preparation of pupils for the synoptic unit. However, it was also found that there was no such effect for the other two A2 units, one of which was coursework.

The Chemistry grade descriptors had been developed using examiners' expectations alone rather than based on empirical evidence. Nevertheless, our findings showed that grade descriptors can be important and helpful to teachers and can enhance classroom practice.

Conclusions

It can be deduced that, when resources allow, it is good practice to write grade descriptors based on empirical evidence. It seems that grade descriptors for different domains and types of questions can be written using a combination of a mastery levels analysis and Kelly's Repertory Grid technique. The grade descriptors developed using these methods describe the distinctive characteristics of achievement at particular grades.

Despite the difficulties of effectively communicating the meaning of grade descriptors to examiners, teachers, candidates and other stakeholders, it is good practice to make efforts in this area.

There is little research about how grade descriptors are used, or could be used, in relation to teaching GCSEs or A-levels, or in preparing pupils for assessments and there is room for further research in this area.

References

Cresswell, M. J. (1987). 'Describing examination performance: grade criteria in public examinations', *Educational Studies*, **13**, 3, 247–265.

Gipps, C. (1990). *Assessment: a Teacher's Guide to the issues*. London: Hodder and Stoughton.

Greatorex, J. (2003). 'Developing and applying level descriptors', *Westminster Studies in Education*, **26**, 2, 125–133.

Greatorex, J. (2002). 'Making Accounting examiners' tacit knowledge more explicit: developing grade descriptors for an Accounting A-level', *Research Papers in Education*, **17**, 2, 211–226.

Greatorex, J. (2001). 'Making the grade – How question choice and type affect the development of grade descriptors', *Educational Studies*, **27**, 4, 451–464.

Greatorex, J., Johnson, C. and Frame, K. (2001). 'Making the grade – Developing grade descriptors for Accounting using a discriminator model of performance', *Westminster Studies in Education*, **24**, 2, 167–181.

Greatorex J. and Malacova E. (in press). 'Can different teaching strategies or methods of preparing pupils lead to greater improvements from GCSE to A-level performance?', *Research Papers in Education*.

Kelly, G. (1955). *The psychology of personal constructs*. New York: Norton. Reprinted by Routledge (London), 1991.

Kingdon, M. and Stobart, G. (1988). *GCSE Examined*. London: The Falmer Press.

Massey, A. J. (1982). 'Assessing 16+ Chemistry: The exposure-mastery gap', *Education in Chemistry*, September, 143–145.

Oxford Cambridge and RSA Examinations (2000). OCR GCSE in Biology 1980, www.ocr.org.uk

Pollitt, A., and Murray, N. L. (1996). 'What raters really pay attention to', in M. Milanovic, & N. Saville (Eds), *Studies in Language Testing: 3 Performance Testing, Cognition and Assessment: selected papers from the 15th Language Testing Research Colloquium*. Cambridge: Cambridge University Press.

Qualifications and Curriculum Authority (2005). *GCSE, GCE, VCE, GNVQ and AEA Code of Practice 2005/6*. London: QCA.

ISSUES IN QUESTION WRITING

Can a picture ruin a thousand words? The effects of visual resources in examination questions

Victoria Crisp and Ezekiel Sweiry Research Officers, Research Programmes Unit

Introduction

Visual resources, such as pictures, diagrams and photographs, can sometimes influence students' understanding of an examination question and their responses (Fisher-Hoch, Hughes and Bramley, 1997). Visual resources are sometimes included to test students' abilities to interpret them, but they are more commonplace than this alone would warrant.

Research on the influences of graphics in instructional texts provides some relevant insights. Such research has often found illustrations to have a positive influence on learning and retention (Weidenmann, 1989; Ollerenshaw, Aidman, and Kidd, 1997). However, the main purpose of examination questions is to assess learning rather than teach. Graphics are thought to 'simplify the complex' and 'make the abstract more concrete' (Winn, 1989, p. 127). Graphics can also provide more information than can be explained in words (e.g. Stewart, Van Kirk and Rowell, 1979). These are justifiable reasons for including visual resources in examinations as they can reduce the length of questions and help students to access abstract concepts. In addition, illustrations are generally believed to have a motivational role in the context of instructional texts (Peeck, 1993) which could apply to examinations.

In their review of work in this area Levie and Lentz (1982) found that in about 15% of studies there were no significant effects of including illustrations. One possible explanation is that the quality and appropriateness of the graphic is important (see Peeck, 1987 for some evidence of this). Such failures have also been explained as either a result of students' learning styles (as Ollerenshaw, Aidman and Kidd, 1997 report) or due to students not processing graphics adequately (Weidenmann, 1989). The latter is thought to be a result of the apparent ease of processing an illustration, giving students the false impression

that they have fully understood an illustration when they have not (Weidenmann, 1989).

The main risks of including illustrations in examinations are that a graphic may lead to the formation of a mental representation of a question that does not match the meaning intended by the question setters, or that students may use a particular aspect of an illustration that was not intended to be important. When a student reads a question, a mental model is constructed as a response to the text (Pollitt and Ahmed, 1999). This representation is based on ideas that are already known to the reader (Johnson-Laird, 1981) and hence students' mental representations of the text (and any illustration) may not all be the same, perhaps emphasising certain aspects that are particularly salient to them. Most of this process is unconscious and automatic.

Visual resources are likely to play a large role in the development of the student's mental model of a question with more emphasis being placed on the ideas communicated by them than the ideas conveyed by the associated text. As Peeck (1987) states, "too much attention may be deployed to the illustrations themselves rather than to the accompanying text" (p. 118). There are a number of possible explanations for the apparent superiority of illustrations over text. Firstly, processing visual material may require less cognitive effort. According to Biedermann (1981) the general meaning of an image can usually be grasped in as little as 300 milliseconds. This may be because the elements of a visual resource can usually be processed simultaneously, whereas a text must be processed sequentially (Winn, 1987). Another perspective is that visual and textual materials may be processed in different cognitive systems. Paivio's (1975) theory of dual-coding explains the superiority of memory for images as a result of them being coded both as images and as their verbal labels whilst words are only encoded verbally, thus resulting in bias towards information gained from illustrations (Schnotz, 1993).

In general, placing information higher on a page will make it seem more important (Winn, 1987). However, there is also some evidence that visual resources are more likely to be 'read' and processed before accompanying text regardless of their relative positions (see Kennedy, 1974). It has been well documented that the first elements contained within a mental model will dominate and strongly influence subsequent elements (Gernsbacher, 1990). Hence the fact that visual resources are likely to be processed first means they will be likely to dominate the representation.

If visual resources do have a disproportionately large influence on the development of mental models, this has implications in examinations where students' ability to process material effectively is already compromised by test anxiety (Sarason, 1988). Students need to understand questions in the way intended in order to have a fair opportunity to display their knowledge and skills.

Method

525 students, aged 16 years, sat an experimental science test under examination conditions. The test included six questions involving graphical or layout elements. For most of the questions, two versions were constructed in order to investigate the effects of changes to visual resources on processing and responses. The questions were compiled into two versions of a test paper which were assigned to students at random. Twenty-seven pairs of students were interviewed after they had taken the test.

The predicted GCSE grades of the students were converted into scores from 8 points for a grade A* to 1 point for a grade G. The mean score for students attempting the test was 4.50 (N = 261, SD = 1.369) for version 1 of the test and 4.55 (N = 254, SD = 1.353) for version 2, suggesting that the two groups were very similar in ability.

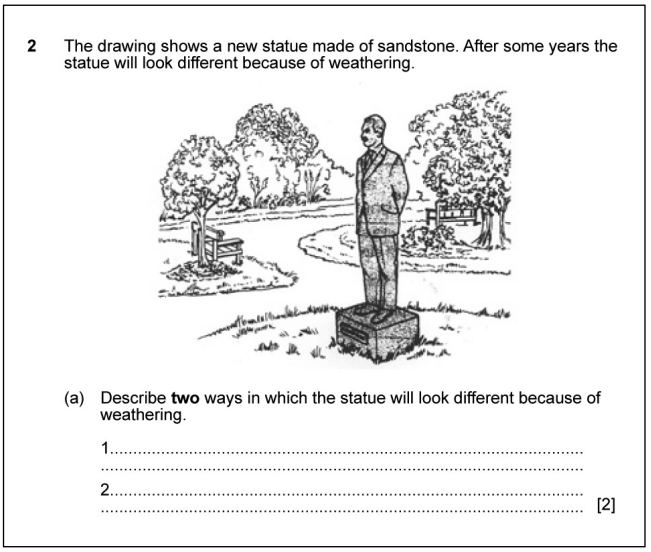
Results

For the purposes of brevity and interest four of the six questions will be discussed here.

Question 2 – Statue

This question was included to investigate the use students make of an illustration that is not essential. Answers such as 'discoloured', 'material worn away' and 'bits broken off' were credited. Responses referring to a named feature being altered were also accepted. Students did not necessarily need to use the graphic but it could help them to gain one of the marking points.

Students scored well on this question (85.5% of students scored both marks). There was a mixture of responses during interviews with regard to the illustration. Some said they found it useful, with slightly fewer stating that they did not find it of use or that it was unnecessary.


2 The drawing shows a new statue made of sandstone. After some years the statue will look different because of weathering.

(a) Describe **two** ways in which the statue will look different because of weathering.

1.....

.....

2.....

..... [2]

Positive comments included feelings of reassurance at having an illustration, and mention of how they could see that the statue had detailed features that might be lost. For example, one said, *it gave you an idea of what to pick out... Like you would lose a lot of detail on the person*. Some students held quite strong views that the graphic was unnecessary. For example, one claimed that *You don't even need the picture. I mean if you say a statue it could be of anything, it works the same way.*

There is also a possibility that the use of an illustration may affect whether students use scientific reasoning. One student commented, *I think if I didn't have the diagram there I would probably use more science instead of just saying its features won't be so defined.*

Another interesting comment supported the view that the inclusion of an illustration could reduce the amount of attention paid to the text: *it might lead you to look at the picture instead of the text so the answer might be wrong because you haven't read the text properly.*

Question 5 – Children's meal

Version 2 of question 5 included an unrealistically large sized portion of chicken nuggets in the visual resource to investigate whether the salience

of this might dominate students' thinking and lead to answers about overeating. Version 1 acted as a control.

No responses about overeating occurred with either version of the question and the marks scored on each version were very similar. Most of the interviewees who had attempted version 2 had not noticed the large portion size. In addition, most comments suggested that students were viewing the graphics as generic illustrations of the food types rather than as the actual meal. After the portion size had been mentioned by the interviewer, one student said, *It doesn't really matter though, it just shows, illustrates what it is but it doesn't really matter how much there is*. Several students made comments along the lines of, *I didn't really look at the pictures, I went straight to the ingredients*.

Additionally, the students who did notice the portion size did not use this in answering, perhaps not expecting an answer relating to quantity of food to be relevant in science. One student commented that *You're thinking about it as in science so it would be like the content in it not the amount*.

Question 5 : Version 1

5 Use the information below to help you answer the following question.

Children's meal		
Chicken nuggets		Chicken, wheat flour, maize flour, hydrogenated vegetable oil, salt, modified starch. Raising agents, mono calcium phosphate, sodium bicarbonate, sodium aluminium phosphate. Starch, spices, whey powder, pepper, dextrose, vegetanbe oil. Acidity regulator, calcium lactate. Emulsifiers, phosphate salt.
French Fries		Potatoes (cooked in our own vegetable oil) dextrose, Salt
Milkshake		Milk, skimmed milk, cream, sugar, skimmed milk powder, glucose. Stabiliser, guar gum, sodium polyphosphate, carrageenan and carboxymethylcellulose. Vanilla flavour.

Give **two** reasons why it would not be advisable for a child to eat this meal every day.

1.....
.....
2.....
..... [2]

Question 5 : Version 2

5 Use the information below to help you answer the following question.

Children's meal		
Chicken nuggets		Chicken, wheat flour, maize flour, hydrogenated vegetable oil, salt, modified starch. Raising agents, mono calcium phosphate, sodium bicarbonate, sodium aluminium phosphate. Starch, spices, whey powder, pepper, dextrose, vegetanbe oil. Acidity regulator, calcium lactate. Emulsifiers, phosphate salt.
French Fries		Potatoes (cooked in our own vegetable oil) dextrose, Salt
Milkshake		Milk, skimmed milk, cream, sugar, skimmed milk powder, glucose. Stabiliser, guar gum, sodium polyphosphate, carrageenan and carboxymethylcellulose. Vanilla flavour.

Give **two** reasons why it would not be advisable for a child to eat this meal every day.

1.....
.....
2.....
..... [2]

One student made an interesting comment in favour of including graphics in examination questions: *the use of pictures isn't particularly useful in trying to answer the question, but it's quite daunting on the day if all you've got is text and you've just got to read it, so maybe a picture would calm your nerves*.

Students, in the case of this question, seemed to know that they should not place emphasis on the information in the illustration.

Question 6 – Products

The word 'products' has a specific meaning in chemistry but a more familiar meaning might be that of 'household products'. Both are likely to be triggered in students' minds with question 6, although those with sufficient subject knowledge are likely to be able to suppress the irrelevant idea. The aim of including this question was to investigate whether the use of an illustration of some household products (in version 1) could affect the interpretation of the word 'products'. This would, of course, be undesirable in an examination but could occur by accident if care was not taken when choosing a visual resource. Version 2 acted as a more neutral control question.

Question 6 : Version 1

6 After eating a meal, your mouth becomes very acidic. This acid can damage your teeth.

[Part (a) omitted]

Brushing your teeth with toothpaste will neutralise the acid. This will protect your teeth from damage.

[Part (b) omitted]

Some brands of toothpaste contain sodium carbonate.

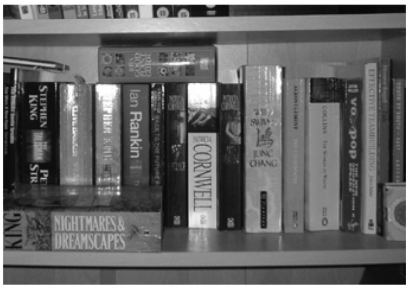
(c) Three products are made when sodium carbonate reacts with hydrochloric acid.

What are they?

1.....
2.....
3..... [3]

Question 6 : Version 2

6 The paper in modern books contains slight traces of acid. The acid in the paper can make it slowly decay.



[Part (a) omitted]

One method of neutralising the acid in books is to use sodium carbonate.

[Part (b) omitted]

(c) Three products are made when sodium carbonate reacts with hydrochloric acid.

What are they?

1.....
2.....
3..... [3]

In version 1, 9% of students gave answers such as 'shampoo' and 'soap', while only 1.5% of students gave such answers in version 2. The inclusion of the photograph showing household products in version 1 seemed to lead to the inappropriate meaning of the word 'products' being more likely to dominate students' mental models of the question.

Obviously students need to be able to cope with the chemical meaning of 'products' in science but it is important that the visual resources used or the context chosen are not such that they make such errors more likely.

Question 12 – Balance

In version 1 of question 12 the text states that end B moves down when weights are attached to the beam, but the beam is illustrated as horizontal. In version 2, the beam's realistic position is shown. The aim was to investigate whether students attempting version 1 might overlook the textual information since the diagram appears to supply the answer.

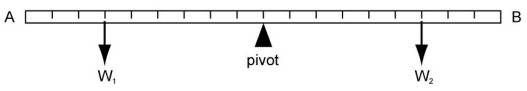
There was a statistically significant difference between marks on the two versions of the question (80.4% in version 1 and 98.8% in version 2 scored the mark, $F = 319.09$, $p < 0.01$). 16% of the students taking version 1 answered that the two weights were equal, suggesting that more attention had been paid to the diagram than the last sentence of the introduction.

Students clearly expected the diagram to reflect the answer. One student said, *That confused me because it's got the text saying one thing and the picture saying they're level*.

Question 12 : Version 1

12 A uniform beam AB is balanced at its midpoint on a pivot. Two weights W_1 and W_2 are then hung at equal distances from the midpoint of the beam.

When this is done, the end B moves down.



(a) Tick the correct statement.

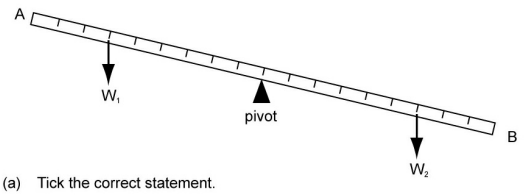
- ☐ W_1 weighs the same as W_2.
- ☐ W_1 is heavier than W_2.
- ☐ W_2 is heavier than W_1.

[1]

Question 12 : Version 2

12 A uniform beam AB is balanced at its midpoint on a pivot. Two weights W_1 and W_2 are then hung at equal distances from the midpoint of the beam.

When this is done, the end B moves down.



(a) Tick the correct statement.

- ☐ W_1 weighs the same as W_2.
- ☐ W_1 is heavier than W_2.
- ☐ W_2 is heavier than W_1.

[1]

Discussion

The analysis of the example questions in this study, along with others the authors have studied, suggest that two variables in particular play a decisive role in the effect of visual resources on the way examination questions are processed and answered. The first of these is the relative *salience* or prominence of the key elements. The most salient aspects of a question relative to the question as a whole are those that are emphasised in the student's construction of a mental model of the question. This degree of salience is to some extent determined by the idiosyncratic unconscious cognitive processing of students. However, as much as possible, the salience of certain aspects to students should match the aspects that the question setter considers important. Salience in examination questions can be increased by emphasising the feature in some way, for example by increasing its size, by using bold, or by including the element at the beginning of the question.

The student must also believe that the element is *relevant* to the answer. This decision is likely to be made at a more conscious level. One factor in determining this is past test experience, which provides expectations regarding under what circumstances visual resources are relevant. The type of illustration used and the context may also be of influence. For example, more technical diagrams, like the beam diagrams in question 12, were more likely to be used when answering than pictures or sketches.

The two variables were found to explain how the visual resources in the experimental test were used. For example, evidence from the interviews suggests that the size of the chicken nuggets' portion in question 5 was of average salience. However, relevance was deemed to be low, as students did not expect that portion size would be relevant in science.

Conclusion

The use of visual resources in examination papers can serve various positive purposes. However, the effects of illustrations are somewhat unpredictable and hence caution is required. It is important to ensure that, when used, visual resources are accurate and unambiguous. In addition, irrelevant information should not be included within a visual resource (except where selection skills are to be tested) as this may result in the wrong information being used. If a visual resource is not strictly needed in a question, the setter will need to balance the advantage that it may make the question seem less daunting against the possible risks that parts of the text may not be read thoroughly, or that a student may be led astray by an element in a visual resource that was not intended to be important.

Taking into account the salience and perceived relevance of visual resources can aid the prediction of their effects. The salience of aspects of visual resources will affect students' understanding of the question, and therefore the aspects that are key to the question should be the most salient ones in the question as a whole, whether they are presented in text or by illustration. If the key information is in the text, then any visual resource should support it rather than contradict or draw attention away from it.

Students have expectations relating to the type of visual resource used in a question, which may influence the kind of reasoning that they use. Evans and Over (1996) distinguish between two kinds of reasoning. What

can be called 'naturalistic reasoning' is innate, automatic and associative and is used in everyday functioning, whilst 'formal reasoning' is logical, controlled, reflective and learnt. It is the latter reasoning that examinations generally seek to assess. Evidence from questions 2 and 12 suggest that scientific diagrams are more likely to encourage formal reasoning, and naturalistic pictures are more likely to elicit naturalistic reasoning. Therefore the choice of type of visual resource also requires careful consideration.

This study constitutes a further stage in the collection of empirical evidence on the effects of features of examination questions on difficulty and validity. The information obtained from such research is used to inform training for question writers.

Further reading

The full report on this research can be found at http://www.cambridgeassessment.org.uk/research/confproceedingsetc

Acknowledgements

The question referred to as 'Question 2 – Statue' in this paper is reproduced by permission of QCA.

The question referred to as 'Question 5 – Children's meal' is adapted from GCSE Design and Technology: Food Technology 1460 paper 3, 1998 and reproduced with the kind permission of OCR.

The question referred to as 'Question 6 – Products' is adapted from GCSE Salters Science Double Award 1774 paper 1, 2000 and is reproduced with the kind permission of OCR.

The question referred to as 'Question 12 – Balance' is adapted from IGCSE Physics 0625 paper 2, 1999 and reproduced with the kind permission of CIE (University of Cambridge International Examinations).

We would also like to thank the teachers and students at the schools involved for their participation.

References

Biedermann, I. (1981). 'On the semantics of a glance at a scene.' In M. Kubovy and J. R. Pomerantz (Eds) *Perceptual organization*. Hillsdale, NJ: Erlbaum.

Evans, J. St. B. T. and Over, D. E. (1996). *Rationality and Reasoning*. Hove: Lawrence Erlbaum.

Fisher-Hoch, H., Hughes, S. and Bramley, T. (1997). 'What makes GCSE examination questions difficult? Outcomes of manipulating difficulty of GCSE questions': a paper presented at the British Educational Research Association Annual Conference. Cambridge: University of Cambridge Local Examinations Syndicate. Available from http://www.cambridgeassessment.org.uk/research/confproceedingsetc

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Erlbaum.

Johnson-Laird, P. (1981). 'Mental models of meaning.' In A. K. Joshi, B. L. Webber and I. A. Sag (Eds), *Elements of Discourse Understanding*. Cambridge: Cambridge University Press.

Kennedy, J. M. (1974). *Psychology of picture perception*. San Francisco: Jossey-Bass.

Levie, H. W. and Lentz, R. (1982). 'Effects of text illustrations: A review of research', *Educational Communication and Technology Journal*, **30**, 195–232.

Ollerenshaw, A., Aidman, E. and Kidd, G. (1997). 'Is an illustration always worth ten thousand words? Effects of prior knowledge, learning style and multimedia illustrations on text comprehension', *International Journal of Instructional Media*, **24**, 3, 227–238.

Paivio, A. (1975). 'Imagery and long-term memory.' In A. Kennedy, and A. Wilkes (Eds), *Studies in Long Term Memory*. London: Wiley.

Peeck, J. (1987). 'The role of illustrations in processing and remembering illustrated text.' In D. M. Willows and H. A. Houghton (Eds), *The Psychology Of Illustration, Volume 1 Basic Research*. New York: Springer-Verlag.

Peeck, J. (1993). 'Increasing picture effects in learning from illustrated text', *Learning and Instruction*, **3**, 227–238.

Pollitt, A. and Ahmed, A. (1999). 'A new model of the question answering process': a paper presented at the International Association for Educational Assessment Annual Conference. Cambridge: University of Cambridge Local Examinations Syndicate. Available from http://www.cambridgeassessment/research/confproceedingsetc

Sarason, I. G. (1988). 'Anxiety, self-preoccupation and attention', *Anxiety Research*, **1**, 3–8.

Schnotz, W. (1993). 'Some remarks on the commentary on the relation of dual coding and mental models in graphic comprehension', *Learning and Instruction*, **3**, 247–249.

Stewart, J. H., Van Kirk, J. and Rowell, R. (1979). 'Concept maps: A tool for use in biology teaching', *The American Biology Teacher*, **41**, 171–175.

Weidenmann, B. (1989). 'When good pictures fail: an information-processing approach to the effect of illustrations.' In H. Mandl and J. R. Levin (Eds), *Knowledge acquisition from text and pictures, Advances in Psychology 58*. Amsterdam: Elsevier.

Winn, W. (1987). 'Charts, graphs, and diagrams in educational materials.' In D. M. Willows and H. A. Houghton (Eds), *The Psychology of Illustration, Volume 1 Basic Research*. New York: Springer-Verlag.

Winn, W. (1989). 'The design and use of instructional graphics.' In H. Mandl and J. R. Levin (Eds), *Knowledge acquisition from text and pictures, Advances in Psychology 58*. Amsterdam: Elsevier.