present study shows that although most students from grade 3 onwards recognised oxygen and carbon dioxide to be involved in breathing, the concept that air consists of a mixture of gases was not well established by girls before grade 12. In contrast boys appeared to recognise the concept much earlier, around grade 7. This would appear consistent with Brook and Drivers' findings that only about half their study's 16 year olds recognised air as a mixture of components.

The continuous or non-particulate view of air appears well developed through out primary school. The view is generally challenged through teachings in early secondary curricula. However, girls appear to resist the challenge to their previously developed beliefs more strongly than boys, with the majority of girls referring to the particulate nature of air early in their senior secondary grades, 11 and 12 whilst boys begin to reflect on the model from grades 7 or 8. Brook, Briggs and Driver (1984) have reported less than 20% of 15 year old students correctly apply formally taught ideas about aspects of the particulate theory. In their study, they found that more than 50% of their 15 year old students used particle ideas but of these only about:

20% were partially correct
30% used alternate particulate ideas, whilst
25% referred to low level, macroscopic ideas with no mention of particles.

Similarly, Novick and Nussbaum (1978) found in their study of 13 and 14 year old (grade 8) Israeli students, that more than half the subjects avoided the use of *particles* to explain their concept of matter.

Students' views on the movement of air principally reflected the continuous or macroscopic view rather than the preferred scientific particulate construct. Students holding the continuous model saw air as undergoing bulk or no movement. These students were principally those in primary schools and secondary girls. Secondary boys, preferring the particulate model of air, emphasised the kinetic movement of air particles as well.

The application of heat transfer was similarly considered by primary students and secondary girls in terms of bulk or continuous ideas of air. It was again only boys from grades 11 and 12 who applied kinetic and particulate ideas to heat transfer. These findings are generally consistent with the findings of Brook, Briggs and Driver (1984) who found about one third of 15 year olds responded at the macroscopic level demonstrating the student's reluctance to accept particulate models.

The concept of air exerting pressure was poorly recognised by students in all grades in this study.

Gender stereotypical uses of air appeared across all age and student gender cohorts reflecting a strong dependence on sociological and cultural norms. Evidence from the research literature, eg. Osborne and Freyberg, 1985, clearly indicates conflict between scientific use and phenomenological use of language. Social conditioning through the common usage of specific scientific terminology, eg. "breathe in oxygen" / "air becomes lighter", appears highly developed in the early years. These students are also more likely to retain the continuous view of air and subsequent bulk air mass, and corresponding heat transfer and pressure concepts. In contrast all students, and particularly boys, are more likely to exhibit particulate and associated kinetic ideas.

The findings in this study are consistent with those of Brook, and Driver (1989) who found that "*girls who study physics and chemistry are less likely to use particulate ideas correctly than boys in the same group*" . A corresponding difference was not found between the 'less able students". Brook and Driver further reported a *"greater percentage of high ability girls who have not had relevant teaching include alternate particle ideas than do boys of similar ability and experience"*.

IMPLICATIONS FOR TEACHING

This study has provided insight into some of the ideas students hold about the structure and behaviour of matter. Whilst it is apparent that most questions have been very effective in determining students' personal perspectives, the responses highlight the mismatch between curriculum intent and actual outcomes as expressed through the students' views. The persistence of counter intuitive responses suggests that formally useful concepts such as pressure may not have been considered personally useful at all (eg. question 12).

Questions raised by such anomalies focus on issues relating to the improvement of learning and include how students can be assisted to reach better understandings and how conceptual change may be effected in a personally committed way.

The methodology of this study has shown how personal constructs may be identified through reflection of students' responses from interviews and formal questionnaires. The information gained can then be used as a basis for evaluating any mismatch between curriculum intent and student's personal views. Should a mismatch exist, student views then become the starting points for the learning process.

The generalised learning cycles or models outlined by Osborne and Freyberg (1985), Driver and Oldham (1986), Needham and Hill (1987) or Bell (1991) together with the principles underpinning personal construction (White, 1991), provide useful frameworks which can be adopted for the formulation of teaching strategies to promote effective learning and conceptual change.

Each of these learning models has features in common:

a preliminary stage which questions children's existing conceptual understandings;

an initial stage which raises questions about observable phenomena; questions raised by the learner which they cannot resolve using their existing constructs;

a focus stage during which the learner engages in a wide range of personal experiences, challenging and clarifying existing ideas thereby laying the ground-work for the reshaping and restructuring of the learner's central constructs;

a problem solving stage during which developing constructs are applied in new contexts;

a reflection stage.

Attempts to engage students in meaningful learning require classroom practice to be based on reflection and action rather than the transmission of teacher or textbook ideas. Such reflection has the potential to generate two positive outcomes. These are:

conceptual development, as students' ideas change, and

professional development , as teachers refine and evaluate their own philosophy to learning and teaching;

The challenge facing teachers is to ensure that the starting point for instruction is a consideration of student current ideas and not the prescriptions of the scientific paradigms, curriculum constraints or stereotypical gender or cultural biases.

CONCLUDING REMARKS

In attempting to facilitate students' acquisition of scientifically useful constructs, a number of significant issues for teaching may emerge. These include:

can teachers not afford to take into account student's prior social and cultural ideas and beliefs and their academic and personal learnings?

how can teachers facilitate student's responsibility for their own learning?

to what extent does conflict become a productive process for learning rather than an undesirable outcome?

Many teachers believe time constraints reduce much teaching to a process of mere dissemination of information. However, the continuum which is bounded by student ideas and the scientific paradigm can only be made less extreme if all involved in the learning process are made aware of the student's pre-existing views. A lack of awareness of these views represents a major obstacle to the achievement of conceptual change.

The age dependency associated with the acquisition of concepts, as revealed in this study, suggests that formally useful concepts - such as the kinetic model of matter frequently introduced in grade 7 curricula, may not necessarily be a personally useful concept for many students. Delaying the introduction of the formal curriculum may not be seen as an option, but dovetailing it to student's needs should be seen as the preferred option. There would appear to be a risk of taking for granted some of the key concepts which students need in coming to an understanding of the physical world around them. Because these concepts are acquired at different rates and from different starting points, it is essential to monitor any variation during teaching and to modify strategies for different ages.

The importance of the role teachers play in helping students to resolve the dilemma of the mismatch between students' ideas and scientists' views cannot be understated. The image of a 'guiding adversary' may be an appropriate description for teachers who confront student's existing beliefs with counter-intuitive examples in order to stimulate conceptual change. The persistence of highly personalised selection criteria concerning ideas and events can be considerable, particularly when social, gender and other cultural factors play an important role.

The effectiveness of this study in highlighting the mismatch, not only between students' ideas and the scientific paradigm, but also between gender and conceptual change, suggests that conflict is as much a learning outcome as it is a strategy.

FUTURE RESEARCH DIRECTIONS

The present study has focused on pupil response through grades to stimuli generated from within the student's personal constructs. The role of significant environmental interactions including student and teacher gender and cultural influences require investigation. Metacognitive studies into the student's perceptions of "scientists' " science and its associated rules of operation and of teachers' perceptions of both "scientists' " science and of "children's science" should provide further insight into the processes of conceptual development in science. To this end, the influence of inservice education on student learning outcomes requires detailed evaluation.

The use of science genre in communication requires longitudinal studies to establish its influence and impact on teaching strategies.

The feasibility of teaching being a reflective practice which considers current research findings, levels of classroom action research, quality of inservice training and the relationship of each to exemplary teaching practice requires extensive exploration.

In the context of National profiling in science with its emphasis on exemplars of students' achievement levels, studies are required to demonstrate that the prescribed curriculum parameters realistically match the conceptual development of students.

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APPENDIX 1

THE AIR SURVEY

Thank you for agreeing to complete the Air Survey. There are no wright or wrong answers. We are only interested in what you think. Please select the response which you believe is the best answer or reason by writing its letter in the box to the right of the question. Select only one answer for each question.

In this survey, you may include your name if you wish. This would allow us to discuss some of the answers with you. Your anonymity, however, is assured.

1. The word which I most associate with air is:

a. fire
b. clouds
c. wind
d. pushing
e. breathing
f. sailing
g. violin
h. weather map

[ ]

2. I would describe air as:

a. empty space
b. vacuum
c. gas
d. nothing
e. oxygen and carbon dioxide
f. oxygen, nitrogen and carbon dioxide
g. matter
h. particles

[ ]

3. For me the most familiar use of air is:

a. bike pump
b. fan
c. electric bar heater
d. soccer ball

e. magnetism
f. television
g. hair drier
h. aeroplane
i. other (please specify) ....

4. I think air is:

a. continuous and everywhere.
if so, go to Question 5a

b. made up of particles without spaces between them.
if so, go to Question 5b

c. made up of particles of the same size without spaces between them.
if so, go to Question 5c

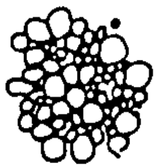
d. made up of particles of the same size with spaces between them.
if so, go to Question 5d

e. made up of particles of different sizes with spaces between them.
if so, go to Question 5e

5a. If air could move then I think air would have to be:

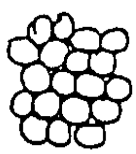
a. continuous with all the air moving
uniformly and together.
b. continuous and does not move.

5b. If air could move then I think air would have to be:



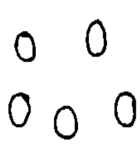
c. made of particles without spaces and does not move
d. made up of particles without spaces. The
air moves uniformly and together.
e. made up of particles without spaces. The air moves separately.

5c. If air could move then I think air would, have to be:



f. made up of particles of the same size
without spaces. The air moves uniformly
and together.
g. made up of particles of the same size
without spaces. The air does not move.
h. made up of particles of the same size
without spaces. The ail moves separately.
i. made up of particles of the same size
without spaces between them. The air particles
do not move.

5d. If air could move then I think air would have to be:

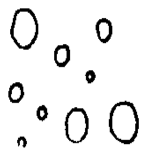


j. made up of particles of the same
size with spaces between them. The air
particles move uniformly and together.
k. made up of parucles of the same size

with spaces between them. The air particles
move separately.

l. made up of particles of different size
with spaces between them. The air particles do
not move.

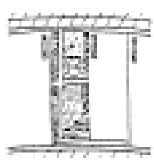
5e. If air could move then I think air would have to be:



m. made up of particles of different size
with spaces between them. The air particles
do not move.

n. made up of particles of different size with
spaces between them. The air particles move separately.

6. Inside the cupboard, as shown in the diagram below, I would expect to find:



a. Cups, saucers, plates and particles of gases in
constant motion.

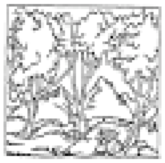
b. Cups, saucers, plates and continuous air
everywhere in motion.

c. Cups, saucers, plates only.

d. Cups, saucers, plates and particles of of oxygen,
nitrogen and carbon dioxide only, all in
constant motion.

e. other (please specify)....

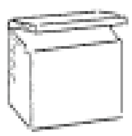
7. The following diagram represents some bush, with trees, shrubs, grass and soil.



Between the very small dirt particles in the soil, I expect to find:

a. Some air and water particles.
b. Dirt particles.
c. Some air particles.
d. Nothing between the dirt particles.
e. Roots only.
f. Some water particles.

8. The lid of a lunch box is about to be closed to make an airtight seal as shown in the diagram below:



After the lunch box is closed, I would expect:

a. The air inside the lunch box would be settling to the bottom.
b. There would be air continuous and everywhere inside the lunch box.
c. There would be air particles moving and bumping into each other.
d. The lunch box would be empty with nothing inside it.
e. There would be separate air particles moving out of the lunch box.

9. This question refers to two identical bottles, each with a lid. Both bottles are known to contain air.

Each lid is removed and a funnel placed in the lower bottle. The top bottle upturned above the funnel as shown in the diagram below:

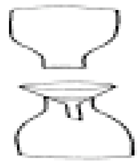
I think the explanation of what will happen is:

a. All the air from the top bottle will escape to the space surrounding the bottles.
b. Some of the air from the top bottle will enter the lower bottle the rest will escape into the surrounding space.
c. All the air from the top bottle will pour into the empty bottle filling it.
d. There may be some particles of air moving between both bottles, but most of the air particles will stay in their own bottle.
e. Some air will go into the funnel but not enter the empty bottle. The rest of the air will escape.
f. The lower bottle will fill with air from the surroundings.

10. I think an empty coke bottle, open to the air will contain:

a. nothing
b. air
c. particles of "coke gas"
d. particles of oxygen, carbon dioxide, "coke gas"
e. particles of nitrogen, oxygen, carbon dioxide, water vapour and other gases

11. Two identical bottles, known to contain equal amounts of air, are arranged as shown in he diagram below. The upper bottle is held above the lower bottle. which contains a funnel.



After five (5) minutes I think there will be:

a. more air in the lower bottle and less air in the upper bottle.
b. more air in the space around the bottles than there was before.
c. the same amount of air in each bottle as they started with.
d. more air in the lower bottle.
e. more air in the upper bottle.
f. the same number of particles in each bottle as they started with.

12. A jug of water is to be poured into a bottle fitted with a narrow funnel. The funnel makes an airtight seal with the bottle:

I think:

a. Only a small amount of water will pass into the bottle as the bottle is already full of air.
b. All the water will pour into the bottle.
c. The water will fill the funnel only.
d. All the water can be transferred pushing an equal amount of air out of the bottle.

13. When air is heated, I think:

a. The heat has no effect on the air particles.
b The air particles expand and rise.
c The heat makes the air lighter and it rises.
d. The air expands and rises.
e. The heat moves through the spaces between the particles.

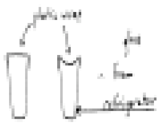
f. Air particles move faster, pushing each other apart.
g. The heat pushes air particles out of the way.

14. You have just blown up a balloon using air from your lungs.

If the air inside the balloon is heated, the balloon will:

a. be filled with carbon dioxide gas.
b. shink.
c . stay the same size
d. expand.
e. become lighter.
f . contain air less dense than its surroundings.
g. contain air more dense than its surroundings.

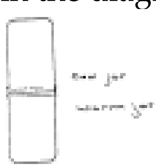
15. Two empty glasses were sealed with plastic wrap. One was placed in the refngerator and the other left on the bench. After (15) fifteen minutes the glass from the refrigerator was removed and placed beside the other glass on the bench.



I think the reason for the shape of the plastic wrap on the glass which was removed from the refrigerator is:

a. Some of the air escaped through the plastic wrap.
b. The plastic became heavy and dropped.
c. The air particles slowed down.
d. The air was split up by being in the refrigerator and there was no longer as much air inside the glass.
e. The particles of air became smaller.
f. When air cools it falls so that the plastic falls as well.

16. This question refers to two identically sealed jars. One is from a cool cupboard and the other has been sitting on a warm sunny window sill. The lid of each jar is removcd and the jars placed together as shown in the diagram below:



a. The cool air would fall into the lower jar.
b. The air from the two jars would mix. leaving some empty space at the top.
c. The air from each jar would not mix and the air would stay in their original jars.
d. The cool air would squash the air below it. There would be very little mixing of the air.
e. Mixing of the air would take place and there would be the same amount of air in each jar as there was to begin with.
f. The particles of air would mix. Some heat would be transferred from the warm air

particles to the cool air particles.
g. The warm air would rise into the upper jar, pushing the cold air down into the lower jar.

17. As I am breathing air in now, the main component of the air is:

a. water vapour
b. carbon dioxide
c. just air
d. pollution
e. nitrogen
f. oxygen

18. As I am breathing air out now, the main component of the air is:

a. water vapour
b. carbon dioxide
c. just air
d. pollution
e. nitrogen
f. oxygen

19. A full glass of water, covered with a piece of
cardboard, can be turned upside down without the water spilling from the glass..

I think this happens because:

a. The water is lighter than air.
b. Only magicians can do it.
c. The cardboard sticks to the glass.
d. Air particles cannot get inside the glass to replace the water.
e. The air pushes up on the cardboard
f. The mass of air particles pushing upwards on the cardboard is greater than the mass of water pushing downwards on the same area.