Observing Context in Action

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‘Context’ has become popular both in the teaching and assessment of science, as it can make science seem relevant to students, as well as allowing us to assess the ability to apply knowledge to different situations. In assessment it is often assumed that context helps students, especially the less able, by making a problem more concrete and less demanding. However, context increases the reading demands of a question, and an unfamiliar or culturally specific context may result in questions that are complex both procedurally and conceptually. We have explored a new methodology for investigating how context affects the process of answering examination questions. For experimental reasons, questions from a science examination were selected and adapted to contain potentially problematic contexts, and students were video-taped while they worked through these questions. They were then asked to talk through their thought processes, while watching the video-tape to aid their recall. The tape showed their actions and their facial expressions during the science test. Results so far suggest that contexts can distract and that students attempted to answer the questions using aspects of the context that they saw as relevant, rather than using their scientific knowledge. Students react in an individual and unpredictable way to different contexts, and schemas provoked by contexts can interfere with those provoked by the science content of questions, causing misunderstandings and errors. If contexts are to be used to test students’ understanding of real-world science, careful consideration of appropriate contexts is needed.

Assessing Science in Context

There are complex issues surrounding the question of whether or not we should assess students’ understanding of science in context. We want students to understand scientific concepts, and we also want them to be able to apply these ideas and concepts to different situations, some in a laboratory setting and some in the real world. It is therefore important to teach science in context, and to introduce students not only to the abstract concepts involved but also to ways in which they can apply these to various situations.

However, whether or not we should *assess* the ability to apply scientific ideas in different contexts is a separate issue. At least it should be a separate issue, but often assessment ends up driving the teaching – teachers want their students to succeed in an examination so they teach them how to answer the sorts of examination questions they are likely to encounter. There is then no time or motivation to teach what is not on the examination syllabus. If assessment of science was context-free we would be in danger of encouraging context-free science teaching. However, questions containing contexts can make it harder to measure the student’s level of understanding of the science involved. A good context allows us to measure the student’s ability to apply their knowledge, but a bad context can prevent us from measuring anything at all.

When contextualised questions are first written, some of the contexts are plausible and appropriate for the science and some are not. Almost all of them contain information that is irrelevant for answering the question, and this information can take the form of words or pictures. Part of the task for students answering these questions is to select information to use when answering, and ignore the rest. It is the lower level papers, making up the Foundation tier of a science exam, that often contain the most context, with the Higher tier papers containing very little context. The large amount of context also results in greater reading demands in the

Foundation papers than in the Higher papers, which causes unnecessary difficulty in a science examination, especially as Foundation tier students are more likely than others to be poor readers.

If the context of a question is emphasised with a picture or diagram this can reduce the reading load. However, because pictures and diagrams are highly salient, students are likely to pay a great deal of attention to these. Any information that is in a picture, and is not relevant to answering the question, will be distracting and may result in responses based on the context rather than the content of the question.

If context is not suitable for the low-achievers should we be using it in the Higher tier papers instead? Context is often used with the aim of helping low achievers answer a science question by showing its relevance to the real world. However, if in fact it is not helping but hindering, should context be something that is used only for the Higher tiers when we want to assess the ability to apply knowledge in a variety of situations?

Also, some contexts may have an emotional impact, and other contexts will be emotional subject matter for some students but not for others. This will cause different reactions from different students, resulting in a lack of control over what we are measuring. Words, phrases or diagrams that provoke emotional reactions will demand attentional processing resources, decreasing the student's ability to concentrate on a problem and select the correct information for an answer.

In the same way, some contexts will be particularly relevant for some students. For example there may be a context with which some students are highly familiar and others are unfamiliar. Those who know a lot about that context already will have the task of selecting aspects of the context that are relevant for answering the question and ignoring everything else they know about it. Those who are unfamiliar with the context may think they cannot answer the question as they have not covered the necessary topic, or they may be put off answering it. They may even find that knowing certain aspects of the context is necessary for answering the question.

So, does context make a question easier or harder? Kotovsky, Hayes & Simon (1985) investigated performance on the Tower of Hanoi problem-solving task in a sparse versus an enriched context, and found that the latter was more difficult to solve. Mevarech and Stern (1997) found that both 11 year-olds and adults found it easier to solve tasks embedded in a sparse context than those embedded in a real-world context. They looked at the interpretation of linear graphs and found that those participants who were given the graph within a sparse context used abstract logic-mathematics to solve the task. Those who were presented the graph within a real context used different non-mathematical knowledge structures relating to practical reasoning and everyday knowledge to interpret the graph, and did less well on the task. They suggest that real contexts not only divert students' attention from the mathematical task but can also activate simplistic models rather than abstract thinking. They also found that experience gained in the sparse context task could be transferred to the real context task, but not vice versa.

Clearly a task can be made less abstract and more concrete by putting it into context, but this does not make the task easier. It just makes it more likely that students will focus on specific aspects of the task rather than the underlying concepts. If we want to encourage the use of abstract thought it would be better not to use contexts at all.

There have been a number of studies looking at the issues of teaching and assessing mathematics in context, many of which have findings that can be applied to science. Wiliam (1997) points out that mathematics is often taught in contexts which are unrelated to the subject matter being taught. These contexts are designed to motivate learners by making the task seem relevant to some real life issue. He calls this 'maths looking for somewhere to happen'. This applies equally to science, and when translated to assessment, it results in students having to identify the task by extracting it from the context in which it is set. Students have to decipher what the examiner is intending them to do by decontextualising the question.

If we want to assess students’ ability to identify the scientific or mathematical task within a real-world problem then there is some argument for using context in examination questions. However, the context should be as fitting as possible to the subject matter being tested, and should also be sufficiently ‘shared’ as Wiliam puts it. If we want to assess whether students can do mathematics or do science, and not whether they can identify the mathematics or science to be done in a real-world situation, then there is no need for context. Those who argue that context makes it more interesting for the students must also be aware of the pitfalls into which they are in danger of leading the students.

As mentioned above, there is an argument for using realistic contexts in teaching, in order to show learners how science can be relevant to them and how they might use it in everyday life. Students may respond with more enthusiasm to learn if they are learning in an interesting context, although Mevarech and Stern’s (1997) work suggests that this might also result in less scientific thinking. However, assessment is a different matter. If we want to measure the student’s knowledge of science, and understanding of scientific concepts, we should do this as directly as possible.

Boaler (1993) found that students tend to choose the procedure with which to do a mathematics problem depending on the setting of the task rather than the task itself. She pointed out the importance of avoiding unfamiliar contexts, especially contexts that are ‘adult metaphors’ such as wage slips. Nickson (1998) found that students tend to focus on a single element of a mathematics question, for example the price of an article that has been illustrated, and carry this through to the end of the question. When the questions were put into context, the aspect of the question on which students chose to focus was more likely to be a contextual one, resulting in wrong answers.

Anderson, Reder & Simon (unpublished) argue that if mathematics is learnt in a narrow context it is more difficult for students to transfer their knowledge, and mathematics that is taught in the abstract is more successfully transferred. Authentic problems in which mathematics applies to everyday life can be encountered after students have learnt the cognitive skills necessary to solve those kinds of problems. If they have learnt the underlying cognitive skills in an abstract form, they will be able to transfer them to any real-world task.

If students are taught in context and assessed in context, they may never develop an understanding of the abstract concepts beneath what they have learned. This could result in students seeing every context in which they are taught as a new piece of science content. If they then come across an unfamiliar context in an examination they may not realise that they have done this before and simply need to transfer their knowledge from a different context.

The Question Answering Process

The psychological processes occurring in students’ minds when they are answering examination questions will be different in context and non-context based questions. The six phases of the Model of Question Answering outlined in Pollitt & Ahmed (1999) are: learning the subject, reading the question, searching the memory, matching stored knowledge with the question, generating a response and writing the response.

During and after reading the question, students are automatically searching their minds for relevant concepts and processes and matching these with elements of their mental representation of the question. Students have no intentional control over this process and it is vulnerable to interference from irrelevant concepts provoked by the question. Many irrelevant concepts will be activated and students are more likely to select these under stressful exam conditions.

As students are reading a question they are forming a mental representation of what the question is asking them to do, and this will be affected by context. If the context in the question is the same or very similar to one the student has been taught in, or if it is a natural context for that topic, then aspects of the context should fit in well with the mental model of the question that the student is building. However, if the context provokes a very different schema from that of the content of the question, or possibly a conflicting schema, processing of the question will be impaired. Such interference may cause students to misunderstand the question. If students have understood the abstract concepts addressed in the question they will be less vulnerable to interference from particular contexts, and less reliant on seeing a question presented in the context in which they learned the topic.

The more complex the context the less likely it is to provoke schemas (Bartlett, 1932), or sets of concepts, that fit in with the required task, and the more likely it is to interfere with answering the question. Every real-world context will induce a different reaction in each individual who encounters it, as each individual builds their own culturally embedded mental representation of the question. Most initial learning of concepts is episodic (Conway et.al., 1997), that is students form a representation of a learning event – a situation. This sort of representation will include features of the context in which the concept was learned. If the learning has subsequently been translated to a generalised schema for the underlying concept then it is semantically represented in long term memory and should be less vulnerable to interference from context. This indicates that higher ability students who have formed a conceptual understanding of a topic are less likely to be led into misunderstandings and confusion by the particular context in which a question is set than the lower ability students who have represented a context-specific learning episode.

If students have formed an incorrect mental representation of a question then they are likely to form a mental representation of an incorrect response. However, students rarely write something that does not make sense to them. Even if an answer looks irrelevant to us it will almost certainly seem relevant to the student in terms of their interpretation of the question. If we can identify a possible misinterpretation of the question at this point it might inform us about what was occurring in the student’s mind at the time of answering, and it might also tell us something about the student’s level of knowledge of the topic.

It is therefore important to try to find methods of investigating the processes that are occurring in student’s minds while they are answering examination questions. If we can find out what students were thinking while they were writing their answers we can learn more about how to write valid questions, and also find out more about how contexts affect student’s understanding of questions.

The Video Protocol Method

A new way to find out what students are thinking while reading and responding to examination questions is to use a method of immediate post hoc rehearsal with video. This involves video-taping students while they answer examination questions and then immediately playing back the video for them to watch while they describe their thought processes. This method was based on a method of post hoc rehearsal used by Taylor (1991) in which she watched students carry out a cloze task and took notes on their facial expressions and gestures, interviewing them afterwards using these notes as prompts. The aim of Taylor’s study was to understand the psycholinguistic processes involved in generating words to fill cloze gaps. She worked with pairs of students in order to elicit more comments and also expressions and gestures when they responded to each other's answers. Poulisse, Bongaerts & Kellerman (1987) video-taped foreign language learners carrying out linguistic tasks and then played the tapes back to them, allowing them to comment upon their performance. They concluded that this kind of retrospective data was a reliable method of analysis of thought processes.

The video method allows us to tape the student writing the answers as well as the student's facial expressions and gestures. These two tapes can be played back to the student (or pair of students) simultaneously using a split-screen method of the kind used by Edwards (1997). In this way we can prompt students' recall of their thoughts with very little delay, using an accurate record of their performance.

Ericsson and Simon (1987) point out that in order to increase recall of thought processes in retrospective reports, non-biasing retrieval cues should be used. The video methodology provides cues in a form that is easily accessible to students during their retrospective reports, and is unbiased. There remains the possibility that students are not recalling their thoughts but are making inferences about what they thought at the time. The paired methodology may be preferable in this case as the students talk quite naturally to each other about what they were thinking at the time. A single student might feel they have to give information to the experimenter, encouraging them to infer thoughts that were not there at the time. Haastrup (1987) argues that a paired methodology stimulates the participants to verbalise more of their thought processes because of the need to explain and justify what they are doing to their fellow participant.

We carried out two pilot case studies. The first was with a single student, using three video cameras to focus on his facial expressions and gestures and what he was writing. The second involved a pair of students and this time one camera was used to record their interactions. The science questions used in the pilot studies were chosen and adapted to allow us to observe students' reactions to particularly problematic contexts.

Pilot Case Study 1

This pilot study was carried out with one participant who had completed a Science GCSE syllabus eight months previously. Three science questions, targeted for 16 year-olds and adapted to contain a rich context, were used in the trial (see Questions 1-3 in Appendix). The student was given as long as he liked to complete the paper, and he completed it in 20 minutes.

Three cameras were set up to record the student answering the questions. One was positioned behind the student, looking over his shoulder at the question paper while he was writing. The other two cameras were positioned in front of the student, one focused on his face and the other was a wider shot. When the paper was complete the student was interviewed and this interview was also recorded on video. During the interview the student had his answers in front of him to refer to and was also able to watch two of the video recordings of the examination. The recording of the answer paper and the wide shot were chosen as the most useful two recordings to play back to the student in order to prompt him about the processes by which he answered the questions.

The interviewer addressed each question part in turn and asked the student to talk through how he answered the question, describing his thought processes in as much detail as possible. By watching the videos of himself answering the questions, the student was able to see his own facial expressions and gestures during the examination, and relate these to the particular question part he was answering at the time. The student and the interviewer were able to pause the video at any point so that the student could talk about what he had just seen on the video.

This prompted his recall and helped him to describe what he had been thinking while reading and responding to each question.

Pilot Case Study 2

In phase 2 of the pilot the post-hoc rehearsal with video was carried out with a pair of students. This was designed to elicit discussion about the questions, to reveal more about the students' thought processes. Two students who will take their GCSE exams this year took part in this phase of the study. The students knew each other well, so were comfortable talking to each other about the questions. They took it in turn to answer each of four science questions containing context (see Questions 4-6 and Question 2 in Appendix). A video camera was set up to record one student answering the questions and the other watching.

The students were asked to 'read out loud' and 'work out loud' when answering the questions. This allowed us some insight into the ways in which they were reacting and responding to the questions, and also allowed us to keep track of which question they were doing when watching the video recording afterwards. This kind of talking aloud is not likely to affect the cognitive processes involved in the same way as a request to 'think aloud' might. Ericsson and Simon (1987) suggest that students who are thinking aloud have to divert their attention to the information being verbalised, whereas talking aloud does not have this effect.

The video was then played back to the students and this prompted them to talk about what they were thinking when they were answering the questions. The tape was paused in order to let them carry on talking about their thought processes for specific questions. The experimenter prompted the students when necessary by asking them to describe what they were thinking.

Results of Pilot Case Study 1

During the video-taped interview the student in phase 1 described how he had approached each question and what he thought of the questions. Some of his comments are outlined below.

Question 1a '*This was a straightforward question although when it said 'button to clean up waste' did they mean it literally to clean it up, so the answer would be movement, or did they actually mean excretion?'*

Here he paused to think before writing the answer 'excretion'.

He had seen an electronic pet in a shop and he though that maybe if they had been going round at school it might help with answering the question.

2b Here he was looking at the picture of the toothbrush and frowning, and reading the context to check it made sense. When asked afterwards he was able to explain that the chemical reacts to stop bacteria in the mouth, and that the light makes the chemical reaction happen.

2b(ii) He frowned a lot while reading this question, and afterwards said '*I haven't got a clue. I had a look at it just to make sure I didn't know it but I haven't revised and I don't have any general knowledge behind it so I thought it wasn't worth wasting time on.'*

He was unable to see a connection between this question part and the previous parts, and saw it as an irrelevant question. When pressed he thought it must be something to do with making the light operate but he was not sure. He also had not noticed that the two arrows that should lead to heat and light were different sizes, and felt the diagram was not clear enough.

Overall he thought all the different parts of Question 2 went together well, apart from b(ii), and that the toothbrush context worked. He could not see the point of the part b(i) about a light ray reflecting on a mirror as he could not really see how this related to the light in the toothbrush unless it was something to do with the way in which light got to the bristles.

Question 3a He reported taking one look at this question and trying not to laugh. His eyebrows were raised while reading it and he was wondering what it was all about and then decided it was a stupid question. The picture and the way the question were set surprised him, and he asked '*why would you be thinking about fish eating golf balls in the first place?*'
He thought the question must be about the ecological ways this would affect fish and the environment but then thought perhaps it was about the biological ways it would affect the fish alone.

3b He thought this was about what happens to the golf ball in water, and said that it decomposes or disintegrates. He thought about this question for quite a long time before answering and said '*I haven't really done it.*' He was referring to not having studied what happens to golf balls made of this substance when they are under water. Of course he had learned the necessary chemistry to answer the question but he did not realise this as the context was unfamiliar. In this case he mistook context for scientific content, indicating that he could not identify and apply the underlying scientific concepts to answer the question.

3c(i) When reading this question he raised his eyebrows and frowned a lot because he saw the bars for writing in the equation and wasn't sure how to fit the answers in. He reported looking back at the context on the previous page to work out what to put into the equation – '*I had to look back to see what would be relevant to put in there.*'

He began by putting 'glue' and 'paper' on the first two bars. As the context states 'These golf balls have an outer cover made from glue and paper.', he thought that these would be involved in the reaction. The only clues that indicate that they should not be included are the word 'inside' in the question, and the number of gaps, which could easily be misinterpreted.

He was then running out of space so tried to write 'sodium hydrogencarbonate' on one bar when he should have used two. When writing the right hand side of the equation he realised he now had more space than needed so he wrote 'sodium citrate' and 'carbon dioxide' over two lines as was intended by the examiner but then realised that 'water' would not fit over two lines – '*you can't break down water unless you break down the syllables can you?*' He felt he should fill all of the gaps because '*they'll be there for a reason.*'

3c(iii) He spent some time thinking about what this process was called although during the interview phase he had forgotten that this had taken him some time. Watching the video reminded him of this and he was able to explain why: '*It took me time to think what it was called. I knew I'd done it in GCSE … I didn't know if it would come back to me but it did.*'

3c(iv) He could not remember learning any other uses of these reactions, and thought he had not covered this in his syllabus so he left it blank without spending much time on it. To answer this question students need to identify that the reaction in the golf ball is a useful reaction between an acid and an alkali, and then to think of two other real world examples of this sort of reaction being useful. This involves going from one very specific example to a general point that can be applied to other examples. Transferring the ideas from this context is a difficult task because the context is so narrow.

Results of Pilot Case Study 2 (two students)

Question 4a In this question the context caused some anxiety at the start: *'That scared me a bit because I thought oh hospitals – I don't know anything about hospitals.' 'I saw the man in the bed and was thinking it wasn't much to do with science.'*
The illustration of the patient was also misleading: *'The patient looks quite fine and relaxed.' 'He looks happy and un-ill'.*
When answering the questions the students were using their everyday knowledge: *'I knew the tetanus one because my brother ran into a fence and messed his nose up and had to have a tetanus injection and my mum's a nurse so it helps.'*

4b(i) Again, they used everyday knowledge in the second part of the question ,*'I was pleased because I know that because I had a cold and had my temperature taken so I knew it.'* although this did cause some confusion as aspects of everyday knowledge can be misleading: *'When I do my temperature it's normally in Fahrenheit so it's much higher so I thought what's wrong with these people with low temperatures then I realised.'*

Question 5 *'I was scared by the funnel picture – I thought I don't know about funnels.' 'I did think to begin with I don't know anything about towers and stuff. There's a factory near my village and I thought of that.'*

5b Although they were initially distracted by the picture of the tower, they realised that the diagram was not relevant for answering the question and did not feel they needed to look back at it as the question does not tell them to. However, one of them did go back and check the answer: *'I just thought conduction, convection, radiation then I looked at it and thought it's conduction because it's through this thing … the material it's made of.'*

When asked about the diagram afterwards they said that sometimes they worry if there is a picture of something they have not seen before because they think they should be familiar with it. In fact this was a fictional tower, and many of the diagrams used to illustrate science questions are fictional. In this case the tower was given an unrealistic height of 1000m, although this did not affect these students: *'It didn't say anything about the height in the question so I didn't notice. If I had it might have been confusing.'*

Question 6 In this question the context was based around removing old paint from boats and this again inspired the students to start thinking about real-life issues: *'I was thinking oh no I need to paint my boat.' 'Would someone have that much paint falling off their boat?'*

The picture was also slightly unclear, and one student said the paint flakes *'look like icicles or something.'* which was perhaps prompted by the fact that very cold solid carbon dioxide was used to remove the paint.

6a *'It sticks and it's messy – I didn't know if that was scientific or not – whether to use common sense or just scientific principles.'*
6b(i) *'I was thinking sand paper then I was thinking when you cut yourself – abrasion.'*

Again, in these two questions, the issue of when to use common sense knowledge to answer contextualised questions was raised.

6b(iii) 1. The wording of this question caused confusion: '*It says use O to represent the carbon dioxide molecule and I was thinking O means oxygen and then I thought a circle – it's a* *bit confusing because it's a text thing rather than a shape and I was thinking of drawing a triangle shape and then I realised it was actually quite easy. It confused me a bit at first. I thought maybe put C for carbon too.'*

6b(iii) 2. and (iv) *'I didn't realise it was the same question from before and I was thinking where's this boat from? I'd done the whole particle bit and then it asks you a question that relates to the bit before – I was thinking about particles and stuff rather than the other bit of the question – it tests how well you've actually read the thing – it's reading comprehension…and the number 2 makes you think it's a different question.'*

In this case the boat context was used in the first few parts of the question, followed by a general question part about molecules. The student had lost track of the 'story' that was running through the question, and did not link this with previous parts.

The next question in this phase consisted of parts b(i) and b(ii) of Question 2 used in phase 1.

Question 2 The students' everyday knowledge was interfering when they were looking at the toothbrush context: *'I have that toothbrush almost. It's got a light.' 'It could electrocute her or something.' 'The toothpaste was scary – what does it do - runs around her mouth?'*

2b(i) The fact that there were glass fibres in the toothbrush led the students to expect to be asked certain questions about fibre optics which they were not in fact asked.
'I was thinking about total internal reflection – as soon as it said glass fibres I was thinking about the picture with the glass fibres where it bounces – you always get the same picture and you have to complete the lines.'
' I thought this was refraction and what materials are used for it and why glass fibres would be used in a toothbrush or when doctors use them inside people.'

In fact the question did not ask about fibre optics, but instead asked about reflection on a flat surface, and then moved on to energy transfer. This illustrates how students' expectations are influenced by context in a question. When the questions then violate their expectations they may be distracted from the task.

2b(ii) The energy transfer diagram caused the students difficulty as they were not sure whether to write in a type of energy or where it is transferred: *'It wasn't clear in the picture.'*
They felt that they knew the science but still did not know how to answer: *'Sometimes from the way the question is phrased you don't know what they want you to write.'*

Analysis of Scripts

An error analysis of the answers given by 199 of the students who answered these questions showed wrong answers to Question 2b(ii) that referred to the context. The question asked students to fill in an energy transfer diagram. The table below shows the categories of answers that were given to this question.

Types of answer	Number
Correct answer: electricity / electric (current) also accepted electrical / electrical energy	39
Answers containing 'bulb'	58
Answers containing 'light' but not 'bulb'	16

Answers containing ‘glass fibre / toothbrush’	7
Answers containing a type of ‘energy’ (not light)	26
Other incorrect answers	33
Not answered	20

Question 3a, asking how golf balls landing in the sea could harm fish, also resulted in a lot of wrong answers, many of which involved aspects of the context. The picture showed a fish with a bib round its ‘neck’, ‘holding’ a knife and fork in its fins. This picture of a fish distracted students from remembering that fish have gills not lungs, and do not breathe through their mouths and throats. The answer required was that the golf ball would cause digestion problems and block the fish’s gut. Answers referring to choking and throats were not awarded marks. The table below shows the types of wrong answers that were given.

Types of answer	**Number**
Correct answer: digestion/blocking gut	107
Answers containing ‘breathing’/‘choking’/’throat’	62
Answers to do with golf balls e.g. ‘hard ball’ ‘elastic bands’ ‘toxic’ ‘mud/fungi/bacteria’	20
Other incorrect answers	8
Not answered	2

The following are some examples of answers given by the students to this question.

Answers about breathing and wind pipes and choking:
‘It could break up their wind pipes making them unable to breath totally or obstructing their breathing...’
‘Because the golf ball gets stuck in the trout and stops them from breathing.’
‘It would block the air tube or wind pipe allowing them to choke.’
‘The fish could choke on them’
‘This could stop the fish from breathing.’

Other answers to do with the context:
‘Because the balls have been in mud which contains bacteria or fungi which isn’t good for anybody or anything.’
‘Golf balls are filled with elastic bands which could cause internal damage.’

This illustrates how an inappropriate context that does not fit in with the science of the question can obscure the ideas that the question is meant to be about. Most of the students will have known that fish have gills and cannot choke, but this knowledge was not available to them in this context. The cartoon picture of the fish was preventing them from accessing their schema for the biology of fish and instead activating their cartoon character schema in which animals and fish are just like humans.

Another question in which the context appeared to be interfering with performance was Question 5. The context of this question involved an idea for making fresh water in the desert. The diagram showed how this might be done, and contained a great deal of detail that was not relevant for answering the question. Part (a) asked about convection and part (b) asked for other ways heat is transferred. Part (b) was in fact a standard text-book question to which many students would know the answer if they recognised it as such. The fact that it occurred as a non-contextualised question part within a contextualised question prevented students from realising that they needed to step out of the context and answer it in the standard way. Many students answered in terms of the context, as can be seen in the table below.

Types of answer	**Number**
Correct answer: conduction/radiation	58
Answers containing ‘sun’ ‘solar energy’	3
Answers containing ‘wind’ ‘air’	14
Answers containing ‘desert’ ‘tower’	4
Answers containing ‘radiators/pipes/domestic heating ’	16
Answers containing ‘evaporation’ ‘condensation’	16
Answers containing ‘electricity’	8
Other incorrect answers	44
Not answered	36

Conclusions

The Video Protocol Method

The method of immediate post-hoc rehearsal in pairs using video was more successful than the single student method, and will be used in future studies. The pair of students verbalised more of their thought processes as they were able to talk comfortably and naturally to each other about what they had been thinking. Watching the video and hearing themselves saying the answers prompted them to explain why they had said certain things. The video also reminded them of which questions they had puzzled over and taken time over, and this again prompted discussion. The video provided an immediate and useful aid to the students’ recall. This post-hoc rehearsal method has advantages over a ‘think aloud’ method as it is less likely to interfere with thought processes at the time of answering the question. A less immediate post-hoc rehearsal method is also planned and this will involve interviewing students a few months after they have taken an exam containing contextualised science questions, in order to discover what they can recall about the questions. Their memories will give us an insight into which aspects of the questions they processed when answering them and how deep this processing was.

The two pilot phases of this study have allowed us to draw some preliminary conclusions about the way in which context affects the question answering process in science.

Schemas and Context

Some contexts are particularly likely to cause activation of incorrect schemas, as illustrated by some of the questions used in this study. The use of a cartoon of a fish 'eating' in question 3 distracted students from accessing their knowledge of the biology of fish which would have told them that fish have gills not lungs. Instead of a fish schema being activated it was the cartoon schema in which fish are personified, causing students to write about choking. The context used in question 5 also caused problems because it was unrealistic and fictional. One of the students expressed the worry that she had not seen this tower before. Students may see a context, for example a picture of such a tower, and wonder whether it was something they should have been taught about but somehow missed. This can lead to students thinking they cannot answer a question as they have not covered the topic. They are confusing the context with the scientific content of the question.

Also, in question 3, the student thought he could not answer the question about golf balls dissolving in sea water as he had not covered that topic. Fictional and unfamiliar contexts are particularly likely to cause students to miss out the question because they mistakenly think they do not know the science.

Students will assume that everything that is in the question is there for a reason and that the question forms a coherent whole. When faced with a context-free question part within a contextualised question, as in question 5b, many students failed to move their thinking out of the context and realise that this question required a simple textbook answer: conduction or radiation. They were attempting to answer the question within a 'tower in the desert' schema. The assumption that all information given is relevant caused problems in the desert question and also in question 2, the toothbrush question, as in both these cases most of the context was not needed to answer the question. Question 2 in fact turned out to be nothing to do with fibre optics although the context strongly suggested that it would be. This sort of expectation, set up by a particular context, can result in a conscious realisation that the question is not as expected, or can result more worryingly in a preconscious biasing (Evans, 1989) of the student's thought processes toward a particular type of answer.

Another effect context had in this study was that it caused the activation of everyday knowledge schemas and the students answered in terms of these rather than using more scientific concepts. Sometimes they used their everyday knowledge to inform their science but at other times their everyday knowledge misled them. When contexts correspond to real-world situations which students know something about it can cause them to be unsure whether to answer in terms of science or whether some of their everyday knowledge would also gain them marks. This occurred in question 6a which asked about the disadvantages of using oil to remove old paint.

As well as the potential dangers context can lead to, there is also evidence that context can make a problem more difficult (Kotovsky et. al., 1985) and reduce the amount of scientific reasoning that is occurring (Mevarech & Stern, 1997). Some evidence to support this was seen in the questions in which students answered in terms of everyday knowledge rather than science.

A science question that is written in a context often contains irrelevant information and this makes an added demand on students to select what is relevant to answer the question. There is a danger that this irrelevant information will bias processing of the question, causing activation of inappropriate schemas or schemas that conflict with those that should be activated by the science. This can result in students giving incorrect answers to questions which they might have answered correctly out of context.

The more able students may have developed a procedure for answering exam questions that involves ignoring irrelevant context and going straight to the question, without being conscious that this is what they are doing. A few others might make a conscious decision to ignore context. The less able students, who are unable to select only what is relevant, will answer in terms of the context rather than the science in the question.

Model of Question Answering

Three of the phases in the Model of Question Answering (Pollitt & Ahmed, 1999), the reading, searching and matching phases, will be affected if a question is set in context. As students are reading the question, schemas are activated and these will depend on context. These schemas set up certain expectations for what the question is about and how it should be answered. The processes of searching the mind for relevant concepts to use in answering the question and matching these with a representation of the question will therefore be vulnerable to interference from irrelevant concepts. Students are more likely to select inappropriate concepts to use in an answer when they are in an exam, as they are likely to be under stress due to high stakes and a time limit. By using context we risk losing control over the thought processes provoked by a question. The schemas that are activated by context will vary for different students and are less predictable than those activated by a question containing only science. If we lose control over what is occurring in students' minds then we risk decreasing the validity of the examination.

Assessing Science in Context

There are good arguments for using context in science education: it can make science seem relevant to students' lives. Even in assessment a good case can be made for the use of context. A familiar context could help students to answer a question. It also allows us to assess the ability to select what is relevant and ignore what is not, and to apply scientific ideas to various situations. However, if context is to be used it must be used with care in order to avoid the danger of biasing the processes occurring in students' minds. A more focussed context which is coherent with the science in the question, and which contains the minimum of irrelevant information, is preferable to a less focussed context, and less likely to activate schemas that interfere with the correct processing of the question.

Future work will involve experimental manipulation of the degree to which a context is coherent with the science in a question, in order to investigate the effects of this on the answering process and on performance, and to discover how context should be used.

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Observing Context in Action

Appendix

Questions 1 – 6

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Appendix – Questions 1-6 with answers in italics

1. Joy has an electronic pet game.

   Joy presses the buttons to keep it "alive".

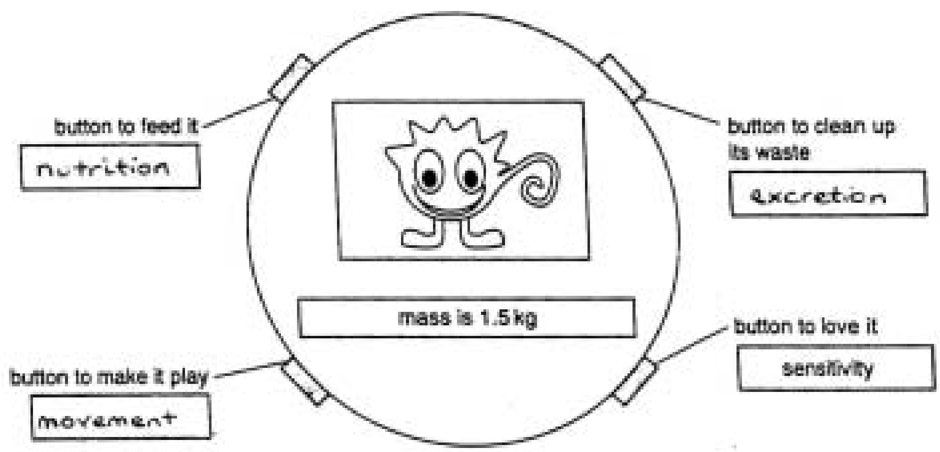
   Each button matches something that a living pet does.

   (a) Fill in the boxes to match each button.

   Choose from:

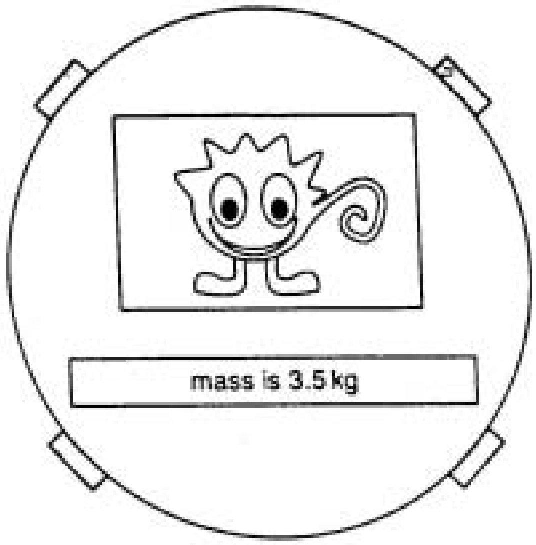
excretion growth movement nutrition reproduction sensitivity

One has been done for you.



[3]

(b) One day later the game looked like this.



(i) What is the difference in mass? ____*2* kg________ [1]

(ii) Which body process does this show?

_________*growth*_______________________________ [1]

[Total: 5]

2. Neil uses a new toothpaste.

The toothpaste contains a chemical which stops bacteria growing in his mouth.

(a) (i) How do bacteria reproduce?

cells divide/fission/mitosis

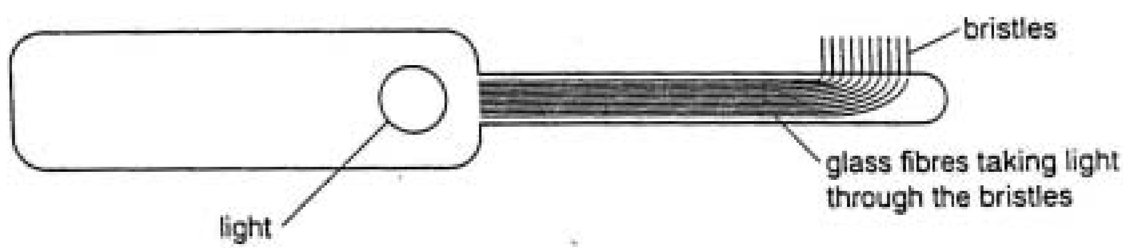
[1]

(ii) Suggest **two** reasons why bacteria reproduce very quickly in your mouth.

1 *warm*

2 *moist* [2]

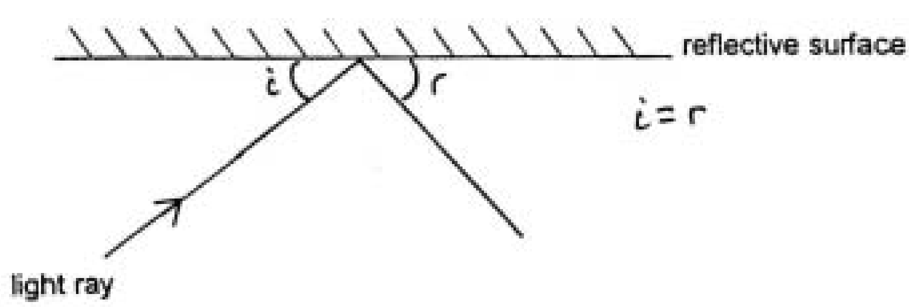
(b) Neil needs a special toothbrush



The chemical in the toothpaste is activated by light.

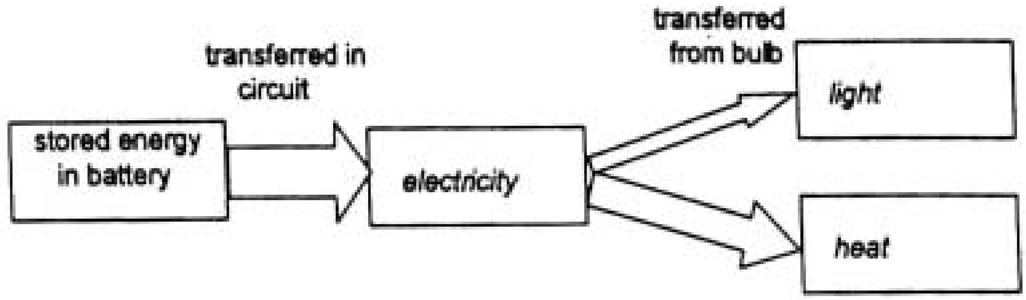
(i) Light travels through the glass fibres inside the toothbrush to the toothpaste.
Light is reflected at the surface of the fibres.

Complete the diagram to show how the light is reflected.



[2]

(ii) Complete the diagram to show how the stored energy in the battery is used to generate light in the bulb.



(c) The bulb used in the toothbrush needs a current (I) of 0.3 amps.
The bulb has a resistance (R) of 5 ohms.

(i) Write down the formula linking voltage, current and resistance.

V=IxR [1]

(ii) Calculate the voltage (V) of the battery.

0.3 x 5 = 1.5

Answer *1.5* Units *Volts* [3]

(iii) In the laboratory, which instrument could be used to measure the current flowing in the toothbrush?

ammeter [1]

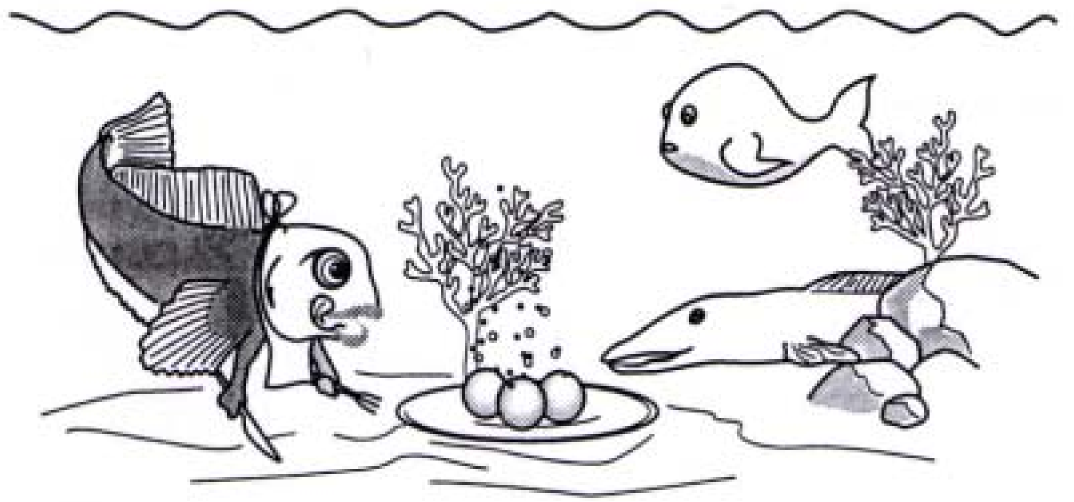
(iv) If the resistance of the bulb increased, what would happen to the current flowing in the toothbrush?

decreases [1]

[Total: 14]

3. Thousands of golf balls end up in the sea.

They are lost by golfers on seaside golf courses and on cruise ships.



(a) Fish sometimes swallow these golf balls.

Explain why this could harm the fish.

physical problem – blocking gut

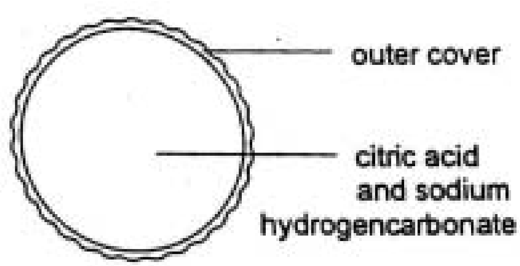
OR chemical problem – poison/toxic/cannot digest

NOT choking/throat/ breathing [1]

You can now buy golf balls which will dissolve in water

These golf balls have an outer cover made from glue and paper.

Inside is a mixture of two compounds, citric acid and sodium hydrogencarbonate.



(b) Explain the differences between a mixture and a compound.

mixture – more than one substance not chemically joined

compound – two or more elements chemically joined/bonded [4]

Water soaks through the outer cover of the golf ball.

The compounds inside react to form sodium citrate, carbon dioxide and water.

(c) (i) Write the word equation for the reaction inside the wet golf ball.

citric acid + *sodium hydrogencarbonate* ⟶

sodium citrate + *carbon dioxide* + *water*

[2]

(ii) Suggest why this reaction causes the golf balls to swell and break up.

releases carbon dioxide gas/increases pressure

[1]

(iii) The reaction inside the wet golf ball is between an acid and an alkali.

What is this type of reaction called?

neutralisation [1]

(v) Write down **two other** examples of useful reactions between acids and alkalis.

1 *soil/indigestion/stings/fertiliser/soap/salt*

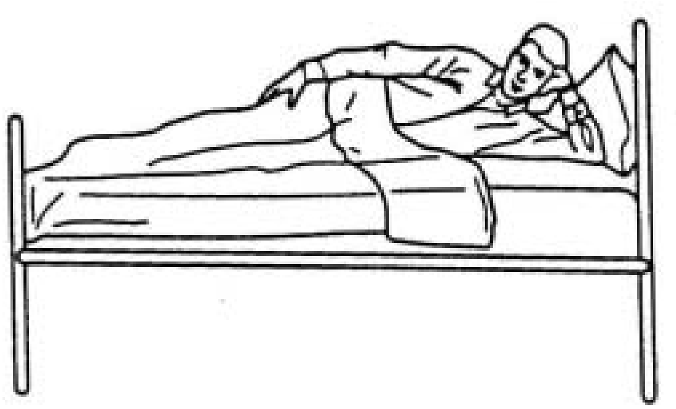
2 [2]

[Total: 11]

1. Notes on patients in hospital are shown on charts.

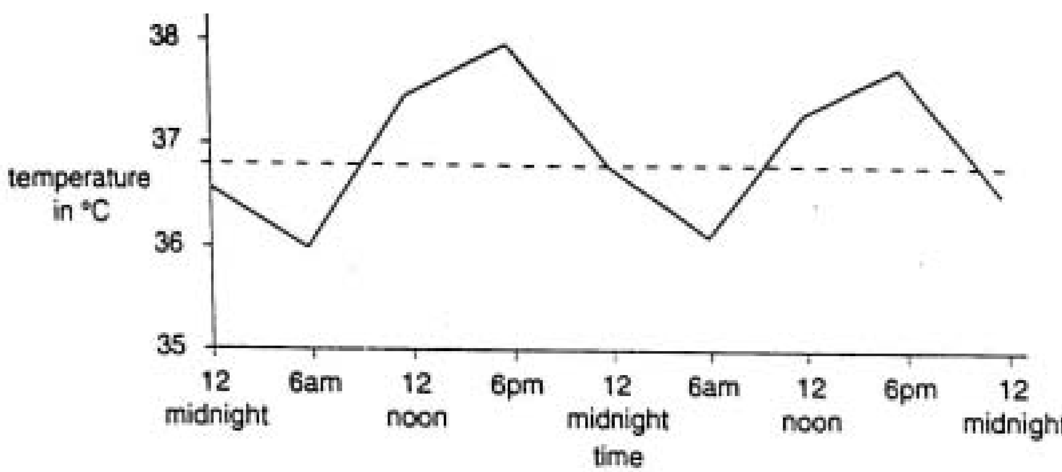
   The charts show the patient's condition and action taken.

   (a) Draw lines to match up condition and action taken.



condition **alveoli damaged by smoke**	**action taken** tetanus injection
condition **pancreas damaged**	**action taken** keep patient in a separate room
condition low numbers of white blood cells	**action taken** insulin injections
condition **cut leg playing football**	**action taken** use oxygen mask

(b) In hospital your temperature is taken regularly.



(i) There is a line drawn on the graph at 36.8°C

What does this line show?

_________*normal body temperature*________________________ [1]

(ii) Suggest why your temperature drops at night.

_________*asleep/lower metabolic rate*_____________________

____ [2]

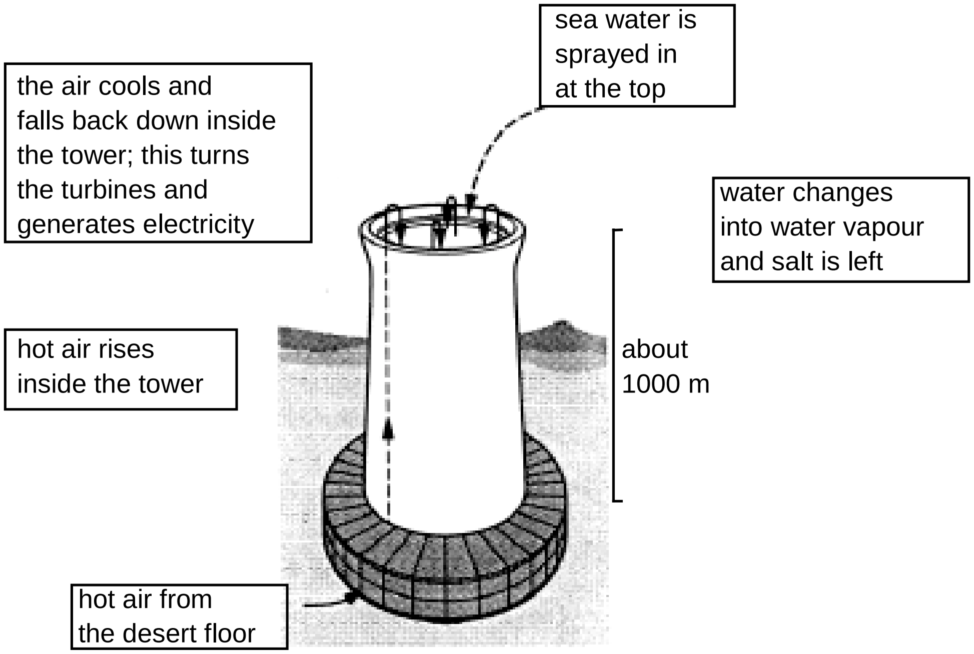
[Total: 6]

5. In desert countries there is a shortage of fresh water.

A scientist has suggested a new way of making fresh water from sea water.

Electricity might be generated at the same time.

The diagram shows the scientist's idea.



(a) Air rises inside the tower in a convection current.

Explain why convection happens.

_____*hot air particles move faster/more spread out*_____________________

____*less dense/lighter*_____________________________________ [2]

(b) Name **one other** way in which heat is transferred from place to place.

_____*conduction/radiation*_________________________________

[1]

(c) (i) Name the process which changes water into water vapour.

Choose from: **condensing** **evaporating** **freezing** **melting**

____________*evaporating*_______________________________ [1]

(ii) What must you do to water to make this process happen?

___________*heat/boil*_________________________________ [1]

[Total: 5]

6. (a) Old paint can be removed from machinery using solvents made from oil.

Suggest **two disadvantages** of using oil-based solvents.

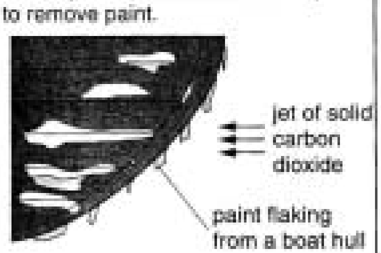
1 _____*flammable/toxic*_______________________________________

2 ____*finite resource*_______________________________________ [2]

(b) The following is taken from a newspaper article.

A New Process Developed

A new process has been developed to remove paint.



A fine jet of carbon dioxide is used to remove paint. The solid carbon dioxide particles act as an abrasive.

(i) What is meant by an **abrasive?**

_______*rough shaped particles/ wears away*_________________

____ [1]

The newspaper article continues.

Solid carbon dioxide is very cold.
When it hits the boat hull some of the solid carbon dioxide turns into carbon dioxide gas.
When paint is very cold it becomes brittle.
The carbon dioxide used is taken from the air.

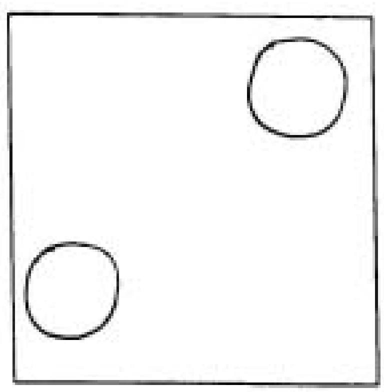
(ii) Solid carbon dioxide turns into gas.

Explain how this makes the paint become colder.

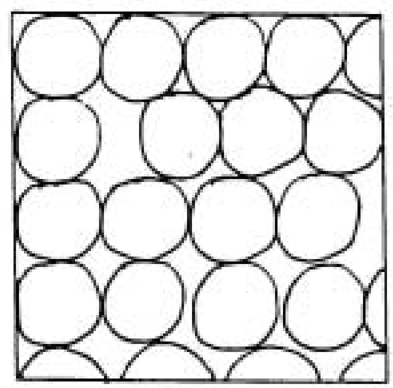
______*energy needed for evaporation, taken from paint*___________

[2]

(iii) 1. Draw diagrams in the boxes to show the arrangement of molecules in solid carbon dioxide and in carbon dioxide gas.
Use **O** to represent a carbon dioxide molecule



gas



solid

2. The solid carbon dioxide turns into gas behind loose flakes of paint. This pushes them away from the surface of the hull.

Explain why.

increase in volume when becoming gas

[1]

(iv) Carbon dioxide helps to cause the greenhouse effect.

Explain why this use of carbon dioxide does not make the greenhouse effect better or worse.

______*taken from air and returned to air*________________

____

____ [2]

[Total: 10]