Local text cohesion, reading ability and individual science aspirations: key factors influencing comprehension in science classes.

Abstract

In response to the concern of the need to improve scientific skills of school children, this study investigated the influence of text design (in terms of text cohesion) and individual differences, with the aim of identifying pathways to improving science education in early secondary school (Key stage 3). One hundred and four secondary school children (56 females, 48 males), aged 12 – 13 years took part in the study. To assess the influence of local cohesion (lexical and grammatical links between adjacent sentences) in science texts, we measured students’ comprehension (by multiple choice questions) of science text that was high and low in local cohesion. To explore the role of individual differences students completed tests to measure general reading ability, general intelligence, facets of conscientiousness, science self-concept and individual, friends and family aspirations in science. Students were more accurate in answering the comprehension questions after reading text that was high cohesion compared to low cohesion, suggesting that high local text cohesion improved students’ comprehension of science text. Reading ability predicted increased comprehension from both text designs. Individual aspirations in science accounted for unique variance for comprehension from high cohesion texts. Implications for the teaching of secondary school science are discussed.

Keywords: text cohesion, individual differences, reading ability, secondary school science
Introduction
There is growing recognition of the crucial role of developing scientific literacy to improve science education, and in encouraging young people to study science to an advanced level (e.g. Norris & Phillips, 2003). Student interest in science declines from approximately 11 years of age (the start of secondary education; Key Stage 3), with one of the main causal factors being the quality of educational experience (Osborne, Simon, & Collins, 2003). Given that students spend two-thirds of their lives outside of formal schooling there is also increasing awareness of the need to understand the contributions of the attitudes and involvement of family and friends in determining science interest and attainment (Science Education in Schools Report, 2006). With the aim of developing pathways to improving science achievement in secondary schools, we investigated beginning secondary school students’ comprehension of science text in a classroom exercise by focussing on two key areas: 1) the influence of text design, 2) the role of individual differences, including beliefs and attitudes. More specifically, we examined the role of local text cohesion in text designs. Local text cohesion can be defined as the presence (high cohesion) or absence (low cohesion) of lexical and grammatical cues which enable the reader to link meanings across adjacent sentences.

Comprehension of Science Text
Successful comprehension relies on reading skills, such as letter identification, accessing word meaning (Perfetti, 1985) and the integration of individual word meanings into a coherent representation of the sentence (local text cohesion) (Vellutino, Scanlon, Small, & Tazman, 1994). The ability to integrate sentences promotes the development of a coherent text representation necessary for sound comprehension (Kintsch, 1998). As such, the ability to integrate the meanings
between sentences in science text is likely to be important for successful
comprehension, and therefore science learning. Accordingly, we chose to explore the
effects of local text cohesion in determining science comprehension.

Text cohesion refers to the extent to which the text supports the reader in
establishing a coherent understanding of the text. In high cohesion text, the text itself
is sufficient for the reader to obtain a coherent representation of the arguments. By
comparison, low cohesion text requires the reader to generate inferences that go
beyond the information provided in the text in order to achieve a coherent
representation of the meaning of the text (see McNamara, Louwerse, McCarthy, &
Graesser, 2010). Our rationale for focusing on text cohesion derives from analyses
showing that science textbooks are frequently of low text cohesion, with regular
omissions of information that may be crucial for achieving accurate comprehension
(Beck, McKeown, Sinatra, & Loxterman, 1991). Such information includes the use of
linguistic devices which provide explicit links between sentences. For example,
studies have shown that text comprehension can be improved by adding cohesive ties,
including elaborating on concepts, replacing ambiguous pronouns with nouns, and
adding connectives (‘and’, ‘because’) (see, e.g. Beck et al., 1991; Ozuru, Dempsey,
& McNamara, 2009).

Modulations of text cohesion can be further illustrated by examining the text
used by Ozuru et al. (2009) in an extract ‘Heat Distribution in Animals’. For instance,
they repeated the terminology ‘warm blooded animals’ in high cohesion text, but used
‘them’ (pronouns) and ‘mammals’ (ambiguous noun) to refer to these animals’ in low
cohesion text. The authors used ‘because’ (connective tie) in high cohesion texts to
explain why some warm-blooded animal allow their body temperature to drop,
whereas in low cohesion text they just stated the facts without a causal connection.
Additionally, they elaborated on concepts in high cohesion text (e.g. by stating that blood vessels are part of the animals circulatory system) but not in low cohesion text. The use of extra connectives and elaborating on concepts produces a longer text when it is a high cohesion design compared to a low cohesion design. Furthermore, by avoiding the use of pronouns, high cohesion text typically contains a greater degree of repetition than low cohesion text.

When links between sentences are not explicit (low cohesion design), the reader has to infer the relationships between different linguistic expressions (e.g. that ‘them’ refers to ‘warm blooded animals’) and this can cause comprehension difficulty (Grasser, McNamara, & Louwerse, 2003). In these situations the reader must dedicate more processing effort in order to comprehend the text, relying on activating memory traces relating to the previously read text sections as well as reasoning activities (Kintsch, 2009; Long & Lea, 2005), and so impairing comprehension. Increasing text cohesion has beneficial effects on adults’ comprehension of both narrative (e.g. Beck, McKeown, Omanson, & Pople, 1984) and expository texts (e.g. Linderholm, Everson, van den Broek, Mischinski, Crittenden, & Samuels, 2000). The effects of text cohesion on comprehension is typically assessed through the use of multiple-choice questions (MCQs) or short answer questions (e.g. McNamara, Ozuru, & Floyd, 2011; Ozuru, Briner, Best, & McNamara, 2010; Ozuru et al., 2009). These measures allow the researcher to directly explore specific aspects of comprehension (e.g. the links made between two sentences) which may not be possible with open-ended style comprehension questions.

More recently, investigations have begun to look at text cohesion in college-aged students’ science text comprehension and found similar increases in comprehension with greater text cohesion (Ozuru et al., 2009). However, only a few
studies have looked at text cohesion with younger school students (Best, Ozuru, Floyd, & McNamara, 2006; McNamara, Ozuru, & Floyd, 2011) and these reports suggest that text cohesion does not significantly improve science comprehension at this age. Both of these two studies used an age range of 9-11 years, focussing on children at the end of primary school (Key Stage 2), rather than the start of secondary education (Key Stage 3), leaving this latter age-group surprisingly under-investigated.

In summary, the cohesive structure of text designs appears to play an important role in determining levels of comprehension. These effects have primarily been investigated in older school students, but may also be important factors for determining comprehension in young secondary school students. Additionally, in secondary school education other factors should be considered in relation to science learning, including individual differences which have been identified, as modulating text comprehension and achievement.

The Role of Individual Differences

Previous research suggests that a number of individual differences variables, focussing on levels of literacy, intelligence, personality and social influences, relate to an individual’s capacity and aptitude for science learning (e.g. St George, Mannes, & Hoffman, 1997; Primor, Pierce & Katzir, 2011; Chamorro-Premuzic & Fumham, 2003). Examining these individual difference variables in relation to the comprehension of texts with varying levels of cohesion could provide valuable insights into specific approaches that may be central to promoting science text comprehension and therefore science achievement.

Individual reading ability is an important factor in determining text comprehension (Just & Carpenter, 1992; St. George et al., 1997). Reading skills, including word decoding and vocabulary have been shown to be strong predictors of
comprehension (Schatschneider, Harrell, & Buck, 2007), with some children who
have difficulties in reading comprehension demonstrating poor vocabulary skills
(Catts, Adlof, & Weismer, 2006). Reading skills help readers to relate concepts, from
different parts of the text, via inferential processes (Daneman & Hannon, 2001). By
relating concepts within the text, readers can form a cohesive representation of the
text, suggesting that there should be a relationship between reading skill, text
cohesion and subsequent comprehension. Whilst poor reading ability reduces
comprehension (Cain & Oakhill, 2004), the interaction between reading skill and text
cohesion in influencing comprehension of text is not linear. For instance, only skilled
readers are thought to benefit from reading high cohesive texts (Ozuru et al., 2009;
O’Reilly & McNamara, 2007). It has been suggested that this reflects the increased
density and complexity in reading text which is highly cohesive (Beck et al., 1991;
Ozuru et al., 2009). It is clear that to date, the relationship between reading ability and
text cohesion is not well established, especially as reading ability can be determined
by a large variety of skills, including word decoding (Perfetti, 1985), syntactic
knowledge and inferential abilities (Oakhill & Yuill, 1996).

There is conflicting evidence as to the importance of general intelligence in
mediating reading comprehension. Oakhill, Cain and Bryant (2003) report that
although IQ (a measure of general intelligence), is related to comprehension abilities,
other skills are more significant, including the ability to integrate text, metacognitive
monitoring and working memory. Additionally, children with lower IQ scores do not
have reliably lower scores of reading ability; likewise, children with higher IQ do not
consistently achieve higher scores on reading ability tests (Meyer, 2000). More
recently, research has investigated whether general intelligence interacts in a similar
manner with the comprehension of narrative and expository text. Primor et al. (2011)
reported that scores on Ravens Matrices predicted comprehension on both text-types for participants with reading disabilities; however, scores on Ravens Matrices only predicted comprehension of narrative texts for participants without reading disabilities. Whilst this study was conducted with Hebrew speaking adult readers, similar effects have been reported with English speaking children (Tiu, Thompson, & Lewis, 2003).

Studies have also shown a relationship between personality and academic achievement. Personality traits of openness to experience and conscientiousness are significantly related to academic achievement (Chamorro-Premuzic & Fumham, 2003; Robinson, Gabriel, & Katchan, 1994), with conscientiousness reported as the strongest personality predictor of college students’ grades (Matthews, Zeidner, & Roberts, 2006; Noftle & Robins, 2007). More specifically, conscientiousness has been shown to be strongly related to science achievement (Eilam, Zeidner, & Aharon, 2009) and interest (Fesit, 2012). However, a recent review highlights inconsistencies within the research examining personality and reading comprehension and appeals for more research to examine the potential relationships between these factors (Sadeghi, Kasim, Tan, & Abdullah, 2012).

It is well documented that academic achievement is modulated by individual beliefs and interests (DiPerna, 2006; Rothon, Arephin, Klineberg, Cattell, & Stansfeld 2011; Valentine, DuBois, & Cooper, 2004) as well as influences from parents and peers (Duncan, Boisjoly, & Harris, 2001; Gonzalez-DeHass, Willems, & Doan Holbein, 2005; Nichols & White, 2001; Rogers, Theule, Ryan, Adams, & Keating, 2009; Seginer, 2006). Individual beliefs that are likely to be important in determining science achievement include self-concept and career aspirations. Academic self-concept is highly domain specific (Marsh & Hau, 2004; Möller, Pohlmann, Köller,
Marsh, 2009); science self-concept refers to an individual’s belief in their abilities in science alone. Both positive (Wilkins, Zembylas, & Tarvers, 2002) and negative (Kifer, 2002) relationships have been reported with science self-concept and achievement, indicating that the role of domain specific self-concepts and subsequent achievements require further investigation. Some research suggests that career-aspirations modulate academic achievement (e.g. Benbow, Arjmand, & Walberg, 1991). Career interest for science occupations has been shown to develop particularly early in secondary education (Foskett & Hemsley-Brown, 2001), providing motivation for investigating the role of science aspirations on science comprehension and achievement. With regard to influences from external sources, including parents and peers, a recent study reported that students who reported positive attitudes to scientific studies were those who also experienced support from significant others in their lives (Aschbacher, Li, & Roth, 2010), demonstrating an important interaction of support and attitudes that requires further investigation. Additionally, students’ experience of school science is an increasing cause for concern (Osborne et al., 2003; Osborne & Collins, 2001), which may prove to have a mediating role in science achievement.

**Aims of the Study**

It is evident that text cohesion may play an important role in determining comprehension of scientific text, and that when considering how students learn in school it is important to consider a range of individual differences. However, two key issues remain to be addressed. Firstly, how do local text cohesion and academic individual differences interact with young science students’ comprehension of science text? Secondly, in order to develop effective science teaching strategies we need to
understand which of these variables are key to predicting science text comprehension in the classroom.

To address these questions we investigated the influence of different text cohesion designs (high and low) on determining secondary school students’ comprehension of science text in a classroom exercise. It was predicted that if a locally-cohesive text design enhanced students’ understanding of textbook science, this would be observed in greater accuracy in responding to MCQs after reading text that was high in local cohesion, compared to low in local cohesion. With the aim of identifying factors which may prove important in promoting scientific attainment, we investigated the predictive role of individual differences that have been identified as being particularly relevant to science text comprehension, at secondary school age.

The individual differences measured were; reading ability, general intelligence, conscientiousness, self-concept in science, science aspirations, experience of school science, parental support and involvement, and peer orientation to school and science.

**Method**

**Participants**

104 participants (56 female, 48 male) from a mixed ability secondary school in Leicestershire, UK, took part in the study. Participants were of mixed ethnic origin, and ages ranged from 12-13 years (12.3 years ± 2.1; Mean ± Standard Error). Participants were instructed that the study was investigating the design of science text books. Parental consent was obtained for all participants. Testing procedures complied with BPS Ethics Code of Conduct (2009).

**Materials**

*Text. To assess the influence of text designs (low vs. high cohesion) on comprehension ability we presented students with four extracts from science*
textbooks that were manipulated in terms of local cohesion (high and low cohesion).

The texts were taken from secondary school science textbooks (Catalyst: a frame work for success; Chapman and Sheehan 2003) on four separate topics so that experience of reading one text should not influence the readers understanding of another text. The four topics were photosynthesis, transport of water and minerals, changes of state, and seasonal changes. The texts were presented in a pseudo-random order across the student group (so that each text was presented in first, second, third and fourth position). Based upon previous research (Ozuru et al., 2009), cohesion was increased through; (1) adding connectives (2) reducing the use of ambiguous nouns and (3) elaborating on unfamiliar concepts. For example, in Figure 1 evidence of elaborating concepts include line 1, where it is made clear that the solids are made up of heated particles, line 2, where it is specified that the particles are closely packed in a solid, line 3, which states that heat makes the particles move faster. Examples of reduced use of ambiguous nouns are on line 2, ‘the closely packed particles within the solid’, line 4 ‘if the substance / liquid, and on line 5 ‘this transformation’. Connective devices are found on line 3, line 4 and line 5. The key changes have been underlined in Figure 1.

All students read two high cohesion texts and two low cohesion texts. Individual students read a text extract as high cohesion, or low cohesion; they did not view the same text extract in both conditions. The topics were counterbalanced so that all of the topics were read as high cohesion and as low cohesion across the participant sample, (i.e. text one was viewed as high cohesion by half the sample and low cohesion by half the sample). The students answered three MCQs on the content of each of the four texts, creating 12 questions in total. The MCQs were composed with four answers, one of which was correct. They were designed to test the students’
comprehension of the text by assessing whether the student had correctly linked the
information in successive sentences (measures of local cohesion), for example,
whether the student had correctly inferred a causal relationship between adjacent
sentence, as determined by the presence of ‘because’ in the text (high cohesion) or by
knowledge based inference when no connective was presented (low cohesion).

[FIGURE 1]

**Individual Differences.** Students were given five tests to measure individual
differences.

*Reading Ability (Nelson-Denny Reading Test).* To reduce testing time and
participant effort only the vocabulary component of the Nelson-Denny reading test
was used to assess students’ reading ability (Brown, Fishco, & Hanna, 1993). The
students read the beginning of a sentence and were asked to choose which one of five
words they felt best completed the sentence. For example, ‘flexible means a) liveable
b) bendable c) fixable d) fragile e) fused’. The vocabulary section has been used in
similar research (Ozuru et al., 2009) and has high Cronbach’s alpha scores of internal
reliability ($\alpha = .90$). Additionally, the test has been shown to be a good predictor of
academic success (Collins & Onwuegbuzie, 2002; Hawes, 1982; Wood, 1982). Scores
of reading ability were based on the total number of correct responses.

*General Intelligence.** We used a measure of general intelligence derived from
the Ravens Progressive Matrices (RPM) (Raven, Raven, & Court, 1998). Each item
requires the participant to infer a rule which relates the elements together, and then to
use this rule to identify the next element in the sequence by choosing from eight
alternatives (Alderton and Larson 1990). Ravens matrices are straightforward to
administer and have well documented reliability and validity scores (Strauss et al.
2006), with correlations with other intelligence test between .40 and .75 (Raven et al., 1998). Recent updates to the Ravens manual state that when time is limited, as with our relatively young sample, Set 1 alone (out of a possible 5 sets) provides a sufficient measurement (Harcourt Assessment, 2003). Indeed, shortened versions of the RPM have been shown to have similar psychometric properties to the full test (Hammel & Schmittmann, 2006; Van der Elst, Ouwehand, van Rijn, Lee, Van Boxtel, & Jolles, 2011), with good Cronbach's alpha scores of internal reliability (.73; Bors & Stokes, 1998), good convergent validity scores consistent with the full item (Arthur et al., 1999), and high test-retest scores (.75; Arthur, Tubre, Paul, & Sanchez-Ku, 1999). Therefore, to reduce participant effort we gave students 10 minutes to complete Set 1 only. It is worth noting then that when using a timed condition, the measure of general intelligence is thought to reflect intellectual efficiency, an overall competency and ability to efficiently use ones general intelligence (Raven et al., 1998). Scores of general intelligence were based on total number of correct responses.

Conscientiousness. The short five (S5) measure of personality (e.g., see Konstabel et al. 2012) was constructed to measure 30 facets of the Five-factor model of personality (NEO-PI-R, Costa & McCrae, 1992) for use when time is limited. As this study was primarily interested in conscientiousness only these 12 items (six positively keyed, six negatively keyed and reverse scored) were selected for use. The questions measured the six facets thought to define conscientiousness; competence (e.g. I am sensible and competent; I can find practical, quick, and effective solutions to problems), order (e.g. I am a methodical person and I love cleanliness and order. I want everything to be in its right place), dutifulness (e.g. I am a reliable person, who values ethical principles; I keep my promises and work carefully and thoroughly), achievement-striving (e.g. I know for certain what I want to accomplish and I work
hard for it), self-discipline (e.g. When I have started something, I finish it despite
fatigue or other distractions. I always finish my tasks on time) and deliberation (e.g., I
consider things carefully before acting or deciding; I take the possible consequences
of my actions into account). The statements were evaluated as to how they reflected
the reader on a scale of one to five, ranging from ‘very inaccurate’ to ‘very accurate’.
The S5 has good internal consistencies for the five broad factors (average $\alpha = 0.87$)
and for the facets (average $\alpha = 0.69$). The S5 has good convergent validity with other
measures of the big-five (average correlation with NEO and NEO-PI-R = 0.71)
(Konstabel, Lönqvist, Walkowitz, Konstabel, & Verkasalo, 2012). Scores of
conscientiousness were based on totalled ratings.

Science Self-Concept (Academic Self-Description Questionnaire Inventory -
ASDQI). The ASDQI was designed to measure secondary school students’ self-
perceived academic competence (Marsh, 1990a, 1990b, 1993). From the original 14
scales only the one scale pertaining to self-concept in science was chosen for use (e.g.
I get good marks in science classes; I learn things quickly in science). Six statements
were evaluated on an eight-point scale as to how well it reflected the participant (1 =
definitely false, 8 = definitely true). Previously reported reliability measures for each
scale are high ($\alpha = 0.88 – 0.94$). Scores on science self-concept and academic
achievement show good correlation ($r = .70$) (Marsh, 1992). Scores of science self-
concept were based on totalled ratings.

Science Aspirations - Science Aspirations and Careers Paradox. The Science
Aspirations and Careers Paradox (SACP) was designed to survey the interests of
school aged children in science and science related careers (Dewitt, Archer, Osborne,
Dillon, Willis, Wong, 2011). To minimise lengthy testing time and to focus
specifically upon the research question, six constructs were selected, ‘individual
aspirations in science’ (four items), ‘experience of school science’ (four items),
‘parental support / involvement’ (three items), and ‘peer orientation to school /
science’ (four items). The items were rated on a five-point scale, from 1 (strongly
disagree) to 5 (strongly agree). The ‘peer orientation’ items were re-worded so that
they could be answered using the 5-point scale, for example, ‘How many of your
close friends get good marks in science’ was changed to ‘Many of my close friends
get good marks in science’. Scores were based on total rating within each construct.
Cronbach’s alpha scores for the components used in this study range from $\alpha = .40 –
.80$, with the majority scoring over .60. Such reduced alpha scores are not considered
unusual in studies measuring psychological constructs with children (Field, 2009),
especially given the limited number of items per construct (Dewitt et al., 2011).

Procedure

As a classroom exercise, students completed one of the science booklets (A or
B, counterbalanced across the group). No time limit was set; the average completion
time was 20 minutes. Instructions were given to read the science texts carefully for
comprehension. After reading the text, the students completed a word jumble task, in
which they had to un-jumble a word (e.g. ospt - spot). This was designed to act as a
short distracter task and took approximately three minutes to complete. The students
then answered three MCQs based on the content of the text they had just read (see
Figure 1B). This procedure was repeated until the four texts had been read. After the
text-based part of the testing the participants were given the psychometric measures to
complete with no time limit. Following this the Nelson-Denny reading test was
administered with a 15 minute time restriction and the Ravens matrices test, with a
five-minute time restriction. The testing time (maximum 50 minutes) and work
required by the students was comparable to a typical classroom lesson.
Results

Text Cohesion

In order to assess whether comprehension performance differed between the high and low cohesion texts, a paired-samples t-test was conducted to compare MCQ accuracy between these two conditions. A significant difference in MCQ accuracy (t (103) = 2.17, p < .05, d = .2) between high cohesion text (62.66% ± 2.24) and low cohesion text (56.57% ± 2.51) suggests that high cohesion text facilitates students’ comprehension of science text. Additionally, these values suggest that the text structures and comprehension questions were suitably designed to ensure that there was variance across the conditions and participants whilst neither floor nor ceiling effects were obtained.

[Insert Table 1]

Individual Differences

Cronbach’s alphas and independent samples t-tests were carried out in order to determine that the scales had adequate internal reliability, and to assess any gender differences in scores on the psychometric measures (see Table 1). All scales showed adequate internal reliability (α = .70 or above; Kline, 1986). The independent samples t-tests revealed no significant differences between males and females on their scoring on the individual difference test and on their comprehension of high / low cohesion texts (see Table 1 for t and p values).

Interaction of Individual Differences and Text Cohesion

The second stage of analysis investigated whether individual differences affected comprehension of science text. Initial analysis used a Pearson’s product
moment correlation to assess whether there was a correlation between the
psychometric measures and accuracy in MCQs for high and low cohesion text.

As illustrated in Table 2, MCQ performance on high cohesion text was
positively correlated with scores on the Nelson-Denny reading tests, Ravens matrices,
self-concept in science, aspirations in science, and experience of school science. MCQ
performance on low cohesion text was positively correlated with the same scales as
high cohesion text, as well as two additional scales: parental support and involvement,
and peer orientation to school and science.

A 2-step Hierarchical Multiple Regression was performed to examine whether the
individual difference variables predicted correct responses with low and high
cohesion text after controlling for sex and age (see Tables 3 and 4). Across both
regression models, Variance Inflation Factors (VIF) for the predictor variables ranged
from 1.02 to 2.05, below the threshold values (VIF of 10 or at least 5) that are used as
rationale to suggest collinearity between the independent variables (Kutner,
Nachtsheim, Neter, & Li, 2004).

For high cohesion comprehension (Table 3), in Step 1, sex and age failed to reach
statistical significance ($r = .10$, $r^2 = .01$, adj $r^2 = -.01$; $F (2, 103) = .519$, $p = .597$)
indicating that these variables were unable to predict performance with high cohesion
text. In Step 2, the inclusion of scores of on the individual difference tests showed a
regression model that reached statistical significance ($r^2$ change = .31; $F$ change (8,
93) = 5.23; $r = .56$, $r^2 = .31$, adj $r^2 = .24$, $F = 4.33$, $p < .001$) with reading ability and
aspirations in science demonstrating a statistically significant regression coefficient ($p$
= .000 and $p = .05$, respectively). This suggests that having a higher reading ability
and having higher aspirations in science predicts a facilitation of comprehension performance when reading high cohesion text.

For low cohesion comprehension (Table 4), in Step 1, sex and age failed to reach statistical significance ($r = .18, r^2 = .03, \text{adj } r^2 = .02; F (2, 103) = .176, p = .177$) indicating that these variables were unable to predict performance with low cohesion text. In Step 2, the inclusion of all the variables produced a regression model that reached statistical significance ($r^2 \text{ change} = .17; F \text{ change} (8, 93) = 2.58; r = .46, r^2 = .21, \text{adj } r^2 = .13, F = 2.56, p = .01$) with reading ability demonstrating a statistically significant regression coefficient ($p = .01$). This suggests that higher reading ability predicts higher levels of comprehension with low cohesion text.

In summary, the findings show that students’ comprehension of science is improved after reading high cohesion text compared to low cohesion text. Higher reading abilities predicted increased comprehension with both high and low cohesion text designs. High aspirations in science predicted greater comprehension from high cohesion text.

**Discussion**

With the aim of investigating the importance of local cohesion in science textbook designs, and the role of individual differences in determining secondary school students’ understanding of science text in the classroom, we compared comprehension accuracy after reading high and low cohesion text and measured individual differences. Three key findings emerged. Firstly, local text cohesion is important in determining students’ comprehension of science text, with high cohesion text facilitating performance on MCQs greater than low cohesion text. Secondly, reading ability is a key predictor of performance on both high and low cohesion text.
Thirdly, scores on the positive aspirations scale predicts comprehension with high cohesion text, but not low cohesion text.

The importance of local cohesion text designs is consistent with previous findings reporting improved comprehension with increased text cohesion (e.g. Beck et al., 1991; Linderholm et al., 2000). It is thought that text which is high cohesion increases recall and performance on multiple choice questions because it is easier to read and consolidate to memory (McNamara, Kintsch, Songer, & Kintsch, 1996). To explain further, it is widely believed that sound reading comprehension is strongly reliant on both the development and retrieval of an accurate mental representation of the situation described in the text (see Zwaan & Radvansky, 1998). High cohesion text promotes the formation of coherent mental representations because it explicitly links sentences together which enables each text unit to be processed in a meaningful way (Kintsch, 1998). Additionally, the linking of sentences and linguistic units strengthens memory traces, by co-activating information that has previously been read (e.g. Cook, Halleran, & O’Brien, 1998). It is thought that these factors contribute to improved memory recognition and recall, which then enhances performance on MCQs.

Our findings provide support for previous research implicating a link between reading ability and the comprehension of science text (O’Reilly & McNamara, 2007; Ozuru et al., 2009; Schatschneider et al., 2007), and the importance of positive educational aspirations in determining academic performance (Rothon et al., 2011). However, our study makes three important extensions to these findings.

Firstly, the majority of existing research has examined the influence of text cohesion on non-scientific text (narrative or expository). Studies which have examined scientific text comprehension to date have largely ignored students at the
start of secondary education, instead focussing on undergraduate students (e.g. Ozuru et al., 2009) or older primary school children (Best et al., 2006; McNamara et al., 2011). By examining comprehension of science text in early secondary school students we show that local text cohesion is important at this crucial stage in scientific education, which is likely to have implications for promoting scientific attainment and interest.

Secondly, previous research has suggested that skilled readers gain the most benefit from reading high cohesion text, possibly because they are equipped with the core skills needed to process the increased text-density associated with highly cohesive text (e.g. Beck et al., 1991; Ozuru et al., 2009). Here we find that skilled readers also perform better with low cohesion text, suggesting that the ability to deal with dense text (associated with high cohesion) may not be the sole reason for better comprehension. It appears that good reading skills also equip students with the ability to make inferences to maintain local text coherence, which promotes comprehension with low cohesion text (Danemn & Hannon, 2001; Millis, Golding, & Barker, 1995; Prat, Mason, & Just, 2011). Therefore, strategies which aim to improve students’ general reading ability may not only improve their core reading skills (e.g. letter identification, word meaning) but also subsequently enhance their inferential abilities and consequently their abilities to learn from both high and low cohesion text.

Thirdly, we show that the relationship between positive aspirations and academic attainment (Rothon et al., 2011) is evident at a subject-specific level; positive science aspirations predicted increased comprehension from science text. However, this was only evident with high cohesion text. Therefore, it seems that positive aspirations interact with science attainment to arguably easier tasks, possibly because of the differing attentional demands associated with processing the texts. The
scores for ‘positive aspirations’ were obtained from a sub-scale in the Science Aspirations and Careers Paradox (Dewitt et al., 2011) questionnaire. This is a relatively new scale which is being developed as part of a longitudinal study investigating factors which influence educational choices. The findings from this study highlight the potential validity of this tool in predicting students’ comprehension of science texts.

Although the scores on the other individual difference scales employed correlated with performance on high and low cohesion text, they did not make significant independent contributions to predicting performance. As such, it seems that reading ability alone is a predominant mediating factor for science comprehension in young secondary school students. However, this study focussed on one specific key aspect of science achievement, the ability to comprehend locally high and low cohesive text as assessed by MCQ accuracy. Future research may further assess the role of individual differences and science achievement in science text comprehension using a range of additional methods, such as a free-flow writing task and a practical assessment, which allow for students’ comprehension to be measured with less dependency upon strong reading skills.

Additionally, whilst the present research has made a valuable start in examining comprehension skills using ‘offline’ measures (MCQs after reading the text), using ‘online’ measures such as the time taken to read sentences in a text comprehension task (Graesser, Hoffman, & Clark, 1980) may further our understanding of how and at what stage of the comprehension process do individual differences influence students’ ability to read high and low cohesion text. Research using online techniques to study science text comprehension has to date focussed on the performance of adults and college-aged children. However,
these methods also have the capacity to reveal individual differences in younger reader’s processing of textual coherence while reading about science. Having established that text coherence does influence students’ offline comprehension processes we can begin to explore online measures in future investigations. Studies that have employed online approaches generally use much larger stimulus sets than in the present experiment. Consequently, further studies that investigate the effects of text cohesion on on-line text comprehension by younger participants will also be able to extend the present findings by demonstrating the generality of these effects across a broader variety of science topics. In the present study, each participant read only two high and two low cohesions texts (on different science topics), and answered only three MCQ questions for each topic in the experimental task, due to time constraints. As such, it will be important for future research to use a broader set of science texts to demonstrate the generality of these findings. Nevertheless, the present finding that even this relatively small stimulus set used in the present experiment can reveal significant effects of text cohesion on performance may attest to the importance of the influence of text cohesion on science text comprehension for this age group.

A further concern may be that participants were given an unlimited time to read each text before answering the MCQs in the present study. Care was taken to ensure that the order of presentation of texts was counterbalanced across the participant group, to avoid order effects that may reflect changes in motivation or attention to the task over time. Moreover, the present findings show that clear differences in comprehension accuracy are observed even under conditions in which participants can take as long as they wish to read high and low cohesion text. This is of particular importance in the context of an investigation of
individual differences (including motivational differences) in comprehension, and so we deliberately chose not to restrict the time available to read each text. Rather we wished to see how these individual differences would influence comprehension in a typical classroom situation and duration (e.g. one hour lesson). Nevertheless, having established the importance of local text cohesion and reading ability on immediate science comprehension under the conditions used in the present study, an important next step will be to investigate these influences at delayed testing stages, such is common for academic assessments, and also their influence on participants’ reading times for science texts. Indeed, it will be important for this research to establish whether the same individual factors or additional individual differences are important for determining performance in these tasks.

The findings reported here have significant implications for the design of Key Stage 3 (11-14 years) science textbooks. Analyses of science text typically report that the structure is lacking in cohesion (Beck et al., 1991; Best, Rowe, Ozuru, & McNamara, 2005), yet the present findings show that students learn more effectively from science text that is high in local cohesion. It seems imperative that science textbooks are produced in a manner that maximises cohesion; by adding connectives, reducing the use of pronouns and elaborating on concepts.

Additionally, teachers should be aware of the importance of factors affecting the coherence of classroom dialogue. Indeed, research has highlighted the importance of teacher-talk in science lessons (Mortimer & Scott, 2003; Ogborn, Kress, Martins, & McGillicuddy, 1996). To elaborate, when presenting written information to students it may prove beneficial to explicitly point out the links, or encourage the student to make local inferences, between the different parts of the text. For example, take a typical classroom situation where the teacher presents factual information on a
projector at the start of a lesson. ‘Heated solid particles vibrate faster. Particles start
to break free from each other. Solids melt into a liquid. Particles move even faster
until they are in random motion if the liquid is heated more. The liquid will become a
gas. This is called evaporation.’ After reading this the teacher may then encourage
local text comprehension by promoting enquiry based upon linking meaning between
the sentences. For example, ‘Why did the particles break free from each other?’
(answer: because the solid was heated), ‘Why did the solid melt? (because the
particles broke free from each other), ‘What is evaporation?’ (linking the
demonstrative pronoun ‘this’, when a liquid becomes a gas). By encouraging students
to achieve local text cohesion, this may increase comprehension (therefore
attainment) in science, as well as developing the necessary skills to independently
achieve local cohesion during self-regulated learning times, including revision for
examinations.

The overarching significance of reading ability highlights the need to improve
basic reading skills and teach reading strategies (e.g. inference making) to improve
comprehension (see, e.g. McNamara & Kendeou, 2011; McNamara, 2009). Other
issues that may be important include promoting interest in, and the value of pursuing
scientific careers. For example, engaging active scientists and engineers in classroom
activities can provide an out-of-classroom context for their science learning, which
has shown to be beneficial for achievement (Gilbert & Priest, 1997) as well promoting
interest in a science-based career. Research suggests that science achievement is
higher if personally relevant (Reiss, 2000).

Conclusion

Beginning secondary school students demonstrated greater understanding of
science text in a classroom exercise when the text was high in local cohesion. Higher
reading skills predicted increased performance with both high and low local cohesion
texts. Positive aspirations in science predicted better performance with high cohesion
text. These results have significant implications for the design of science text and
teaching strategies of secondary school science. In order to promote science
achievement and interest it is important to pursue the role of local text cohesion,
reading ability and scientific aspirations.
Acknowledgements

This research was financially supported by The Leverhulme Trust. Project title ‘Improving Secondary School Students’ Science Text Comprehension’, RPG-094.
References


doi:10.1177/0013164498058003002


Daneman, M. & Hannon, B. (2001) Using working memory theory to investigate the construct validity of multiple-choice reading comprehension tests such as the SAT. *Journal of Experimental Psychology: General*, 130, 208-223.


decision-making in education, training and careers markets. London:
Routledge/Falmer.
visit to a museum. Science Education , 81, 749-762.
TRLP, London.
relationship between parent involvement and student motivation. Educational
Psychology Review , 17, 99-123.
learn in order to process coherence relations in narrative and expository text?
In A. P. Sweet & C. E. Snow (Eds.), Rethinking Reading Comprehension (pp.
82-98). New York: Guilford.
the Raven Advanced Progressive Matrices Test. Educational & Psychological
Correlations of scores in the Nelson-Denny reading tests, form E, and
measures of academic aptitude, academic achievement, readers’ attitude, and


the Internal-External Frame of Reference Predictions Across 26 Countries.

*Journal of Educational Psychology*, 96, 56-67.


