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Overtures and Obstacles: Teaching and Learning about Air Pressure in a High School Classroom.

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Abstract.

This paper presents an analysis of teaching and learning science concepts in a high school setting and draws upon theoretical frameworks relating to both personal and social construction of knowledge. The analysis is based upon case study data which document the planning and teaching of a short unit of work on air pressure as well as the progress made by students (aged 11-12 years) in response to that instruction. The ways in which the teacher attempts, in class, to promote 'shared understandings' with students are considered through an analysis of discourse between teacher and students and between students; the ways in which individual students' understandings progress are monitored and are related to the developing 'shared understandings' of the classroom and to an analysis of 'learning demands' for this conceptual area. This study is part of an ongoing programme of work into teaching and learning science concepts which is being carried out by members of the Children's Learning in Science (CLIS) Research Group in collaboration with local teachers.

INTRODUCTION

It is widely recognised that children have informal ideas about natural phenomena prior to being taught science in school. These ideas form the 'personal theories' through which children interpret the physical and social world around them (Piaget,1929; Kelly,1955) and include notions such as 'matter disappears when it burns', 'constant motion implies a constant force' and 'electricity gets used up as it passes round a circuit' (see Driver, Guesne & Tiberghien 1985). A number of extensive bibliographies document the research which has been carried out in this area (Carmichael et al 1990; Pfundt and Duit 1991) and studies show that children's prior ideas can fundamentally influence science learning outcomes in that they may not easily be displaced, changed or modified by teaching (e.g. Brumby, 1982; McDermott, 1991).

These findings are consistent with evidence in such diverse fields as cognitive science, social psychology and anthropology, which are currently portraying learning as a constructive process. In a recent review Resnick (1989) presents the position thus: 'First, learning is a process of knowledge construction not of knowledge recording or absorption. Second, learning is knowledge dependent: people use current knowledge to construct new knowledge'.

Recognition of the influence of personal conceptions on learning and of learning as a constructive activity has contributed to a re-appraisal of what is involved in teaching and learning science (Osborne and Freyberg,1985; Glynn, Yeaney and Britton,1991). Moreover science itself has increasingly come to be recognised as a distinct and important way of knowing about the world, which involves systematic negotiation and validation within the scientific community (Driver 1992). Learning science, therefore, involves moving beyond the informal theories of everyday knowledge into use of the concepts, values and organising principles of the science community.

This view is compatible with ideas recently emerging from a reconsideration of the work of Vygotsky (1978), which characterise learning as the appropriation of the values and knowledge structures of a particular culture and which stress the role of language and social interaction in that process. Teaching is seen as involving the provision of temporary 'scaffolding', that is, assistance which is effective because it builds on the learner's existing resources (Bruner,1986; Tharp & Gallimore, 1988).

This paper focusses upon the ways in which students develop understandings of particular science concepts in a classroom context and describes how shared meanings or 'common knowledge' (Edwards and Mercer 1987) develop through the social interactions and discourse of the classroom. At the same time, it is recognised that learning science concepts must involve personal sense making by the individual and so the development of personal understandings provides a complementary and necessary further focus for analysis. To this extent the paper offers a socio-psychological perspective on learning science concepts in a classroom setting.

The data presented here are taken from a case study on teaching and learning about air pressure which was prepared as part of a developing programme of work of the Children's Learning in Science (CLIS) Research Group. The data are used to illustrate the ways in which a teacher works, through negotiation and appeals to evidence, to establish shared meanings in his classroom thereby to encourage individual knowledge construction. The understandings that individual students construct as the lessons proceed are examined and the ways in which students' existing conceptions can create 'obstacles' to such knowledge construction are demonstrated.

The intention here is not to offer a detailed case study for a whole teaching sequence. Instead, an overview of the lessons and the rationale behind their planning are presented, then a number of teaching and learning 'episodes' from that sequence are considered in some detail.

BACKGROUND TO THE TEACHING

The teaching was carried out in a comprehensive school in the North of England and involved four lessons each of 75 minutes duration. The aim of the lessons was to teach a class of 11/12 year old students to apply pressure difference explanations to a range of phenomena. The class had a nominal roll of 27 students although this number was never present for any of the lessons observed; it had a generally poor reputation in the school, both in relation to behaviour and to overall academic achievement. Although a mixed ability group, attainment levels were considered by school standards to be skewed towards the lower end.

The teacher of the case study lessons, Richard, had senior responsibility in the school science department and had recently been promoted to the post of Senior Teacher within the school as a whole. Richard has been a teacher member of the CLIS Research Group for over seven years during which time he has been actively involved in a number of research projects.

The topic 'Air pressure' was selected for this study for two reasons. Firstly, and pragmatically, air pressure was already part of the study school's science curriculum for 11/12 year-old students. In addition we wanted to set the teaching in a conceptually demanding context; research findings (Brook and Driver 1989) and teaching experience both indicated that air pressure would provide such a context.

PLANNING THE TEACHING

The instructional sequence for the lessons was planned collaboratively by the two principal researchers and Richard with the aim of setting the teaching in a well-defined pedagogic framework within which the teacher's practice and students' actions and meaning making could be observed.

Initial planning focussed upon three factors: the nature of the students' existing ideas about air pressure phenomena; the nature of the science learning goals set for the topic on air pressure; the nature of the intellectual demands involved, for students, in developing the science view from existing understandings (Scott, Asoko and Driver 1991).

The overall aim of the teaching was that students learn to apply pressure difference explanations to a range of simple phenomena such as a plunger sticking to a surface or a child drinking through a straw. To achieve this aim it was considered that students would need to understand that:

a) air exerts a pressure in all directions, all of the time.

b) forces act when pressure equilibria are disturbed. Resultant forces act from areas of HIGH to LOW pressure.

c) the amount of air in a space sets the pressure:

- more air squashed into a fixed space exerts more pressure; less air in the same space exerts less pressure.
- the same amount of air squashed into a smaller space gives more pressure; the same amount of air in a larger space gives a smaller pressure.

The findings of existing research (Brook and Driver 1989) indicated that many students in the target class would have problems in conceptualising air as a substantive medium which exerts a continuous and steady pressure. Furthermore, student explanations of phenomena such as drinking through a straw would almost certainly be based on the action of an internal sucking force rather than on the action of the external atmosphere. In such cases the internal sucking force might be attributed to the action of the person drinking or to the action of air, or a vacuum, in the straw. In comparing the learning goals and likely student starting points, we therefore inferred that the learning demands on students, in constructing the pressure difference explanation, would include both conceptual and ontological elements: conceptual in the sense that students would need to construct a new conceptual framework to explain the phenomena; ontological in terms of the learner needing to re-formulate basic assumptions about the nature of air and some of its physical properties (for example that static air exerts a pressure).

Given that pressure difference explanations (air pushing from outside) were likely to be contrary to students' existing explanations (sucking from inside) and that those student explanations were likely to be closely supported by everyday use of language and thereby be particularly resistant to change, we decided that learning in this area might usefully be conceptualised in terms of *developing an alternative viewpoint* rather than as *changing existing conceptions*. In planning an instructional sequence, we therefore decided that students' existing explanations would not offer a useful starting point to teaching; in crude terms, it was difficult to imagine what pedagogical moves might be employed to help students transform an explanation based on 'forces-from-within' to one set in terms of 'forces-from-outside'. There are resonances here with Garrison and Bentley's (1990) characterisation of learning science as 'breaking with everyday experience' rather than building upon it.

Bearing in mind these issues, the following instructional sequence, consisting of three principal phases, was developed:

1. Construction of the science ('new way') explanation of phenomena in terms of air pressure differences.
2. Application of the science explanation to a range of phenomena.
3. Explicit comparison of the 'new way' of explaining with the 'old way'

Firstly students' explanations for two air pressure related phenomena were elicited and these responses, which were explicitly referred to as the 'old way of looking', were put to one side. The teacher then introduced the science explanation, the 'new way of looking', through demonstrations and other activities. Students were then helped to transfer this explanation to a range of phenomena. Finally, the students were involved in an exercise which encouraged them to compare old and new ways of explaining. As stated above the aim of the teaching was not necessarily that students should see the new explanation as being superior to the old and therefore be inclined to replace old with new (an approach proposed by Rowell, Dawson and Lyndon (1990) in a similar instructional sequence). Rather the intended outcome was for students to appreciate the 'fitness for purpose' of each type of explanation; that old ways of explaining continue to be very effective in establishing shared understandings in everyday situations whereas the science perspective is more useful in other science oriented contexts (Solomon 1987). An overview of the instructional sequence is provided in Appendix 1.

The instructional sequence, as outlined above, prompted consideration of three specific questions which are addressed in this paper. These are:

- how was the 'new way of explaining' introduced and established in the classroom?
- to what extent were individual students able to construct and apply this 'new way of explaining'?
- what were the intellectual and other obstacles existing for students as they attempted to construct and apply the new way of explaining?

These questions are addressed through consideration of two principal forms of data:

a. The ongoing discourse of the classroom and particularly the exchanges between teacher and students.

- what did the teacher say and do to introduce the new way of explaining to his students?

- how did students contribute, through discourse, to the development of shared understandings?

b. Insights into the knowledge construction of individual students as the teaching proceeded.

- these insights were gained from researcher interviews with students, interactions between the teacher and individual students and from students' written responses to classroom tasks.

During the lessons the researcher followed the progress of a group of four boys and from that group one boy, Jamie, featured prominently in whole class discourse. In this article, therefore, the development of Jamie's thinking is documented in some detail and this is complemented with data relating to other students.

OLD WAYS OF LOOKING: STUDENT RESPONSES TO THE PRE-TEACHING DIAGNOSTIC QUESTIONS

Two questions 'Apple juice carton' and 'Spring back' were administered three weeks prior to the teaching on air pressure. Students completed their written responses individually and then placed their sheets in a sealed envelope which was collected in by the teacher. The teacher told the students that they would be returning to this topic after half term and in the meantime he would look after their responses.

Details of the two questions are provided in Appendix 2.

22 students completed responses to the two questions and these were coded as follows:

Apple juice carton: Why do the sides move in?

Code	Response	Number (n=22)
A	when air is sucked out, carton goes in.	18
B	suck air out, air brings carton in with it.	2
C	sides are sucked in to fill the empty space..	1
D	trying to get more air from outside	1

Table 1. Responses to 'Apple juce carton' prior to teaching.

Code A was the the most common response, examples are as follows:

'*because you are sucking out the juice and you are taking the air out with it. So when the air comes out the carton goes in.'* (Tarben)

'It is because you are sucking the air out so the sides cave in.' (Nicholas)

'when you are drinking the apple juice you are sucking all the are out so the volume goes in and in untill you stop to take breath and all the air in..' (Nathalie)

Jamie's response was as follows:

Because you are sucking all the air out and the inside of the carton is trying to get more air from it's outside but it can't because of the sides of the carton. So instead of sucking air in it sucks the sides of the carton. (code D)

Spring back: Why does the plunger go back?

Code	Response	Number (n=20)
A	the plunger is pulled back in.	11
B	nothing to hold the plunger in place	4
C	plunger returns to fill empty space	3
D	syringe tries to pull in more air	1
E	the plunger is pushed back in	1

Table 2: Responses to 'Spring back' prior to teaching.

Code A was the most common response; a variety of mechanisms were suggested to account for the pull on the plunger:

. The air inside the syringe pulls, '*it plungers back because the air in the syringe is trapped and if it was not blocked the air would run straight through. But it is blocked so the air pulls it back.*' (Tarben)

Elastic air, '*it is like a peace of elastic. When you strech it, it springs back but in the case the air is the elastic and the plunger springs back*.' (Nicholas)

Gravity, '*the syringe goes back because of gravity pulling back in because it is stuck inside*.' (Samantha)

Jamie's response was as follows:

Because when you pull the plunger out there isn't enough air to fill that space that's been made by pulling the plunger out, So it trys to pull in more air but it can't so it pulls in the plunger. (code D)

In the responses to both questions from the full sample there was one example of an explanation framed in terms of 'forces from outside'.

JAMIE AND 'SPRING BACK'

Immediately prior to the first lesson on air pressure, the researcher talked to Jamie about the question 'Spring Back'. Jamie's verbal response was identical to what he had written three weeks earlier:

Jamie (verbal response): *Well, it was like ,er, same as the carton...You're making the space bigger and it's only got a small amount of air. So it's trying to get more air in and it can't cos that's there. So instead of bringing more air from there, it's bringing that* (the plunger) *in.*

The researcher probed further:

Researcher: *You know when you say,'it, pulls in the plunger', what is it that is doing the pulling?*

Jamie: *I don't know*.....(5 seconds)

Researcher: *cos normally if something's doing the pulling...*

Jamie: *Mmm*.....(7 seconds)

Researcher: *A bit of a problem, eh?*

Jamie: *Yeah. Is it the small amount of air that's pulling and trying to get a bigger amount of air?....*

Researcher: *The only bit that I don't understand is what...how air can do any pulling.....*

Jamie: *You know when there's air in...*

Researcher: *Mmm...*

Jamie: *and you know when..you pull it out?*

Researcher: *Yeah*

Jamie: *what's in there then?* (inside the syringe)

Further discussion led to agreement that there was 'thinner air' inside the syringe when the plunger is pulled back:

Researcher: *so the air is thinner and fills the whole of that space.*

Jamie: *like if you're higher up.*

Researcher: *yes, exactly like that. There's a bit of a problem here, isn't there? How thinner air can do any pulling at all?*

Jamie: *...was it that... the thinner air just trying to make itself thicker air because it's thicker air all around it, so it was trying to adapt...*

Researcher: *Mmm...*

Jamie: ...*to the normal air...around here? So it's like if you fill that with air here and you kept it so as no air could get in or out and you took it high up..*

Researcher: *yeah...*

Jamie: *and you pulled it and it doesn't go back in It doesn't come back because the air's the same.*

Researcher: *yes.*

Jamie: *Right I understand.*

The researcher's question, 'what is **it** that is doing the pulling', prompted Jamie to reconsider the form of his explanation. It is clear from his hesitant response that Jamie recognised the issue which the researcher was referring to. He offered a tentative suggestion, 'is it the small amount of air...', before introducing a new line of thinking relating to the air getting 'thinner' when the plunger is pulled back in the syringe. Jamie developed his idea by going through the 'thought experiment' of considering what might happen if the plunger is pulled back and then released 'high up'. He was able to satisfy himself that 'it doesn't come back because the air's the same'.

In this way Jamie was able to take first tentative steps in moving from an explanation based on 'something inside the syringe pulling' to being able to recognise that it is the *differences* between air inside and outside the syringe which are important. Jamie had made some progress in his thinking even prior to the first lesson.

INTRODUCING THE 'NEW WAY OF EXPLAINING'

The new way of explaining was based on the ideas that:

- more air in a fixed space produces greater pressure,
- less air in a fixed space produces smaller pressure,
- a resultant force acts from higher to lower pressure,

and these ideas were introduced through three separate contexts, 'Plastic bottle', 'Balloons in a bell jar' and 'Rubber suckers'.

Introducing the 'new way of explaining': The plastic bottle demonstration.

We join the class with the students sitting around the teacher's bench at the front of the room so that they can see and follow what the teacher is doing. The room is quite a spacious laboratory; it is fitted out with traditional heavy benches and there are windows down one side overlooking the school playing fields.

In the previous lesson, Richard had briefly demonstrated the effect of removing air from a plastic bottle with a hand (bicycle) pump, 'air remover', and then adding air with an 'air adder'. Richard now repeated the demonstrations with the plastic bottle, this time using an electric pump, first using it as an air remover:

Teacher: *Let's see what happens... this is the air remover connected.* (the plastic bottle collapses in spectacular fashion and the pupils are buzzing with excitement) *Look at that! Well! Alright, so what we've done with this electric one is to do what we can do with the mechanical one faster.*

Richard went on to re-state the purpose of the present activities and to provide a first introduction to the form of the explanation:

Teacher: *We need to find out why. We talked about this the other day, where people were saying 'Ah, hang on...it's when it collapses in like that it's because there's something on the inside pulling it'. We're going to call that the old way of looking at it because I want you to think about it in a new way. I want you to think about it by thinking about pressure. I want you to think about it in terms of air pressure. We're going to say that where there's more air there's more air pressure. Where there's less air, there's less air pressure. So the more air there is in a space, the more air pressure there is and the less air there is in a space, the less air pressure there is. Jamie?* (Jamie has his hand up to attract the teacher's attention).

This was a significant sequence in the development of the lesson. Richard re-emphasised the goal of 'finding out why' using the *'we construction'* (Edwards and Mercer 1987) to emphasise the joint nature of that goal (although the students had not been party to setting the goal it was talked about as such by Richard, 'we need to find out why'). He reminded the students of the kinds of explanations which had been suggested for these effects in the previous lesson and then explicitly *differentiated* earlier forms of explanation (the 'old way') from a 'new way' of explaining based on air pressure.

As Richard introduced the new way of explaining he very noticeably modulated his voice and spoke in a slow, clear and very deliberate manner, thereby drawing attention to the importance of these new ideas. It was a form of *public exposition* which did not encourage intervention by the pupils. In contrast to much of the preceding talk it was clear that the new mode of explanation was *not* open to negotiation.

It is interesting to reflect for a moment on the sense that the students would be able to make of the new explanation, as it was introduced. Although the class were aware of the concept of pressure in relation to solid structures (for example, the pressure under a student's feet), the concept of air pressure had not yet been addressed in lessons. With this in mind, it can be seen that the teacher introduced a new way of explaining which the students would initially need to accept as a *provisional fiction.* The teacher hoped that there would be sufficient familiar features (such as pressure, force, air) within this new way of explaining to make it intelligible to pupils but recognised that novel aspects of the explanation (particularly that *air* can exert a pressure) would need future exemplification and practice. Initially the pupils were required to accept the new way of explaining as a 'provisional fiction' in that the new 'story' was unlikely to make immediate and complete sense to them.

As Richard completed his presentation of the new way of explaining, Jamie attracted his attention and, unbidded, spoke out:

Jamie: *Well, when all the air's been sucked out, it's er...there's nowt in there so you'll have...air pressure's pushing the side of the bottle in.*

Teacher: *Which air pressure Jamie?*

Jamie: *From the outside.*

Teacher: *Say that again so that people can hear.*

Jamie repeated his explanation.

Teacher: *Right, so you're saying that when we suck the air out of the bottle, there's less air inside the bottle so there's less pressure, less air pressure....and why did the sides push in? What did you say again?*

Jamie: *Cos there's more air pressure outside.*

Teacher: *Because there's more air pressure on the outside pushing it. That's what we're going to call the new way of looking at it. The new explanation is that there's two lots of air involved here not one. There's one lot inside the bottle and there's one lot in this room immediately surrounding it. And if we take air out of the bottle, that means there's less air pressure inside the bottle than there was before...there's more pressure outside, then, and it pushes it in.*

So why is it then, why is it that if I don't attach an air adder or remover to the bottle it stays with fairly straight sides? Why is it...Nick?

Nick: *Because the air pressure's the same inside the bottle as the outside of the bottle.*

Teacher: *The air pressure's the same inside the bottle and outside. Good lad. Now we're going to be using that idea a lot...so I want you to make a note of it in your book.*

As Jamie competently outlined the air pressure explanation, drawing on his earlier talk with the researcher, the teacher seized the opportunity to review the new way of explaining. Jamie referred to 'air pressure pushing the sides of the bottle in' and the teacher asked for clarification as to which air pressure he meant. This point was central to the new way of explaining and when Jamie identified the air pressure 'from the outside' the teacher asked him to repeat it 'so that people can hear'. Jamie is not the kind of boy who has problems in making himself heard! Richard was using Jamie as a partner in a *public dialogue* to rehearse the new way of explaining in front of the rest of the class. His questions and prompts were not so much aimed at checking Jamie's understanding of the explanation but as a means of breaking up the presentation of the explanation and identifying its component parts for the rest of the class.

Richard completed the 'public dialogue' with Jamie and repeated the new way of explaining , this time emphasising that there are 'two lots of air involved' (this being in contrast to old ways of explaining in which the external air generally has no part to play). Once again he presented the explanation in a deliberate and measured way using his 'public exposition' voice. Finally Richard checked out a 'boundary condition' for the new explanation- what happens if neither pump is attached. Nick provided a good answer and Richard signalled an advance warning, that 'we're going to use that idea a lot'. (Note the further use of the 'we construction').

In introducing the new way of explaining, Richard had *repeated* the explanation, in full, three separate times.

Introducing the new way of explaining: Balloons in the Bell Jar.

After the class had completed drawing diagrams of the plastic bottles into their books Richard called them back to the front of the room for a second demonstration. The demonstration focussed upon two partially inflated balloons positioned under a bell jar which was connected to a vacuum pump. Richard explained the apparatus to the class and then asked for predictions as to what would happen when the pump was used as an air remover:

Teacher: *This big jar's got two bungs in. One of them's got a little valve in it so we can connect the pump to it....Inside it, it's just air...we hope and the're two balloons which have got a* <u>*tiny*</u> *bit of air in. They're partly blown up but then there's been a knot tied in the neck of the balloon....and then put a bung in the top* (of the jar)...*fits so it's quite tight and we're going to connect it to the air remover. So very quickly, just one person...Gled?*

Gled: *Well, when yer...if you* <u>*were*</u> *going to put it on go...*

Teacher: *On air remover we said.*

Gled: *Oh, well on air remover...it'll like suck...it'll be sucking all t'air out and t'balloons will go...like towards the hole.*

Teacher: *Right we're going to suck the balloons from the edge of the jar over here towards the hole. Will anything else happen to the balloons?*

Pupils: *Might pop!*

Teacher: *OK, lets just watch and see.*

As Richard described the apparatus he emphasised that inside the jar *'it's just air'* and that the balloons have *'a tiny bit of air'*. in them. There were many features of the apparatus which students could focus upon, but Richard drew attention to the air in the jar and in the balloons. The new way of explaining is based upon pressure differences in these two lots of air and Richard provided an *advance prompt* in drawing attention to them.

The exchange between Richard and Gled is an interesting one. The teacher was using the term 'air remover' to avoid references to notions of 'sucking'. Gled initially talked of putting the pump *'on go' and* Richard interjected (*we said*) with the correct term, 'air remover'. Gled then proceeded to refer to the air remover *'sucking all t'air out'*. Richard re-iterated Gled's prediction to the whole class without comment.

Richard switched on the pump and the balloons slowly began to inflate, much to the amusement of the class:

Pupils: *They're going up. Yeh....Yeh they <u>are!</u> They're floating...(much laughter) ...They're going to pop ! I hope they do !*

Teacher: *They're <u>not</u> getting sucked towards the hole that's for sure. Your prediction wasn't on.*

Pupil: *Sir, when you get hold of a balloon...and put yer, put yer mouth over the balloon and suck... it inflates in yer mouth....it's doing t'same thing.*

Richard firmly stated that Gled's prediction was incorrect; the idea of the pump providing a 'sucking force' was not consistent with the teacher's new way of explaining. The follow up comment from one of the pupils clearly illustrated the strength of associations with 'person-centred sucking' ideas.

Richard very sternly pointed out that sucking balloons in this way was a ridiculous thing to do, *''you're lucky you haven't died of asphyxia'*. He then called attention to something which Matthew had been muttering to him during the demonstration:

Teacher: *Hang on, hang on. Just you hang on a minute Matthew. Alright I'm going to have to stop this now.*

Pupils: *Look, look ...(laughter).*

Teacher: (teacher switches off the pump). *Matthew's just told me that if we suck all the air out of this jar, the pressure in the jar is less. There's low pressure 'cos there's less air in the jar. Now what's the next bit Matthew? Why should that make the balloons go up?*

Matthew: *Cos the balloons...erm...have got the same air pressure as outside still...so that when there's less air pressure in the jar there's more air pressure in the balloons and... cos the pressure is more, it ...inflates.*

Teacher: *Good lad! We haven't affected the air in the balloon because the air in the balloon is fixed, it's been sealed in when somebody tied a knot in the balloon, so we're only taking air away from inside the jar. We're not taking air out of the balloons. The air in the balloons stays the same...that's the same air pressure as they are right <u>now</u>*

before we started connecting the pump. So if we make less air in the jar, there's less air pressure in the jar, the pressure in the balloons is still the same as it was before...and so the balloons inflate. Now I think that's quite a difficult idea to understand because we've now got three lots of air... we've got the air in the room, the air in the jar and the air in the balloons and it all seems to be doing different things. Then what Matthew said is the idea that I want you to use, the new explanation...

Richard then *repeated* the full explanation for the air remover case in his 'public exposition' voice before demonstrating what happens with the air adder.

This exchange between Richard and Matthew was very similar in form to the earlier one involving Richard and Jamie. As the demonstration was proceeding (amongst considerable excitement), Matthew explained, within earshot of the teacher, what was happening. Richard switched the pump off, called the class to order and asked Matthew to go through the explanation so the whole class could hear. The teacher was using Matthew as a kind of *surrogate mouthpiece.*. Richard knew that Matthew understood the explanation and was keen for him to rehearse it in front of the class. In a sense Richard was demonstrating, through Matthew, the level of understanding which all of the pupils should be aiming for. Richard then drew pupils' attention to various features of the explanation, commented that these were difficult ideas to understand and finally ran through the explanation once more.

<u>Introducing the new way of explaining: Rubber suckers.</u>

After the 'balloons' demonstration was completed, the students returned to their normal seating places in the laboratory and Richard introduced a new activity in which the students were to measure the force needed to remove two rubber 'suckers' from a board. Richard firstly outlined the practical details of what was to be done and then reviewed an explanation of how the sucker works:

Teacher: *I want you to understand how these things work using that new idea we've got about air pressure. Inside here the cup is curved and if I put it against the flat surface the air inside the curved bit, inside the cup, is trapped. Now if I push on the middle of the sucker, it squashes that trapped air out so there's now less air in the cup. If I let it go again there's no way the air can get back in....because it forms a seal with the surface. So that means we've got less air inside than we have in the room...there's less air inside, that means less pressure, that means there's greater pressure on the outside pushing the cup,* *the sucker against the surface. The first thing to do is to put the results table and diagram into your books.*

The students worked in pairs and used spring-balances to measure the magnitude of the force needed to pull each cup from the board. The activity created a great deal of interest, there was a genuine buzz of excitement around the room as students struggled to pull the suckers from the board and to measure the forces required. They were clearly suprised by the size of the pulls which were needed.

A researcher spoke to Jamie and his partner Nick as they worked at the activity:

Researcher: *Do you understand what this has got to do with what Mr. N. was saying before about air pressure?*

Jamie: *Yes...basically.*

Nick: *Yes.*

Researcher: *Let's go through it. You start off and you put that* (the rubber sucker)*on there...*

Nick: *Yeah and there's air trapped inside...*

Researcher: *and there's air under the sucker...go on...*

Jamie: *and it's the same pressure as the air outside.*

Researcher: *Right, so if you don't do anything...it just slips off.*

Jamie: *And when you push that like that ...*

Researcher: *Right...*

Jamie: *It's the same area...except the air's been pushed out the sides*

Researcher: *So I press down and it pushes the air out?*

Jamie: *the same area you see...*

Researcher: *right...*

Jamie: *there's low air pressure...*

Researcher: *So there's lower pressure underneath the sucker...*

Jamie: *And higher on the outside...*

Researcher: *You haven't changed the pressure on the outside.*

Jamie: *No, it's keeping it down on the low pressure.*

Nick: *Yeah, and there's high pressure outside*

RUBBER SUCKER REVIEW

The second lesson began with Richard vividly reminding the class about the activities with the rubber suckers and commenting particularly on the large forces needed to move them:

'Teacher: *Some people had to tug really quite hard before it started to come off and when it came off, it came with quite a bang! Some people didn't quite fly across the room but they went reeling backwards. That was a tremendously big force...why does it take so much force as all that? Adam.*

Adam: *Right, the clear one...when you push it down more air can get out than the white one and so more had to ...get out....or.*

Teacher: *So what exactly was sticking it on the board Adam?*

Adam: *Air pressure and...*

Teacher: *Air pressure, where was this air pressure that was sticking the sucker on the board?*

Adam: *Well it were inside the sucker and then it came out and so it could let air pressure out so it could get back inside it to pull it off.*

Teacher: *Where was the air pressure highest then, inside or outside the sucker?*

Adam: *Er, in.*

As Adam started his explanation a now familiar situation appeared to be unfolding in which the teacher helps a student to re-iterate the details of the new way of explaining a particular phenomenon. In this case, however, Adam was unsure. He used the term 'air pressure' when referring to the movement of 'air' and then stated that the air pressure was highest *inside* the sucker. This was not such a promising situation for the teacher:

Teacher: *Inside. You went 'er' then as if you weren't too sure and that's not quite what I explained to you before. Jamie, you have a try.*

Jamie: *Y'know when you push it down? It forces the air out of the sides. Its the same area inside the sucker, it's the same area, it's just been pushed down and all the air's been pushed out. So it's a smaller amount of air in the same area.*

Teacher: *So where would you say the air pressure was the highest? Inside or outside the sucker?*

Jamie: *Inside.*

Teacher: *You'd say inside.. Damian, what would you say?*

Damian gave a perfect response in terms of air pressure (lower pressure under the sucker) but Richard recognised that the students *'hadn't all got it yet'* and went back to the original case of the plastic bottle. He rehearsed the whole arguement once more but found that students were still suggesting (even in the case of the bottle) that removing air increases the air pressure. Finally, Richard asked students to vote on the issue:

Two (Matthew and Samantha) thought that less air gave a smaller pressure.
One (Nick) thought that less air gave the same pressure.
Fifteen thought that less air gave a greater pressure.
The others weren't sure.

Richard responded directly to this outcome:
Teacher: *Well I'm afraid 15 people are wrong. If you take air out of an object so that there's less air inside the space it means the pressure is less.*

Richard went on to review the pressure difference arguments in detail reminding the students:
'*That's what we said, and that's what you wrote in your books'.*
This was a most unexpected development. At the end of the previous lesson the class had seemed generally confident about the basic pattern of the air pressure explanation; what had happened since then? Interviews later in the lesson helped throw some light on this question.

The researcher firstly talked with Jamie:
Researcher: *You said you thought it would be a bigger pressure under the sucker, what did you mean when you said bigger pressure?*
Jamie: *I thought it'd be more pressure cos it was harder to pull up. There'd be bigger pressure under there. You see if it were low pressure it'd be easier to pull up.*

Through this line of argument, Jamie was basically reverting to considering only the air under the sucker. A big pressure under the sucker demands a big pull. The researcher continued:

Researcher: *The question is where is the bigger pressure?*

Jamie: *Inside the sucker.*

Researcher: *So what's actually holding the rubber sucker onto the table as far as you're concerned?*

Jamie: *The pressure underneath the sucker.*

Researcher: *Mmm, it's just that you were saying at the end of the previous lesson, it's not just thinking about the air under the sucker, but you also have to think about the air on the outside.*

Jamie: *Yeah, cos there's air pressure pushing down on the sucker.*

Researcher: *I think that's what the teacher was on about. If you take air out it's lower pressure than on the outside, so the pressure's bigger on the outside, so that's holding the sucker in place.*

Jamie: *Right, yeah.*

At this point Jamie appeared to slide easily from one form of explanation to another. At one moment he related the big force needed to remove a sucker to a big pressure under the sucker; then, when the pressure difference argument was re-introduced he seemed to accept that without any problem. A little later he confirmed that the pressure difference ideas made sense to him and related them to an earlier idea of his:

Jamie: *Yeah, that's right cos if you went up in outer space where there's no air pressure, it'd pop up.*

The researcher then talked to Tarben and Adam who, with help, were able to present a good pressure difference explanation for the rubber sucker. Both boys had voted that the pressure was bigger under the sucker:

Researcher: *Right, well why did you say it was high pressure in the lesson?*

Tarben: *I forgot, I just put me hand up.*

Adam: *I forgot all about it..*

Tarben and Adam's explanation for their incorrect prediction of 'high pressure'; bears the hallmark of the real world of schools; they have been introduced, in an earlier lesson, to a novel way of thinking about a familiar phenomenon (why the sucker sticks) and have simply forgotten the 'workings of the explanation'. With the support of the researcher they were able to reconstruct competently what they had previously forgotten.

Tarben's comment, '*I forgot, I just put me hand up''* indicates that perhaps the situation of fifteen students voting against 'the developing understanding' was not so bad as might first have been judged. Whereas some students (such as Jamie) were arguing from a considered point of view, it is just as clear (in retrospect) that others were not. In general terms, the students' thinking about the air pressure explanations, at this point, appeared to be lacking in consistency of interpretation and application.

As a final point, it is interesting to note the teacher's unequivocal response to the class vote, '*Well, I'm afraid 15 people are wrong.'* He was apparently faced with a shared understanding, which in his terms was incorrect, and stated very clearly to the class that this was the case. For the teacher an anchor point in the teaching had been disturbed and challenged; he must very clearly draw attention to this and restate the developing line of argument. When the teacher commented, *'that's what we said...'* he was, in a sense, reminding the students of an earlier 'joint agreement' which, from his point of view, had been broken.

THE PRESSURE CIRCUS

Richard now turned to the activity whch was to take up most of the lesson. The pressure circus consisted of 7 work stations and at each station the students were presented with a simple activity and instructed to 'Explain in terms of air pressure'. Richard gave the following final instructions prior to the students starting the circus:

Teacher: *You're going to have 7 activities to do where it's going to ask you to do something and then write down what you think is the explanation for it. We want you to use those new ideas, those ideas that more air in a space means more pressure. I'm going to divide you into pairs and each pair will start with a different activity...'*

At this point the students formed pairs and started to work their way around the circus. This activity continued right up to the end of the lesson and as work proceeded both Richard and the researchers talked briefly with different groups of students.

Ian and Monica were working with a U-tube water manometer (one arm of which was connected to the gas supply) when Richard approached them:

Teacher: *Have you turned the gas tap on?*

Ian: *Yeah.*

Teacher: *What happened?*

Ian: *The water goes up and stays there.*

Teacher: *Did it keep going out the end of the tube?*

Monica: *No...it went to a certain point.*

Teacher: *Why not?....you kept the gas on and it stopped? So how do you explain that?*

Monica: *I dunno.*

Teacher: *Why did n't it keep on going up?*

Ian: *I get it!* (excitedly!)...*the gas gets stuck sir!*

Teacher: *Right, the gas is stuck in the tube.*

Ian: *Yeah!*

Teacher: *So why doesn't it come out of the other side ?*

Ian: *Cos water's there.*

Teacher: *So why doesn't it keep on going up ?*

Monica: *I dunno....*

Teacher: *The gas is still coming out of the gas pipe, why isn't the water still going up? What's stopping it going up any higher?*

Monica: *Is it because the gas is coming out of the other end and not staying pushing there?*

Teacher: *Do you mean the gas is going <u>through</u> the water somehow?*

Monica: *Yeah!*

Teacher: *Couldn't see any bubbles going....*

Monica: *Mmmm !*

Teacher: *A clue ! What topic are we doing at the moment?*

Ian: *Air pressure.*

Teacher: *Air pressure, right. Now would that have anything to do with it?*

Monica: *The air pressure's going through that* (the open end of the u-tube) *and it pushes on t'water.*

Teacher: *Right, the air pressure's going in the other end and pushing down. Right.*

Monica: *And that one's trying to push up so they stay the same.*

Teacher: *So they balance out. Good.. You've got it!*

At the start of this exchange Richard asked a key question, 'Did it (the water) keep going out the end of the tube?', which *anticipated* problems that students were likely to have in applying the pressure difference explanation to this system. The follow up question, 'you kept the gas on and it stopped?' clearly defined the *discrepant event* which Richard revealed for the students and their current way of thinking. The students attempted to resolve the situation with various explanations and Richard helped them to evaluate those possible explanations. Richard then re-focussed attention on air pressure and Monica was able to suggest a satisfactory explanation in pressure difference terms.

Nick and Jamie were talking about 'Dropper' (a teat pipette) and explained to a researcher how, when the teat is squeezed and released, water comes up into the pipette:

Nick: *it thinks it's going to get air back in....can't get the air back in that it needed, so you get water back in.*

Jamie: *instead.*

Nick: *and it gets the same amount of water back in as the air that went out.*

For the 'Dropper' activity, Jamie wrote the following in his exercise book:

'You blow the air out of the dropper and the dropper trys to get the air back but it sucks the water back instead.'

Once again, Jamie had reverted to his 'old way' of explaining.

The researcher moved on and talked to Matthew about 'Plunger' (a domestic 'rubber sucker' device):

Researcher: *So what happens when the plunger's pressed down onto the table?*

Matthew: *Sticks to the table.*

Researcher: *Right, and explain in terms of air pressure.*

Matthew: *Well, it's when you push all the air out of there, the air pressure is less in there, so the air pressure here* (outside the plunger) *cos it's more than that, presses that down, so it doesn't come off again.*

Adam and Tarben were talking about 'Dropper':

Researcher: *I put it in the water and press it...*

Adam: *push all the air out.*

Researcher: *I let loose...*

Adam: *sucks...water up...and...*

Researcher: *does this business about air pressure, could you bring that into it at all?*

Adam: *Mmm, well air pressure's forcing it out isn't it?*

Researcher: ...*what about that business when you remove air from somewhere you get low pressure? Can you see it working here?*

(7 seconds pause, no response)

In his exercise book Adam wrote:

'*when you squeeze the dropper it forces the air out when you let losse the water comes back in.'.*

The pressure circus proved to be very revealing of students' thinking in a number of ways. Firstly it was clear that most of the students in the class experienced problems in applying the 'new way of explaining' to the full range of phenomena presented in the circus. The extent to which students were able to apply the new ideas depended largely upon the degree of similarity between the taught, and much talked about, 'anchor cases' (plastic bottle, balloons, sucker) and the phenomenon under consideration. Thus responses to 'Plunger', which is identical to the sucker case, tended to at least contain elements of the new explanation, whereas 'Dropper' and 'Tube' saw virtually all students reverting to their old ways of explaining. There were also many cases of 'hybrid responses' in which elements of old and new ways of explaining were combined. Thus Claire wrote the following for 'Springback':

'*There is no air in the syringe, but there's air pressure pulling the plunger back in'.*

The students' attempts at explaining the various phenomena presented in the pressure circus draws attention to the distinction which can be made between learning an explanatory theory and learning how to apply that theory in a range of situations which might bear quite different 'surface features' to taught cases. 'Dropper', for example, can certainly be explained in terms of air pressure but that explanation is based upon pressure differences across water and how the water moves as a result of those pressure differences. The framing of the explanation in this example differs significantly from the 'anchor cases' and the student must *learn* how to apply the explanation in this novel situation. In the following extract a researcher is talking to Sharon and Samantha about 'Dropper':

Researcher: *Now, when I squeeze the dropper what do I do to the air inside?*

Sam. : *Push it out.*

Researcher: *Push it out OK.*

Sharon: *So that means the air out is bigger than..*

Researcher: *So the air pressure outside is bigger than the air pressure...*

Sam.: *inside.*

Researcher: *And if I then let go?*

Sam.: *The air, the air pushes back in and its the same again*

Researcher: *But the air can't get in cos...*

Sam: *Oh, yeah...*

Researcher: *...the end of the syringe is in water. So what is it that goes in? Not air...*

Sam: *Water*

Researcher: *And what makes the water go in ?*

Sam: *The air pressure*

Researcher: *Which air pressure?*

Sam: *The outside air pressure.*

Here the researcher provided considerable support for the students as they worked together to construct the explanation. Samantha's 'Oh yeah' response mid-way through the dialogue almost suggests 'Oh yeah, I remember how the explanation goes...' It is not the case that the students are unable to transfer the new way of explaining to novel situations, it is certainly the case that they require support in learning to do so.

There is a further aspect to this issue of applying explanations to novel contexts. During the pressure circus Adam approached one of the researchers with the following question:

'*When I put my pencil box on the bench, is the air squeezed out from under it so that it's kept there by air pressure?'*

This question illustrates the point that the student faces the challenge of not only learning *how* to apply the explanation, but also of coming to recognise *when* to apply it. The latter issue was not addressed in the pressure circus (where the contexts were given) nor, indeed, in any other part of the teaching.

The same issue was raised as a researcher was talking to Jamie and Tarben. Jamie had just outlined a full and correct pressure difference explanation for the Spring-back syringe:

Jamie: *I still don't understand. though...*

Teacher: *You still don't understand what?*

Jamie: *About that....why you.....it's the same principle....so why doesn't it do it on t'Earth?.....Why doesn't it squash all t'flowers? Sort of the air pressure?*

Tarben: *Why doesn't all t'planets fall out of the sky?*

A final point relates to the question of how the students interpreted what was actually demanded of them in the circus activity. From an instructional point of view, the circus was planned with the aim of encouraging students to apply a specific explanatory model to a range of situations. In this respect the activity is underpinned by the epistemological assumption that science models and theories should be generalisable across instances. To what extent were the students aware of this underlying rationale for the activity? In practice students responded to the direction '*Explain in terms of air pressure'* in whatever terms they were able to and frequently their responses were not based upon the new way of explaining. Did the students see the aim of the activity as one of trying to apply *a single* way of explaining in these novel situations?

NEW WAYS OF LOOKING: STUDENT'S RESPONSES TO THE POST-TEACHING DIAGNOSTIC QUESTIONS

Three months after completion of the teaching on air pressure, 17 students from the class attempted two questions, 'Springback' and 'Plunger'. Details of the questions are provided in Appendix 2. The students' responses were coded as follows:

Spring back: Why does the plunger go back?

Code	Response	Number (n=15)
A	air pulls the plunger back in	1
B	plunger returns to place it started	3
C	plunger returns to fill empty space	2
D	air stretches, plunger returns to compact air	4
E	air inside pulls, air outside pushes	1
F	air pressure forces plunger back	1
G	differential air pressure	3

Table: Responses to 'Spring back' 3 months after teaching.

Jamie's written response was:

The plunger goes back in because when you pull it out your making the air pressure decrease so the air pressure all around us pushes the plunger back in (coded G).

Plunger: Why does the plunger stick?

Code	Response	Number
A	Something pulls plunger down to table	4
B	Air pushed out, plunger sticks.	8
C	Air pushed out, air pressure falls, sticks.	2
D	Air/ pressure on outside pushes down	7
E	Differential air pressure	2

Table: Responses to 'Plunger' 3 months after teaching.

Jamie's written response was:

When the plunger is pressed down the air in its rubber dome is been forced out so the air pressure decreases so the pressure is greater on the outside of the rubber dome so the pressure is pinning the plunger down (Coded E).

ISSUES ARISING FROM THIS STUDY

At the start of the lessons outlined in this article no students used pressure difference explanations to interpret simple air pressure phenomena. By the end of the teaching (and some time later) some students were able to use the 'new way of explaining' competently whilst others were still offering explanations more closely linked to their original ideas. Let us return to the three questions posed at the beginning of this article and review how the new way of explaining was introduced in the classroom and what 'obstacles' existed for students as they attempted to construct and apply this new way of explaining.

The first striking feature of the data presented here is the extent to which 'meaning making' in the classroom was carried by various modes of discourse. Although Richard used demonstrations and practical activities to support the development of arguments it is clear that none of those activities, by themselves, could prompt the development of students' thinking towards the intended goal of pressure difference explanations. Those models, or theoretical objects of science (Matthews, 1987) are simply 'not there to be seen' in an external world and are therefore unlikely to be stumbled upon through undirected 'discovery' approaches to teaching.

What was observed in the lessons was an elaborate combination of activity and discourse in which, at different times, we saw the teacher: drawing attention to the importance of new ideas by talking in a slow and deliberate manner (in 'public exposition mode'); emphasising some points of information whilst ignoring others; stressing the use of certain items of vocabulary; linking new ideas to ones raised in previous lessons; repeating explanations over and over again; drawing competent students into the process of presenting new ideas by means of 'public dialogue'. We also saw 'experts' (both teacher and researchers) supporting or 'scaffolding' students as they attempted to construct specific lines of argument or explanation. This support assumed different forms with the expert, at different times: offering a word here and there to help students develop a line of argument; referring to evidence not considered by the student; providing points of information; drawing attention to problematic features in students' thinking as a starting point to constructing new ideas.

By such means the teacher attempted to develop a shared understanding or common knowledge (Edwards and Mercer, 1987) of the pressure difference explanation with his students. Largely, it seems, through discourse Richard was able to introduce his students to a new way of explaining familiar phenomena. It might be argued that Richard was simply introducing his students to the specialised forms of language which are peculiar to science explanations of air pressure phenomena; that learning pressure difference explanations consists of 'learning to talk' those explanations (Lemke 1990).

However, if the ways in which discourse supported the development of shared understandings is strikingly obvious, it is just as obvious that in the context of this particular study, many students experienced problems in coming to terms with the new way of explaining. It is also apparent, from the pre- and post-test scores that there was considerable variation in the extent to which different students were able to develop an understanding of the pressure difference explanation and apply it in a range of contexts. Why should this be?

By any standards Richard would be considered to be a competent teacher; in the lessons observed he was unfailingly sensitive to the thinking of his students and developed arguments with skill and clarity. So why should so many students have experienced difficulties?

This question can be addressed by identifying the learning demands existing for students in the context of learning about air pressure. The learning demands can be conceptualised in terms of the *differences* between students' existing ways of thinking about the phenomena in question and the science perspective. Furthermore, those differences can be considered in terms of conceptual, ontological and epistemological features (Scott 1992).

The point has been made earlier that there are clear differences in the *conceptual* frameworks drawn upon in science and everyday thinking to explain air pressure phenomena. Furthermore, the everyday explanations are often closely associated with human actions (such as sucking) and are reinforced by day to day language. As such one would expect everyday explanations of air pressure phenomena to be well established and resistant to change. The data from this and other studies demonstrate that this is the case.

A further aspect of learning demand which became apparent in the study relates to the changes in *ontological* categorisation (Chi 1993) associated with developing new conceptual frameworks. During the lessons it became clear that the new way of explaining lacked plausibility for many of the students. Thus we have seen instances where students were able to apply the pressure difference explanation to a particular situation but where they were still uncertain as to *how* static air was able to make such a force. In developing pressure difference explanations, students were not only required to learn a new register of vocabulary; in a very real sense they were also required to relocate their existing concepts of air to new ontological categories.

The final aspect of learning demand which is exemplified through this study relates to differences in the *epistemological* assumptions underlying the everday ways of explaining and those associated with a science perspective. Examination of the students' responses to the pre-teaching diagnostic questions indicates that many of the students used different kinds of explanations for each of the two cases. Thus there was no commitment to using a single idea which might satisfactorily account for both phenomena. Indeed there is no reason why there should have been; many students would not have seen any connection at all between 'Apple juice carton' and 'Spring back' However, later on in the teaching it was very obvious that even when students were instructed to use a *single* way of explaining (in context of the Pressure Circus), this epistemological restriction was not guiding practice. There appeared to be a mismatch between what the teacher wanted the students to do (apply a single mode of explanation to a range of phenomena) and what they actually did (generate any explanation within their capabilities).

FINAL COMMENTS

Studies reported in the literature, about teaching and learning science in classroom contexts, have often tended to focus on conceptual areas generating low learning demands for students. Edwards and Mercer (1987), for example, analyse a teaching sequence which aims to identify the factors affecting the period of oscillation of a simple pendulum. In this and other such cases, the analysis focusses heavily upon the social perspective, possibly because the process of individual meaning making has become 'transparent' due to the low conceptual and epistemological learning demands. This is certainly not the case in the present study where the various 'obstacles' to personal sense making are thrown up in sharp relief against a background of socially sustained teaching activities and overtures.

In this paper, I have attempted to make and illustrate the case that any analysis of learning in classroom settings needs to include both personal and social aspects. Social analysis focusses upon the way in which the teacher uses and controls discourse to develop shared understandings with students. The personal perspective tells of how *individuals* develop personal meanings by engaging with and participating in the unfolding social event. Identifying the ways in which the different aspects of that event sustain the articulations (and failiures of articulation) of the personal and social narratives is the central problematic of this developing programme of work.

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APPENDIX 1: Outline of the instructional sequence.

0. Pre-teaching questions: set three weeks prior to Lesson 1(see Appendix 2).

1. Lesson 1 (75 minutes duration): Construction of the science ('new way') explanation of phenomena in terms of air pressure differences.

a. *Collapsing plastic bottle* : teacher demonstration and class discussion (25 minutes).

b. *Balloons in the bell jar* : teacher demonstration and class discussion (25 minutes).

c. *Rubber suckers* : class practical activity (25 minutes).

2. Lesson 2 (75 minutes duration)

a. *Rubber sucker review* : class discussion (20 minutes).

b. *The pressure circus* : class activity, application of the pressure difference explanation to a range of phenomena (55 minutes).

3. Lesson 3 (75 minutes duration)

a. *Review of items from the pressure circus* : class discussion and individual writing task (45 minutes).

b. *Old way/ New way* : class activity to review a selection of responses to the pre-teaching questions and to classify each as an old or new way of explaining (30 minutes).

4. Post-teaching questions: set 3 months after completion of the final lesson (see Appendix 2).

APPENDIX 2: Pre and post-teaching questions.

For each of these questions the teacher demonstrated the actual phenomenon before asking the students to write down their explanation for it.

1. <u>Pre-teaching questions.</u>

Collapsing apple juice carton.

When you drink juice through the straw, the sides of the carton bend inwards.

Explain why the sides move in:

Spring back

The opening of the syringe is blocked up. When you pull out the plunger and let go, it springs back into the syringe.

Explain why the plunger springs back:

2. <u>Post-teaching questions.</u>

Plunger

What happens when the plunger is pressed down onto a table?

Explain in terms of air pressure.

Spring back

The opening of the syringe is blocked up.

What happens when you pull out the plunger and let go?

Explain in terms of air pressure why the plunger does this: