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Constructing meaning from school mathematics texts: Potential problems and the effect of teacher mediation

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Abstract

Much current thought in linguistics asserts that during text comprehension meaning is constructed by the reader and triggered by the text on the page rather than there being a simple process of decoding the meaning. This research is predicated on the idea that text comprehension is a dynamic process and that the meaning of the text that is 'built' by an individual's mind may not always exactly match the meaning intended by the author and can be influenced by the reader's current knowledge, ideas and previous experiences.

In the context of education it is important that learners construct the intended meaning from teaching materials (e.g. textbooks and class handouts) in order that they understand new concepts correctly and understand classroom, test, exam and oral questions as intended so that they can show their knowledge, understanding and skills.

This pilot research looked at whether misinterpretations of texts occurred in a class of GCSE pupils during the study of one maths topic and sought to identify why any unintended meanings arose. Lessons were observed, textbook materials and handouts were collected as were copies of pupils' work. Some pupils were also interviewed about their study of the topic. Analysis revealed occasional constructions of meaning that did not match the intended meanings even within the study of one topic. The teacher's mediation of texts generally seemed to help pupils construct the intended meanings and helped to prevent any difficulties. This may mean that a teacher's awareness of possible misinterpretations is very important to the avoidance of such misunderstandings.

Introduction

Texts do not exist in isolation. They are part of a complex relationship between author, text, and reader. Early theorists thought that linguistic communication was solely a matter of information transfer requiring a simple procedure of coding by the transmitting person and decoding by the receiver. Theories of reading in recent decades have moved away from this view to the idea of making sense of language being a constructive process (see Pollitt and Ahmed, 1999). In such theories, meaning is built from pre-formed knowledge structures through an active (albeit mostly unconscious) process prompted by the linguistic input. Psychologists see text as provoking the reader to construct a coherent mental representation of a real or imagined world by triggering various ideas and structured frameworks that the reader already possesses (Johnson-Laird, 1983).

Cognitive psychologists tend to agree that various structures exist in the mind as a result of previous experiences. Minsky (1986) considered 'frames' the building blocks of memory consisting of hierarchical data structures for concepts with top levels that are essential to the concept but lower levels of typical but non-essential features. Minsky argued that these likely features are 'default values' which will be triggered if the frame is triggered and will lead us to expect certain things. Default values can be overwritten if the real data is available but are likely to be assumed where details are missing.

Schema-based theories are somewhat similar and have also commanded considerable attention. Schema theories argue that facts are not held in isolation in memory but that information is "gathered into meaningful, functional units" (Gerrig, 1988, p. 245). Schemata (Bartlett, 1932) are frameworks for a particular type of event or a particular context and include our expectations of what will be in that situation. Contexts and ideas presented in a text call up certain schemata which relate the ideas to one another (see Sanford and Garrod, 1981) and affect the mental representations that we construct. Usually a schema will help make sense of the linguistic input but sometimes errors occur when features of a stored schema become part of the mental representation of the text because they are compatible with the input from the text even though they are in fact inappropriate.

In the case of expository texts where the content is new to us, we cannot use memory structures which relate to content to help construct meaning from a textbook passage. However, it has been suggested that memory structures representing the most typical organisation of texts are used to guide our processing of expository text (Kieras, 1985, Meyer, 1985). Gerrig (1988) gives the example of how reading a phrase describing a function might lead us to expect the following sentence to describe a mechanism by which the function is achieved. If writers diverge from such conventional structures (e.g. not opening a paragraph with a statement of the main idea of the paragraph) then comprehension may be adversely affected (Gerrig, 1988).

Another point of relevance relates to the sequential nature of reading. As Garnham (1987) states "the context for the interpretation of the next

sentence in a discourse can be derived in a systematic way from the preceding context, together with the semantics of the sentence that has just been processed and knowledge about the world" (p. 137). In other words, as well as the reader's own schemata or frames, the interpretation of a new sentence will be influenced by the meaning of the previous one (where the reader expects them to be related). New input is fitted in with our construction of the meaning of the passage so far. Johnson-Laird (1983) argues that in order for us to build a single mental model (or mental presentation) the text must be coherent with links between sentences being possible (whether stated explicitly or not) and with ideas being compatible and not contradictory.

Gernsbacher (1990) defines 'memory cells' as representing previously stored memory traces. When they are activated by incoming stimuli information represented becomes available for cognitive use. Initial activation forms the 'foundation' of mental structures and information that follows which is coherent with the previous information, and hence activates similar memory cells, is mapped onto the developing structure. If subsequent incoming information does not activate similar memory cells and is less coherent, a different set of cells will have been activated which forms the foundation of a new substructure. As a result, most representations consist of several branching substructures. Careful structuring of a text can indicate when new structures need to be started. If the need for a new structure or substructure is not cued by the text, the meaning being constructed can be distorted due to the reader assuming continued relevance. According to Gernsbacher, at any time the cells that are currently activated transmit signals to enhance or suppress the activation of other cells depending on how useful the information they represent is to further structure building. This can also have consequences since if a particular element is considered more or less important than the author intended it to be, unhelpful ideas may be enhanced or useful ideas suppressed.

Memory structures such as schemata and frames will have developed as a result of each individual's own experiences. As a result, although there will be many similarities there will also be differences between different peoples' memory structures. These idiosyncrasies mean that there can be differences in the meanings that people construct from the same text. For example, Gerrig (1988) explains how because schemata are "abstracted over time from repeated exposure to a domain" (p. 262) experts in a particular area will have better generalisations or background knowledge to guide their comprehension of new elements of a domain or new problems within the same topic. As a result "expertise in a domain enables us to distinguish what is important from what is trivial and to commit to memory more easily information that is important" (p. 262). Gerrig also discusses how readers' different purposes or goals in reading a text will influence how they process it in terms of what they choose to focus on. For example, we would focus on different things if we knew we were going to be tested on our understanding of the content than if we knew we were going to need to be able to solve problems beyond the material actually presented.

This research is predicated on the idea that a reader's own knowledge contributes to the way that they understand text and that this may not always match the meaning intended by the author. In the context of education this

means that students may not always understand explanations in textbooks, what the teacher says, or a homework question in the way intended because their interpretation will be influenced by their own memory structures which are a result of their individual experiences. This would obviously be disadvantageous, especially since if a student thinks they understand something, they are unlikely to seek further information (Alexander and Kulikowich, 1994). If a student interprets a question in an unintended way, they will be trying to answer the wrong question and hence will automatically fail. This has been seen to occasionally occur in the case of exam questions (e.g. Pollitt and Ahmed, 2000).

Authors do not necessarily have complete control over the meaning that readers take from a text. Indeed much current thought in linguistics asserts that a text cannot have one single predetermined message (Forrester, 1996). However, some linguists would take the stance that a text will be interpreted in the intended way by a 'Model Reader' who shares the same assumptions as the author and this is reflected in the way that in most instances most people will build very similar meanings of the same text.

Underwood and Batt (1996) provide a useful summary of the ideas discussed above with their description of three levels of representation in the process of comprehending text. Firstly, visual perception occurs and words are recognised. Secondly, ideas or propositions are triggered by the words that have been seen. This propositional representation then draws upon the reader's knowledge to make sense of the information and this results in the construction of a mental model (Johnson-Laird, 1983). Previous knowledge provides a structure for the information and influences which information is perceived as important (Beck and Carpenter, 1986).

So what evidence is there about how specific features of texts affect comprehension? Alexander and Kulikowich (1994) found that some text features that were designed to assist, actually adversely affected students' understanding (e.g. inclusion of interesting but unessential details, use of analogies). Prins and Ulijin (1998) noticed how the sequencing and structure used could affect comprehension, with information placed early on being seen as more important, and that abstract or condensed information made a text harder to comprehend.

An added demand for students is that each school subject tends to contain some specific vocabulary and grammatical structures (Chenhansa and Schleppegrell, 1998). Students have to be able to understand and use this subject-appropriate language in order to learn the concepts of the subject. This can "present barriers to or facilitate learning" (Chenhansa and Schleppegrell, 1998, p. 55). Chenhansa and Schleppegrell discuss how scientific texts tend to use the passive voice and present concepts in such a way that processes are seen as central. This can lead to the use of dense, abstract language that is more complicated to comprehend.

There is also some relevant evidence regarding understanding questions and tasks. According to Bernardo (1999), understanding the task is the crucial first step to answering questions presented in words. Reading and forming a mental representation of the task is the first phase of Pollitt and Ahmed's (1999) model of the cognitive processing involved when students

attempt a question. They argue that a question will no longer make a valid contribution to assessment if a student misunderstands a task and attempts an alternative. In such a case control over what knowledge, understanding or skills are being measured has been lost and we can no longer trust the marks awarded to reflect ability. Bernardo found that some wrong answers to tasks were the result of misinterpretations of the questions due to abstract or ambiguous language, and not necessarily of lack of ability (Bernardo, 1999, see also Pollitt and Ahmed, 2000).

The aim of this pilot research was to study texts used for teaching in schools and how students interpret the content and learn as a result. In addition, the research sought to investigate whether students ever interpret text in ways that weren't intended by the author and if so why. A further aim was to consider the implications of the findings in order to inform text writers and test developers on material preparation issues and teachers on classroom practice.

Method of investigation

Participants

One class of Year 10 (14/15-year-old), middle-ability Mathematics students was studied. Mathematics was chosen as it is a compulsory subject and because textbooks tend to describe concepts partly in textual form and partly using mathematical notation that could place additional demands on students (Alexander and Kulikowich, 1994). Also, a substantial number of tasks are set in everyday contexts which results in them requiring substantial language comprehension (Prins and Ulijin, 1998).

There were 28 pupils in the class but it was only possible to obtain work from 24 of these due to absences. The school was chosen because it is a large comprehensive school, following a popular maths syllabus with a textbook designed specifically for the course. This was an attempt to obtain a typical case and increase the generalisability of the results. The class chosen was one of the middle-ability sets in the year group. It was planned that these pupils would enter for higher tier GCSE Maths and most were anticipated to achieve a grade 'C'. Middle-ability students were used, as they are likely to be fairly motivated but not overconfident in their abilities. This choice is supported by pilot work by Prins and Ulijin (1998) which suggested that middle-ability students would be most affected by issues to do with text comprehension. This choice of ability group also relates to typicality of cases since grade 'C' is one of the most commonly achieved grades at GCSE.

Data collection – Lesson observations

The data collection spanned four, fifty-minute lessons, over a period of one week and the study of one topic (congruency). The lessons were observed, with observation notes being made to record the content covered and any interesting occurrences with regard to the research focus. The observation notes from one of the lessons are included in appendix A as an example. It was hoped that observing lessons would help identify the cause of

any misconceptions that could not be accounted for by the text. Observation notes aimed to be objective with facts rather than views on occurrences being recorded as much as possible in order to avoid observer bias. Observer interpretations of the events were noted only tentatively. In order to minimise effects of observer presence, the researcher arrived at the classroom before the students and sat at the back. Both the pupils and teacher seemed unconcerned by the researcher's presence.

Data collection – Classroom materials and student work

Copies of all printed or photocopied materials used during the lessons were obtained. These consisted of copies of textbook pages used and other handouts provided by the teacher. Some linguistic and documentary analysis was carried out on these.

Photocopies of students' exercise books were obtained after the teacher had marked homework. The analysis considered how the students coped with the material and their understanding of concepts. The conceptions illustrated in the students' work were also considered with reference to the explanations included in the printed materials. The students' responses to particular tasks were coded by the kind of answer given.

Data collection - Interviews

Short, semi-structured, stimulated-recall interviews were carried out with five of the students after their study of the topic and after their work had been reviewed by the researcher. The interviews were carried out three days after the completion of lesson observations and were audio-taped with the interviewees' permission. The aim was to provide respondent validation of the analysis of their understandings. The semi-structured format was chosen to maximise validity and flexibility. Providing students with their work during the interviews was intended to help prompt recall.

The students who were interviewed were selected on the basis of their written work displaying evidence of unintended interpretations of text or general confusions. This sampling was not intended to be representative but to allow further investigation of the research focus. Students were of course given the option to decline being interviewed, however, none did so, suggesting that the interviews were not viewed as threatening. Students were informed that the interviews were confidential although their comments might be used anonymously.

The first two interview questions aimed to put students at ease and get them talking (e.g. *What do you think of maths?*). The questions that followed aimed to allow opportunities for students to mention any problems they had encountered with the topic (e.g. *How did you find the homework exercise?*) and to validate specific issues already identified from observations and students' written work (e.g. *How did you find using the notation that you have to use in this sort of work, such as 'triangle XYZ' or 'angle ABC'?*). A final question informed students more precisely of the focus of the research and allowed them to comment. Additional questions were added where

appropriate to encourage elaboration of responses. These questions aimed to bring to light any instances where students constructed inappropriate meanings from text perhaps due to misunderstanding text materials, misunderstanding something the teacher said, or not applying their full attention in the classroom.

One complete interview transcription is included in appendix B as an example. The interviews were analysed by the main issues raised with pupils' comments being related back to their written work and the text materials hence allowing identification of the reasons for any problems.

Results

Observation notes

The observation notes provided a record of the content covered, text materials used, notes written on the board by the teacher, and class and homework exercises completed. The essence of topic-relevant conversations that occurred between the teacher and individual pupils were also recorded.

In the first lesson the teacher introduced congruency using a handout and then went through a few examples orally with the class. In the next two lessons, after going through a few more examples from the textbook with the class, the teacher asked the pupils to work on some more questions themselves. There was no indication of any problems when the teacher explained the topic or worked through example questions orally asking pupils for contributions. However, once they started working alone, some seemed to experience difficulty. More than once the teacher explained to individual pupils (and later to the whole class) that more explanation of the reasons for their answers was needed, that they needed to spell out how they can tell that two angles or two sides are equal. Later, the teacher reviewed some of the questions attempted individually with the whole class, asking them for answers and reasons. Again it seemed that some were experiencing difficulties explaining in words why two angles were equal, for example. The pupils were also given a handout of questions as homework, which was returned and discussed in the fourth lesson observed. The teacher again pointed out that some students were still not giving enough justification and were making too many assumptions about which angles were equal.

Conversations with teacher

The teacher was very forthcoming and chatted informally after the lessons with the researcher. These conversations provided useful validation of observations. For example, the teacher was first to acknowledge that some pupils were struggling to explain their answers sufficiently. The teacher also pointed out that some pupils had difficulty constructing the diagram required as part of question 8 of the homework. Several pupils drew a regular quadrilateral (e.g. a square) rather than an irregular one and hence could not complete the rest of the question. The pupils' responses to this question will be considered later.

Conversations with the teacher were a useful unplanned method of validating findings.

Analysis of text materials

The introductory handout consisted of a photocopied section from the course textbook with some annotations by the teacher. Other parts of the textbook were also used, namely some worked through examples and some questions. The handout of homework questions was taken from a different textbook.

The introductory handout started by defining the meaning of congruency using some example congruent shapes. Four different ways in which triangles can be proved congruent are explained with the aid of diagrams, followed by a counter example. Various mathematical terms are used (e.g. 'rotated', 'corresponding sides', 'faces', 'vertices'). Most pupils of this age would be sufficiently familiar with these terms although together they make the sentences somewhat dense and abstract. The grammar used is natural and neither over-complex or over-simplified. Four codes specific to this topic are introduced, representing the four ways of proving congruency: SSS, AAS, SAS and RHS. The teacher had added a key for these that is likely to have aided the pupils (e.g. SAS = Side Angle Side). The use of diagrams to illustrate is likely to have been advantageous. Most research on the use of illustrations in instructional texts has found them to aid learning and retention (Schnotz, 2002, Weidenmann, 1989).

The rest of the section in the textbook consisted of exemplar questions and actual questions. Most of these require understanding and use of diagram notation such as 'triangle ABC', 'angle BAC' and so on, which could be a potential difficulty, in fact some hesitations in using these orally in class were observed. Again subject-specific vocabulary is used and the grammar used seems unproblematic. Overall the textbook extracts are not textually-dense and diagrams took up much more space. Several questions on the homework handout required pupils to draw the diagrams themselves. This could be, as has already been noted with question 8, an additional difficulty. Subject-specific vocabulary is used to describe the constructions (e.g. 'isosceles', 'quadrilateral', 'bisectors'). Again most pupils of this age will be familiar with these but any uncertainty could lead to difficulties.

The questions in the textbook and homework exercise were all very similar in format and aim. Pupils are asked to either determine whether two shapes are congruent and explain why, or to justify why two triangles within a more complex diagram are congruent. This common format probably reduced the risk of questions being misunderstood.

Carrying out this brief analysis of the texts involved was vital to the research.

Analysis of students' written work

The table below shows the numbers of students performing in certain ways on each question. The categories are mutually exclusive and were

derived from looking at pupils' work and the teacher's comments. Answers coded 'more explanation needed' were essentially correct but included insufficient justification.

Questions		Correct	Incorrect	Omitted	More explanation needed	Diagram incomplete/ incorrect
Classwork	**5**	20	3	0	1	n/a
	6	17	4	1	2	n/a
	7	17	6	1	0	n/a
	8	9	4	4	7	n/a
Homework	**1**	24	0	0	n/a	n/a
	2	15	9	0	n/a	n/a
	3	18	6	0	n/a	n/a
	4	22	2	0	n/a	n/a
	5	17	6	1	n/a	n/a
	6	18	6	0	n/a	n/a
	7	5	7	1	10	1
	8	8	3	5	0	8
	9	7	8	5	2	2
	10	7	4	6	7	n/a

Pupils appear to have done well on the questions completed in class (question 5 to 8 from the textbook), particularly the earlier questions. However, questions 5 to 7 were worked through by the teacher on the board after the pupils had attempted them so it is hard to know how much of them they completed successfully alone and how much was just copied down in retrospect. This could be the reason why the numbers of answers requiring more explanation were low on questions 5 to 7 but higher on question 8. Performance on similar questions for homework (questions 7 to 10 on the handout) was noticeably lower with only five students answering question 7 correctly, for example, whilst ten students provided insufficient justification. However, questions 7 to 9 require construction of diagrams from instructions, which may have increased their difficulty. Quite a few pupils experienced problems with constructing the diagram for question 8. The question states:

> ABCD is a quadrilateral and a line through A parallel to BC meets DC at X. If <D = <C, prove that ADX is isosceles.

Eight students completed the question correctly (although two of these initially drew an incorrect diagram). Others either left out the question or failed to construct the diagram correctly. This appeared to be due to the term 'quadrilateral' which was intended to mean an irregular quadrilateral. Students interpreted the term in different ways: some chose to use the quadrilateral with which they were most familiar (i.e. a square or rectangle) since the question seemed to be open for them to choose any quadrilateral; others, perhaps quite sensibly, assumed that if a regular quadrilateral had been intended, the question would probably have said so and hence drew irregular quadrilaterals. This difference in interpretation may well be a result of previous

experiences of exercise questions and from students having drawn more or less astute generalisations about what is usually expected. For students who drew a regular quadrilateral, this resulted in it not being possible to complete the rest of the question based on the first sketch. Unfortunately, some students gave up at this point and did not persevere and attempt the construction with alternative quadrilaterals. There were also issues relating to labelling the angles of the quadrilateral. For any irregular quadrilateral there are some positions for A for which a line through point A parallel to line BC will not cut line DC. This means that further trial and error may be needed to complete an appropriate sketch even when an irregular quadrilateral is chosen. It is also a requirement that angle C and D are equal which is a further demand in completing an appropriate sketch.

Since sketching a diagram from written instructions is probably a desirable skill in maths, practising this skill as part of non-assessed school work may be beneficial to learning. However, in a higher-stakes test situation this question would have led to some students losing credit regardless of their understanding of congruency which would be unfair. Clearer indication of the irregular nature required of the quadrilateral and also an instruction for angles C and D to be equal as part of the description of the shape rather than as part of the statement of the question would have improved the question and made students more likely to interpret it as intended. Students displayed fewer difficulties with the other questions involving diagram construction.

Questions 1 to 6 were well answered as students were only required to state whether pairs of triangles were congruent and to provide a reason in the form of one of the three-letter codes (e.g. SAS).

Analysis of interviews

The students interviewed were chosen because they either appeared to have had difficulty constructing a diagram (e.g. on homework question 8) or because they did not provide enough justification in some of their responses to questions. This choice aimed to allow validation of issues already identified.

The views expressed during the interviews were mixed. Two students reported feeling confident when in the classroom but less so when it came to attempting the homework task. One said *I thought it was fine until we got to that homework then it wasn't fine after all*. In one case this was attributed to having teacher help available: *It's nice having the teacher there as you know you've got someone to rely on.* This raises the important issue that when dealing with texts in the classroom, students do not do so alone. The teacher in fact mediates the students' processes of constructing meaning and even when they work individually the teacher is available to respond to questions. Bruner's (1985) ideas about how adults 'scaffold' pupils' learning by providing supportive dialogue are relevant here. Scaffolding can mediate between direct experience of a text and the acquisition of understanding (Edwards and Mercer, 1987) by providing organisation for new concepts and relating ideas to other experiences. In the classroom context, meaning can be seen as socially constructed.

Two students expressed difficulties in writing down proofs. One said: *It was quite hard to explain it. I worked out how they were the same but I didn't understand how to actually write that down in words.* The written work of these particular pupils showed evidence of incomplete justifications. There was also confirmation of the difficulties experienced with drawing the diagram for question 8 of the homework:

> *That one I didn't understand, where it said quadrilateral I just drew a square. And then when I read the instructions it didn't fit in. And I didn't really know how I was going to do that one.*

The interviews proved useful in validating observations and getting an impression of how the students felt about the topic. However, it was difficult to focus the questions on how meaning is constructed from texts since most of the processing involved in text comprehension occurs at an unconscious level and hence are not easily available for personal reflection. It may have been useful to ask students to explain congruency during the interview to gain further insight into their understanding of the topic.

Discussion

Encouragingly there was no strong evidence of misconception in terms of the topic content. It seems that pupils grasped the basic idea of congruency (as evidenced by good work on questions 1 to 6 of the homework). Not all pupils were competent at providing complex justifications i.e. more than just stating SAS for example. This could be because this was not covered in the initial handout and was only explained later by Example 6 in the textbook. In addition, the justification in the example consists mainly of abstract codes for the sides and angles of shapes, which are perhaps difficult to understand at first glance. For example, making sense of 'AC = CY' or '<ACQ = 90^o + <ACB' requires looking for each letter in turn in the diagram to discover the location of each referent and hence of the line or angle in question. It seems that pupils did not internalise this justification method as a model for their work, and only viewed it as an example. This is not so much a case of constructing a meaning of the text that is different to that intended by the author, but of not realising the intended purpose and significance of the example. Ideally, the text needed to more clearly indicate to students that this example provides a model of how to show proof of congruency and that providing such explanations is an important part of answering questions of this nature. Understanding tasks was generally not problematic although there was evidence of difficulties in constructing diagrams in one instance where there was ambiguity due to a particular technical term.

The generalisability of this pilot work is fairly low since only the study of one topic by one class was researched. However, the textbook involved was a popular one and there is no reason to suspect that the participants were atypical in any significant way. Further similar work looking at the study of a range of subjects and topics across a number of schools and ability levels would provide further, more generalisable insights into how pupils' minds construct meaning from educational texts.

One finding from the pilot study was that the teacher's mediation of the classroom texts seemed to reduce the likelihood of students constructing unintended meanings. Given the potentially important role that this may play in students' learning, this should also be investigated in any further research. Teacher-pupil dialogue could be analysed in detail to investigate strategies used by teachers and hence their contribution to pupil understanding. This could provide teacher trainees with possible strategies to aid pupils in constructing meaning from texts. Asking students to carry out a pre-study task involving reading textbook extracts and answering exercise questions in isolation may be an advantageous method to allow comparison between learning directly from text and learning facilitated by the teacher. The construction of unintended meanings may be more frequent in isolated conditions (e.g. homework and exams) than in classroom situations since mediation between text and learner by the teacher seems to reduce problems. Also, the forming of a mental representation of a task that does not match the intended meaning is less likely in classroom and homework than in a test or exam since the questions are more often all of a similar type because they are set to aid learning of a single topic and to practice a certain kind of task. Bringing together ideas from cognitive research and from a sociocultural perspective will be a necessary part of gaining a fuller understanding of how meaning is constructed from school text materials. Work by de la Mata and Santamaría (2001) on how interactions with teachers may facilitate the development of strategies for understanding texts has started to do this.

It cannot be concluded from the pilot study how frequently the meanings that students construct from educational texts deviate from the intended meanings since we only have evidence from the study of one topic. However, this pilot research along with previous research evidence suggests that well-structured, clear and specific text materials, illustrated where appropriate, with sufficiently emphasised key points, combined with teacher mediation, may act to reduce the risks of unintended meanings being constructed. Further work, as described, could improve generalisability, help to further understand the process by which teachers mediate pupils' understanding of texts and identify good practice in text preparation to avoid the formation of unintended interpretations.

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Appendices:
Appendix A: Observation notes from one lesson

Lesson 2 8.45 - 9.35 a.m.

8.48	Pupils start arriving
8.52	Teacher directs them to p.49 question 2(b)
8.53	Teacher talks through question and asks for their answer Asks one pupil R. bit of a pause then gets answer right with reasons.
8.55	Teacher asks which rule proves this.
8.56	(Lost info sheet returned to its owner) Teacher directs them to part (c) and asks them for the answer. Correct answer given.
8.57	Pupils to do questions 5 to 8 p. 50-51. Directed to sketch shapes and label sides and angles, using letters to identify equal sides.
8.58	Pupils are quietly starting this
9.01	Teacher is talking to one student – explaining that more explanation of the reasons is needed. E.g. have to spell out that AB = BC etc.
9.04	Misprints spotted and brought to class' attention by teacher: EDC should read EBC Second Q6 should read Q8
9.05	Teacher goes through question 5 to make sure they've got it. Explains this one to them rather than asking them for their answers.
9.06	Pupils continue with individual work. Teacher is explaining to another boy that they have to write out their reasoning. General chatter and individual work going on.
9.09	Several hands up. (Are they hitting a stumbling block?)
9.10	The teacher tells one student that they need to think about question 6 more. They don't know that the third length is equal. They have to prove it. Individual work continues.
9.13	Teacher goes through Q6 on the board. Asking them to point out angles or sides that are the same. Draws out diagram. AC=AD BD = CE "$\angle$BCA = 180º – x $\angle$ADE = 180º - x BC = BD – CD DE = CE – CD BD = CE => BC = DE ΔABC and ΔAED are congruent (SAS)" Pupils then continue to work in the rest of the questions.
9.18	Teacher emphasises to them all that they need to explain why angles or sides are equal. Pupils continues with next questions
9.23	Teacher refers to Q7. Tells them a clue: they are looking for SAS. Pupils continue
9.26	Teacher comments again on Q7. 'You've got 2 sides, you know which angle you're looking for, write on everything you know.'
9.29	Homework announced to be finishing Q8 and a doing a worksheet of questions *(Sheet 2)* Teacher works through Q7 on the board asking the pupils questions

	as goes along. Draws diagram Teacher had told them that SAS so they need to prove that "$\angle$ABD = $\angle$EBC $\angle$ABE = 180º – 2x $\angle$DBC = 180º – 2x" Some muddling over labelling the angles correctly when responding to teachers questions. They seem to find it hard to explain appropriately that two angles are equal even when they know it. One student attempts: "take away the middle bit" is getting at the right idea.
9.36	Homework explained again. P.51 Q8 and handout Q1 to 10. Told that they have to draw their own diagrams for Q7 to 10.

Appendix B: Example interview transcript

Interview 3
(R=Researcher, P=Pupil)

R: What do you think of Maths?

P: I think it's OK I normally find some bits better than others. I think I've improved a lot recently ( )

R: Is there anything particular that you like or dislike about it?

P: I quite like, I'm not keen (.), I like algebra where you have to work out x and all that. I don't like it if it's written out as a question. I like if it's written out in numbers and like the letters. I don't mind it but if it's like as a question then you've got to form it into numbers.

R: So you find equations easier to understand?

P: Yes

R: What did you think of the topic you've just covered, on congruent triangles?

P: I found it really difficult. I don't think I'm very good at working out (.) seeing where they match.

R: So you don't feel very confident?

P: No

R: Here is the homework you did and the questions you answered. How did you find this homework exercise?

P: I found some of them, these ones (were ok) [Q1 to 6] with the triangles. And some were more difficult. I think it just depends.

R: Did you experience any difficulties?

P: That one was ok. I think it's just where you're finding which lines (are equal). I think it's just having to write it down. I could see where it is but it's just writing it down and proving. But I found it, I found that quite easy. ( ) I think I didn't really understand what that was, that one.

R: With some of these questions you had to draw the diagrams yourself. Did you find that ok?

P: No, that one I didn't understand, that one [Q8], where it said quadrilateral I just drew a square. And then when I read the instructions it didn't fit in. And I didn't really know how I was going to do that one

R: And you found the others ok? You could understand what you needed to do?

P: Yes

R: How do you find using the notation that you have to use in this sort of work? Such as 'triangle XYZ' and 'angle ABC' and so on?

P: Well, yeah I find it ok because I know that it's the angle (at the middle letter).

R: And how do you find coping with the special words that are used in maths like 'congruency' and so on?

P: I tend to forget about them. Yes they have things that are really similar ( ) which gets confusing. And on those ones I didn't understand that side angle angle, side side angle, ( ).

R: Ok. Now the other topic you've been doing is line graphs of inequalities and finding certain regions. How did you find that topic? Was it OK?

P: Yes it was really. I didn't really understand that sort of thing before, but once I saw it written out with numbers it was a bit better ( ).

R: What I'm particularly interested in is how students learn from using texts, like textbooks, homework questions and so on, and how they understand questions. How do you usually find this? (3 secs)
Is it always nice and clear?

P: Yes most of the time its ok and I can do it all. I suppose quadrilaterals there was the square ( ) But normally I think it's quite ok.

R: Good. Is there anything else you'd like to comment on?

P: No

R: OK that's great. Thank you very much for your help.

Key:

(.)	short pause
(3 secs)	timed pause
(were ok)	transcription uncertain - guessed
( )	unclear speech – couldn't be transcribed
[Q8]	pupil was referring to question indicated