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'Eighteen hands high': A narrative reading of *Animal Farm* from a mathematical perspective

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This article addresses the interconnection between two education practices: reading and mathematics. These are two common aspects of schooling. Learners engage with these critical practices, regularly. There hardly goes a day in the life of schoolgoing children without them engaging in these two practices in one form or another. However, the point of this article is to examine how these two practices come together in activities of learning mathematics, and seeing mathematical ideas within the context of reading texts that may be considered non-mathematical. The question we address is: to what extent are high school mathematics learners able to see mathematics in non-mathematical reading texts? We examine this question based on an analysis of research project data collected from South African high school learners' interactions with *Animal Farm*, one of the 2015 Grade 10–12 South African English Home Language literature books. The learners were drawn from five schools in three provinces, namely Limpopo, Gauteng and Eastern Cape. In the first phase of data collection, 430 Grade 10–12 learners were purposively sampled to participate in the study. In the second and third phases of the study, 100 out of the 430 learners were purposively sampled. These were learners who had read *Animal Farm* before the time of data collection. Based on our analysis, we argue that high school mathematics learning and teaching do not adequately prepare learners to be able to see mathematics in spaces that may be isolated from traditional environments in which learners learn mathematics.

Introduction

In his book *Animal Farm*, George Orwell (1945) writes:

> Boxer was an enormous beast, nearly *eighteen hands high*, and as strong as any *two* ordinary horses *put together*. (p. 2)
>
> There were *fifteen* men with *half a dozen* guns between them. (p. 63)
>
> Food stuffs had increased by *200 per cent*, *300 per cent*, or *500 per cent*. (p. 57)

These excerpts from *Animal Farm* are examples of the many instances in which mathematical ideas, especially those connected to number, are used in the book. The author used his 'common' knowledge of mathematics and his familiar language to present the story of *Animal Farm* using mathematical ideas explicitly or implicitly. It is possible that the author's intentions were not to present mathematics or mathematical ideas, but because some storylines needed the use of mathematical language, he could not do so without using mathematics. This article emerges from a study that assessed learners' abilities to interpret what they read and in particular, to 'see' mathematical aspects in the book *Animal Farm*. The study sought to find out learners' abilities to read mathematically since mathematics is a specialised language that requires a specialised domain of practice. *Animal Farm* was one of the English Home Language literature books for high school learners in Grades 10–12 in South Africa in the 2015 academic year. According to the Department of Basic Education (2014), other novels for English Home Language were *The Great Gatsby* (Fitzgerald, 2008) and *Pride and Prejudice* (Austen, 2008). Learners were presented with excerpts from *Animal Farm* such as the ones quoted above. They were required to identify the mathematics part of the excerpts and to interpret what the excerpts meant. In the first excerpt, the mathematics part is 'eighteen hands high'. According to conversion rates one adult hand is approximately 0.1016 m long. Therefore, Boxer's height in metres was approximately 1.83 m. It was important for learners to understand this mathematical aspect in order to make sense of the extract. Without this understanding, the statement: 'eighteen hands high', does not make sense as one reads it in the printed media. Understanding what one is reading and how one needs to read is a critical skill required in relation to learning and achievement in education generally and mathematics education specifically.

Results from several international educational achievement tests such as Trends in International Mathematics and Science Study (TIMSS), Progress in the International Reading Literacy Study

(PIRLS) and Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ) and local standardised tests – National School Effectiveness Study (NSES) and Annual National Assessments (ANAs) – show that the vast majority of South African learners in all the grades are significantly below where they should be in terms of the curriculum and, more generally, have not reached a host of normal literacy and numeracy milestones (Spaull, 2011). National averages of 30% – 35% on tests of mathematics and languages are the norm for tests calibrated to measure grade-appropriate performance as a 50% score, and can be seen in both the NSES and the ANA evaluations (Taylor, 2011).

The ability to read and comprehend mathematical ideas in non-mathematical texts is important in learning mathematics especially at Grades 10–12 (Further Education and Training, FET) level. Stanic and Kilpatrick (1989) pointed out that non-mathematical texts have non-routine mathematical problems and non-routine problem-solving skills. Non-routine problem-solving is characterised as a higher level skill to be acquired after the skill of solving routine problems which in turn is to be acquired after learners learn basic mathematical concepts and skills. The study from which this article emerges analysed FET learners' readabilities (abilities to read) of mathematical texts in a non-mathematics specialised book, *Animal Farm*. The study attempted to address two problems affecting mathematics learning in South Africa. Firstly, in terms of the problem of poor performance in mathematics and literacy tests, we addressed the question: how much are learners able to see, identify and comprehend mathematical ideas in non-mathematical texts? Secondly, are learners at FET level able to extend their routine mathematical knowledge to non-routine mathematical knowledge in non-mathematical texts?

Literature review and theoretical framework

Reading and mathematics are regarded as basic activities in schools. However, research findings lament learners' inadequate attainment of these basics. Learners' attain basics that enable them to solve well-defined, ready-made, classroom problems but are unprepared to deal with ill-structured situations that they face in real life contexts. Learners are found ill-prepared to deal with real-life situations. Educators have begun to argue that the traditional sense of basic skills as algorithms for acquiring stable bodies of facts has created rote thinkers. If, instead, students are to become critical thinkers, then a new view of the 'basics' must be forged (Borasi & Siegel, 2001). Learners do not seem to acquire the benefits of the basics of education.

What is reading?

In the conceptualisation of the study, several meanings of reading were explored. The seminal work of Lee (1969) provided two categories of answers to the question 'what is reading?' She defined reading as 'translating symbols into sound, saying words, getting meaning from the printed page'. She also defined it as:

> bringing personal meaning to the printed page, reacting to the ideas, evaluating the author's recorded thoughts, gaining increased understanding through experiencing the recorded understandings of another. (p. 403)

Lee's first definition involves the mechanics of reading, the superficial (not by any means unnecessary) phases of reading. The second definition involves more personal, more true aspects of reading by giving meaning to the printed words in the readers' own understanding and experiences. The first definition assumes that the *meaning of what one is reading is in the printed words* while the second definition assumes that the printed words have no meaning in themselves, but that the reader *gives meaning to the words*. Lee's second definition is among others more personal, transformative, political, radical and progressive.

Allen (2000) defined reading as a process of moving between texts, moving out from the independent text into a network of textual relations. Meaning becomes something that exists between a text and all the other texts to which it refers and relates. The text becomes the inter-text. Allen's definition contends that the written text does not have meaning of its own. It depends on other texts to which it refers and relates to provide meaning to the reader. The reader makes sense of the text in an interrelated way. This definition of reading shows the relationship that exists between and among texts in bringing meaning to the reader. The definition is in line with Lee's first definition of reading as 'getting meaning from the printed page'. However, Allen goes a step further to explain the interrelatedness of texts in bringing meaning to the reader. Otherwise, it is difficult for the reader to make sense of the texts without what he calls inter-text.

Educational research has pinpointed a number of factors that contribute to underachievement and underlying many of these factors is reading ability. Differences in the sociocultural backgrounds and home backgrounds of certain groups of and individual students have been shown by a large body of research to affect the ways in which students learn (Pretorius, 2002; Pretorius & Ribbens, 2005). Research has shown that a literate home background in which parents read a great deal themselves and also read to their young children, and in which there is a significant collection of varied books which children have opportunities to read themselves, contributes significantly to the level of achievement in later life. Following on from this, a number of studies have shown that the amount of leisure reading in which individuals engage is directly related to their reading achievement (Evans, 2002). Most sub-Saharan countries suffer from a scarcity of materials for students to read on their own, materials such as storybooks or informational texts. School libraries, classroom libraries and community libraries are rare (UNESCO, 2007). Put simply, there are few opportunities for students to engage in the reading of extended texts that would allow them to practise their reading skills and engage in the kinds of choices around reading that promote independence (Macro International, 2008).

Studies on the development of reading have shown that variations in children's reading skills are associated with large differences in reading experience. Children at the 80th percentile in reading level were estimated to average more than 20 times as much reading per day as children at the 20th percentile.

Many African education systems including South Africa do not provide adequate reading opportunities to learners. Learners have insufficient access to reading materials. This affects both their skill and will to read and develop into mature and effective readers to be able to cope with advanced academic work at the secondary school level. For example, according to Sailors et al. (2014), in Malawi, the core curriculum textbooks related to literacy instruction in the primary grades are the language textbooks for Chichewa (the local language) and English texts only. There are no reading textbooks, nor is there a curriculum area called reading.

Chall, Jacobs and Baldwin (1990) observed that reading is a very powerful learning tool, probably the most important and empowering skill that learners need in a learning context. Reading ability in the middle school years is crucial in later academic success. 'Reading science and social studies texts becomes an almost impossible task for students who cannot read at this level'. If schools wish to improve the overall academic performance of their learners, they should change their assumptions about what is important, and provide opportunities for their learners to develop their reading skills.

Reading mathematically

Adams (2003) explained that mathematics is a language that people use to communicate, to solve problems, to engage in recreation and to create works of art and mechanical tools. She defined mathematics reading as reading words, numerals and symbols in order to uncover the message of and about mathematics. Included also in reading mathematics is the reading of graphics, diagrams and illustrations. Adams identified three areas of focus in reading mathematics: words, numerals and symbols. Words in mathematics may or may not have the same meaning as in everyday language or outside the discipline. For example, a ruler in mathematics means an instrument for measuring length while in everyday life it means someone in power or authority. Examples of words that have the same meaning in mathematics and everyday life include dozen and time. Words in mathematics are also used in context form to communicate ideas. For example, consider the statement: 'Write any two numbers whose product is 50'.

The benefits of reading to learn mathematics include: (1) contributing to better learning and understanding of mathematical content, (2) developing new learning strategies useful in new learning situations and (3) developing a deeper understanding of mathematics as a discipline. Reading to learn mathematics may be able to play a role in bringing about much-needed reform of the mathematics curriculum and lead to a reconceptualisation of the role of the traditional 'basics' in educating students as critical thinkers. A review of the research on the reading process shows how the concept of reading as a transaction contributes to the attainment of these goals for mathematics instruction (Borasi & Rose, 1989).

Reading fluency is a significant variable in secondary students' reading and overall academic development. For both reading and mathematics, children's performance at the end of elementary school is an important predictor of their ultimate educational success. If they have not mastered certain basic skills, they can expect problems throughout their schooling and later. Research on reading indicates that all but a very small number of children can learn to read proficiently, though they may learn at different rates and may require different amounts and types of instructional support. Furthermore, experiences in pre-kindergarten and the early elementary grades serve as a crucial foundation for students' emerging proficiency. Similar observations can be made for mathematics (Kilpatrick, Swafford, & Findell, 2001).

Theoretical framework

The study from which this article emerged was informed by Dowling's (1998) theory of mathematical practice. The theory of mathematical practice gives theoretical tools to approach and analyse school mathematical knowledge and how language affects the understanding of this knowledge. It gives a distinction between practice that is highly organised at the level of language and practice that generally lacks systematic organisation in language. Dowling has thus identified four domains of mathematical practice: esoteric, expressive, descriptive and public domains to distinguish how mathematics content and expression of the content are used in mathematics practice. Dowling uses the concept of classification to produce a model for analysing different types of mathematics statements in pedagogic texts and providing a language for describing relationships between school mathematics and other domains of practice. Dowling's work involves analysis of the relationship between mathematical and extra-mathematical knowledge, contents, discourse and practices. The argument in this regard is that academic (generally) and mathematical (specifically) activities are incommensurate with everyday activities and that academic mathematical knowledge cannot be used as a theory for facilitating adequate or appropriate understanding of everyday practices (North & Christiansen, 2015). Ensor and Galant (2005) pointed out that the power of the theory of mathematical practice is threefold. Firstly, it allows us to classify the content and mode of expression of school mathematics with respect to other subjects in the curriculum. Secondly, it illuminates the task of apprenticeship, which is to move novices from the public (or other domains) into the esoteric domain. Thirdly, it allows us to discuss the articulation between school mathematics and out-of-school practices.

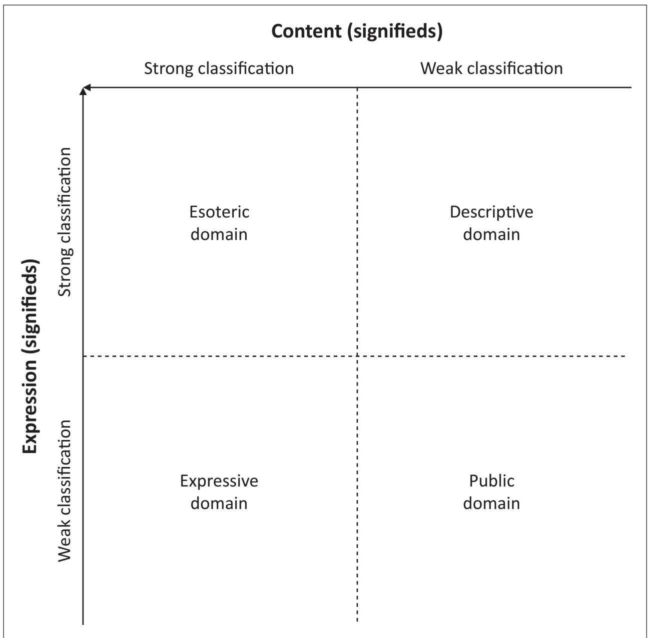
Domains of mathematical practice

Dowling (1998) identified four domains of mathematical practice: esoteric, expressive, descriptive and public domains. These domains are characterised by the degree of specialisation of mathematical content and mode of expression employed in the messages through which the practices of the activity are transmitted (see Figure 1).

Figure 1 shows two axes: the content axis and the expression axis. Both axes have strong and weak classifications. Classification here refers to the boundary strength between mathematics as specialised knowledge and practices, and everyday knowledge and practices (Bernstein, 1971).

Along the content axis, the esoteric and expressive domains of mathematical practice have strong classification while the descriptive and public domains have weak classification. What this means is that the esoteric and expressive domains have a strong degree of specialisation of mathematical content which can unambiguously be identified as mathematics (North & Christiansen, 2015). The descriptive and public domains on the other hand have a weak degree of mathematics content such that mathematics appears to be something other than mathematics, that is, 'mathematics parading as something other than itself' (Dowling, 2013, p. 331).

Along the expression axis, the esoteric and descriptive domains have strong classification while expressive and public domains have weak classification. What this means is that the esoteric and descriptive domains use a strong mode of expression through which the message of mathematics is transmitted. The expressive and public domains use a weak mode of expression to transmit the message of mathematics.



Source: Adapted from Dowling, P. (2013). Social activity method (SAM): A fractal language for mathematics. *Mathematics Education Research Journal*, *25*(3), 317–340 (p. 324). https://doi.org/10.1007/s13394-013-0073-8

FIGURE 1: Dowling's domains of mathematical practice.

Several researchers have used Dowling's domains of mathematical practice to analyse and discuss different issues in mathematics education. Dowling developed the theory to help him to construct the sociological language of description for the analysis of school mathematics textbooks. This helped him to make empirical claims about the texts themselves and the wider practice of school mathematics in England and Wales. North and Christiansen (2015) used the domains of mathematical practice to analyse the examination papers for Mathematical Literacy in South Africa. Parker (2006) used Dowling's domains of mathematical practice to analyse the National Curriculum Statements for Mathematics. This theoretical framework has also been used to analyse other mathematical texts (Dowling, 1994, 1995), mathematics classrooms (Coombe & Davis, 1995; Johnstone, 1993) and to recontextualise pedagogic practices in initial teacher education and initial teaching appointments.

Although the domains of mathematical practice have mainly been used to analyse mathematics textbooks and examination papers, this study used the domains in analysing learners' understanding of mathematics in contexts other than the mathematics textbook. The domains were used to analyse learners' access of mathematics outside mathematics textbooks and the mathematics classroom. This is important because it shows the connection between mathematics and everyday activities and practices. Two important aspects were analysed and discussed using the four domains of mathematical practice. These are learners' mathematical content knowledge in *Animal Farm* and learners' understanding (and access) of mathematical aspects (content) in *Animal Farm*. The study used excerpts from *Animal Farm* (that are connected to the concept of number) as pedagogic texts for learners to interpret.

Ensor and Galant (2005) explain that Dowling's model is valuable as it allows us to discuss the articulation between school mathematics and out-of-school practices. North and Christiansen (2015) argue that Dowling's work involves analysis of the relationship between mathematical and extra-mathematical knowledge, content, discourse and practices. A central argument in this regard is that mathematical activities are incommensurate with everyday activities and practices. Teaching and learning of mathematics can start with the non-mathematical content as a vehicle towards accessing the specialised mathematical content. Conversely, teaching and learning of specialised mathematics content should enable learners to make connections between mathematics and out-of-school or everyday experiences.

Study methodology

The study collected both qualitative and quantitative data, most of which were qualitative. Data were collected from Grades 10–12 learners from five public schools in three provinces in South Africa using three different questionnaires in three phases. Most learners from these schools were from a predominantly low socio-economic background. Four out of the five schools had school feeding programmes.

The school without a feeding scheme at the time of the data collection was in Gauteng and had learners with similar characteristics to the ones from the other provinces. The data were collected towards the end of the 2015 academic year. The schools were purposively sampled as they were participating in a community engagement programme based at a tertiary institution. The community engagement programme involved providing in-service training to Mathematics and Science teachers and supporting the teaching of Grade 10–12 learners in Mathematics and Physical Science. The study purposively sampled Grades 10–12 learners who were studying mathematics during the period of data collection.

Phases of the data collection

In the first phase of data collection, a questionnaire was administered to 430 Grades 10–12 learners. They provided information on the reading resources that were (made) available to them. They also reported on their favourite reading materials. The learners also provided information on how their reading materials were connected to mathematics.

The second phase of data collection started with a document analysis of *Animal Farm*. *Animal Farm* was one of the books in the English Home Language curriculum in 2015 for the FET phase in South Africa and was identified as one of the learners' favourite reading materials in phase one. We read *Animal Farm* several times (document analysis) and identified mathematical aspects from the book. The mathematical aspects showed the connection that the book has with mathematics. A questionnaire, developed based on the connection between mathematics and *Animal Farm*, was administered to some learners who participated in the first phase of data collection. We purposively sampled 100 learners who had read *Animal Farm* by the time of data collection. The data were collected from 100 Grades 10–12 learners who had read *Animal Farm*.

In the third phase of data collection, a questionnaire was administered to 83 out of the 100 learners who participated in the second phase of data collection. These were the learners who were available during the day of data collection. The questionnaire was also based on *Animal Farm* but was different from the previous one. In this phase, deliberate efforts were made by the researchers to extract statements in *Animal Farm* that had connections with the concept of number. Learners were asked to identify mathematics from the extracts and to explain the meanings of the extracts.

The data collected from the three phases were entered into an Excel spreadsheet and analysed.

Ethical considerations

Several ethical considerations were undertaken when conducting the study from which this article was taken (Mwale, 2017). Ethical clearances were granted from the Department of Education district office in March 2009 (reference TZIMBIZO/232009) to establish the Community Engagement Project. Learners who participated in this study were sampled from the project schools. Further consent was granted by the same office to conduct research from the project schools. At school level, consent was granted by the principals, parents of participating learners and the learners. Parents and learners signed consent forms to accept their participation in the study. They were, however, free to withdraw from the study anytime they felt compelled to do so. Participating learners were assured of confidentiality of the findings of the study and that their identities would not be revealed at any point. In analysing learners' responses below we use the notation L1, L2, … for Learner 1, Learner 2, …. The ethics committee of the university also gave approval for data collection in the sampled schools in June 2014.

Findings of the study

In phase one of data collection, we found that the reading materials available to secondary school learners were mostly school textbooks in science, mathematics and English. These books were made available to learners by their schools. The other reading materials that were not made available by the schools were magazines, newspapers, storybooks and the Internet but were read by few learners. For the reading materials provided by the schools, most learners read English books. They included novels, drama, short stories and poetry books. Most learners also indicated that their favourite reading materials were English textbooks.

In phase 2 of data collection, most learners were unable to indicate how the stories they read were connected to mathematics. The common response from those who read English books was that their books were storybooks and were not connected to mathematics in any way. Similarly, learners were unable to show the connections between *Animal Farm* and mathematics in phase 2 of data collection.

Since learners were still unable to see or identify mathematical aspects from *Animal Farm* in the second phase of data collection, deliberate efforts were made in the third phase of data collection to extract statements connected to the concept of number and ask learners questions based on these aspects. Learners were given an example to show them how the concept of number is implied in the statement. Results from this phase showed that most learners were now able to see and identify mathematical aspects from *Animal Farm* especially from extracts that had explicit connection to the concept of number. Learners only saw the connections when the extracts were isolated from the storyline. However, most learners were unable to interpret the extracts. They tended to give the literal meaning of the extracts that did not make sense. We therefore concluded that learners had a weak 'mathematical gaze' and comprehension skills to enable them to see and comprehend what they read.

Learners' perspectives of mathematics from *Animal Farm*

The questionnaire that the learners responded to had 10 excerpts, connected to the concept of number. The excerpts were taken from Chapter 1 of *Animal Farm*. In choosing these excerpts, we ensured that they had number words or an application of the concept of number which could be identified by the learners. We ensured that the excerpts had enough words to convey the mathematical meaning they carried. As such, leaving out some words from the sentences that were extracted would still bring out the mathematical aspects captured in the sentence.

Is there mathematics in the excerpt?

Learners were asked to indicate if there was any mathematics in the given excerpts. Table 1 shows the results.

Table 1 shows the percentage and number of learners who were able to (yes), unable to (no) or did not respond to the question: 'Is there mathematics in the excerpt?' There were 100 learners who were asked to respond to this question. The results show that most learners were able to 'see' mathematics in excerpts 1–4. The percentages of those who were able to see mathematics in these excerpts ranged from 66% to 78%. These excerpts had an explicit connection to the concept of number. For extracts that had an implicit connection to the concept of number, the percentages were lower. None of the extracts had 100% yes responses from the learners. This shows that some learners did not see mathematics in the given excerpts, even though some of them had number words such as eighteen, two and a thousand. The table shows that some learners did not provide any response to the excerpts. The number of non-respondents was large in excerpts 5–10. Although it was not made known to us why many learners left the excerpts unanswered, non-response is likely to have arisen from learners' uncertainty about possible connections between the excerpts and mathematics.

The 'mathematics part' of the excerpts

Apart from identifying mathematics in the excerpts, learners were asked to identify the mathematics part of the excerpts. This helped the researchers to know if learners were indeed able to recognise or see mathematics in the excerpts. The data analysis showed that most learners were able to identify mathematics as it appeared in the excerpts. Table 2 is an example of learners' responses in relation to identification of the mathematics part of the excerpt 'Boxer was as strong as any two ordinary horses put together'.

Table 2 shows aspects that learners identified as the mathematics parts of the excerpt 'Boxer was as strong as two ordinary horses put together'. In terms of number words, the expected response was 'two'. Sixty-three (63) out of 75 learners (i.e. 84%) were able to identify two as the mathematics part. Other learners indicated that the mathematics part was 'addition'. This response appeared to have been based on the learners' reading of the phrase 'put together'. Although 'put together' is used in mathematics to mean addition, it did not carry the same meaning in this case. The following were some of the reasons why some learners thought that there was no mathematics in the excerpts:

- No numbers or numerical values in the statement.
- No mathematical language.
- Because there is no such topic in math.
- None of the words are found in mathematics content.

Meaning of the excerpt

After identifying the mathematics part of the excerpt, learners were asked to give the meaning of the excerpt to show their understanding of the excerpt. This is in line with Lee's definition of reading: being able to interpret, analyse and evaluate the author's thoughts. Table 3 is an example of learners' responses on the meaning of the excerpt 'Boxer was eighteen hands high and strong'.

Table 3 shows learners' responses upon being asked to provide the meaning of the excerpt 'Boxer was eighteen hands high and strong'. In this case the number word 'eighteen' is being used to show the size of the horse called Boxer. We had expected learners to explain the meaning of the excerpt in relation to the height of Boxer who was 18 hands high. In analysing learners' responses, it is evident that most learners did not understand and appreciate the author's use of 'hands' as a unit of measurement. Learners L2, L4 and L5, for example, provided the literal meaning of the word

TABLE 1: Is there mathematics in the excerpt?

Excerpt	Yes (%, *n*)	No (%, *n*)	No response (%, *n*)
1. Lose an hour's sleep	78 (78)	5(5)	17(17)
2. Eighteen hands high	71 (71)	6(6)	23(23)
3. Two ordinary horses put together	75 (75)	6(6)	19(19)
4. First rate intelligence	66 (66)	14(14)	20(20)
5. A thousand times no	42 (42)	4(4)	54(54)
6. Throughout the short remainder of your lives	22 (22)	21(21)	57(57)
7. Five times in succession	39 (39)	3(3)	58(58)
8. The whole farm burst into singing	33 (33)	12(12)	55(55)
9. Every drop of it	24 (24)	14(14)	62(62)
10. Approaching middle life	26 (26)	14(14)	60(60)

Source: Mwale, L. (2017). *Reading practices for mathematical learning in a non-mathematical text: An analysis of South African learners' sense making of* Animal Farm. Unpublished doctoral dissertation, Tshwane University of Technology, Pretoria, South Africa (p. 165). Retrieved from http://tutvital.tut.ac.za:8080/vital/access/manager/Repository/tut:4142

TABLE 2: Mathematics part of 'Boxer was as strong as any two ordinary horses put together'.

Mathematics part	Frequency
Adding and two	2
Addition of horses	2
Altogether	1
Counting horses	1
Number of horses	1
Put together means addition	3
Two	63
Two is showing us that its mathematics language	1
Using a + sign to add two things	1

Source: Adapted from Mwale, L. (2017). *Reading practices for mathematical learning in a non-mathematical text: An analysis of South African learners' sense making of* Animal Farm. Unpublished doctoral dissertation, Tshwane University of Technology, Pretoria, South Africa (p. 167). Retrieved from http://tutvital.tut.ac.za:8080/vital/access/manager/Repository/tut:4142

TABLE 3: Learners' responses to 'Boxer was eighteen hands high and strong'.

Learner	Meaning of the excerpt
L1	Describing how high he was
L2	Eighteen people raise their hands to measure someone
L3	He was helping or giving a hand to others
L4	Raising hands and count up to 18
L5	Tall by eighteen hands
L6	The height takes up to 18 hands
L7	The size of someone
L8	There were 18 hands by measurement
L9	Too tall and strong

Source: Adapted from Mwale, L. (2017). *Reading practices for mathematical learning in a non-mathematical text: An analysis of South African learners' sense making of* Animal Farm. Unpublished doctoral dissertation, Tshwane University of Technology, Pretoria, South Africa (p. 173). Retrieved from http://tutvital.tut.ac.za:8080/vital/access/manager/Repository/tut:4142

hands, which does not make sense. Learners L7 and L9 used their knowledge of number to explain the meaning of the excerpt as 'the size of someone who is too tall and strong'. None of their responses recognised the word hands according to the author's idea. Findings such as these were evident in the analysis of responses to several other excerpts given to learners.

Interpretation of findings

The analysis presented in this article shows that although most learners were able to see mathematics in the excerpts, they were unable to articulate the mathematical meaning of the excerpts. Their meanings reflected simple paraphrases of the excerpts or literal meanings that did not make sense. For example, the following are some of the learners' interpretations of the excerpt 'Boxer was as strong as two ordinary horses put together':

> Adding, adding two horses.
> Adding two horses that are ordinary to make one strong horse.
> Adding two horses with similar strength.
> Boxer = 2 horses.
> Two horses were put together. (Mwale, 2017, p. 174)

This observation raised several questions such as: Did learners understand what they read: the story in general and the extracts in particular? Why did their interpretations not connect to the story, and to mathematics if they now saw mathematics in the extracts? For example, the following are some of the learners' interpretations of the excerpt 'Boxer was eighteen hands high and strong':

> Raising hands to count up to eighteen.
> He was helping or giving a hand to others.
> Eighteen people raise their hands to measure someone. (Mwale, 2017, p. 173)

What do these findings imply for the learning of mathematics?

In analysing the excerpts with respect to learners' interpretations we found that the excerpts from *Animal Farm* can be characterised by low levels of institutionalised ways of expression and mathematical content. According to Dowling (1998) they fall under the public domain: 'the universe of mathematical statements which are unambiguously mathematical, either in terms of the content that they refer to, or in the language which is used to do this' (p. 135).

Therefore, the excerpts could not be easily identified as mathematical in nature because of their weak mathematical contents and the weak mathematical language of expression used. As is the case with the public domain, they followed no set rules or specialised technical or mathematical language.

Animal Farm is a storybook and therefore the language used is in most cases different from a mathematics textbook. A storybook and a mathematics textbook have what Dowling (1992) describes as *distinct regions of practice* and have fundamentally *different modes of practice*. Dowling (1992) describes mathematics as an example of a practice that is heavily dominated by explicit principles. In contrast, *Animal Farm* uses metaphors with implicit, implied and hidden meanings of words including mathematical aspects. For example, words such as 'hour', 'eighteen', 'first', 'whole' and 'five times' in the excerpts above have been used in metaphorical ways such that although they are mathematical in nature, they carry a different meaning in the excerpts. The metaphorical demands of the excerpts may have affected learners' interpretations.

Secondly, Orwell, the author of *Animal Farm*, used mathematical terms in his familiar, local and everyday mode of expression which is different from that of the participants of this study. The author was a European and this study was carried out in South Africa. Dowling (1996) refers to this difference as 'language that is not within the readers' everyday domain of participation'. For instance, expressions such as: 'lose an hour's sleep', 'eighteen hands high', 'two ordinary horses put together', 'the whole farm was asleep', 'first rate intelligence', and 'five times in succession' may not be the learners' everyday domain of participation. Therefore, the text sent different messages to the learners other than what the author intended it to be.

The purpose of the public domain in mathematics books is to help learners to access the esoteric domain. Although the excerpts can be termed as public, they are not meant to help the learners to access the esoteric domain. The mathematical aspects in the excerpts serve a different purpose from the mathematical aspects in the mathematics practical problems. They appear as the authors' way of communicating mathematical aspects in his familiar, everyday language and not necessarily expressing mathematics in everyday, familiar language. Harel and Kaput (1991) explain that the to-and-fro movement between mathematical and everyday representations in such a case contrasts with descriptions of the one-way movement from everyday to mathematical meanings in mathematics. Morgan (1998) and Sfard (2008) argue that the activity of explaining using practical terms differs from the deductive reasoning based on mathematical definitions and theorems that characterises academic and advanced mathematics discourses. Therefore, the excerpts from *Animal Farm* could not easily send a message of mathematics to the learners because they were not meant to send such a message.

In addition to language issues that affected learners' abilities to see and interpret mathematical aspects from *Animal Farm*, the study also unveiled learners' inadequate mathematical knowledge and comprehension (reading) skills. Adequate mathematical knowledge could enable them to see mathematics from *Animal Farm* as identified by the researchers. Dowling (1998) argued that gaining mastery of esoteric domain mathematics equips one with a mathematical 'gaze' with which one can look out upon the world and 'see' mathematics in it. This gaze results in the incorporation of aspects of everyday settings into mathematics learning. This raises the question of whether secondary school learners are attaining the esoteric domain of mathematical practice to enable them to acquire the mathematical gaze.

Dowling (1996) pointed out that the other domains of mathematical practice do not adequately prepare learners to see and do mathematics like the esoteric domain. He argued that school mathematics is driven by the esoteric domain with its intents, purposes, self-referential and closed. School mathematics might recruit a whole range of non-mathematical texts and contexts for pedagogic purposes, but this 'use' of mathematics is by and large confined to the school. The recontextualised mathematics is not the core of school mathematical knowledge. It is what teachers and textbooks use to help learners to access subject matter knowledge and it is used in schools only. North and Christiansen (2015) reported that the predominant use of public domain inhibits mathematical understanding and affords only a limited degree of lifelong preparation. The implication for mathematics books that use the public domain more than necessary is that learners may not be able to access the mathematical knowledge they are meant to learn. In his empirical studies of school textbooks, Dowling (1998) identified practical problems that obscure the specialised mathematical knowledge and thus close opportunities for participation in school mathematics.

This finding has an implication on solving word or practical problems in mathematics. Le Roux and Adler (2015) explain that solving a practical problem involves first recognising the problem as a particular type of mathematics problem, or genre, and then recognising the mathematical-practical boundary and the specialised mathematical knowledge that casts a gaze on the practical. Can learners without a mathematical gaze see mathematics in word problems? And if they cannot see mathematics, can they solve word problems?

Another critical issue that this study has highlighted is learners' limited comprehension skills. The study showed that learners were unable to interpret what they read. This finding has an implication for mathematics learning and for learning in general. Do learners understand what they read or learn? In mathematics, learners' inability to interpret what they read is clearly shown in word problems. A number of studies have highlighted several challenges that learners face in solving word problems. Dossey (2000) pointed out that the linguistic form of word problem texts affects students' efficacy in solving word problems. For bilingual learners, another known factor related to the problem of comprehension is their proficiency in the language in which the problem is stated. Bernado (1999) reported that the ability to understand word problems is affected by internal variables or factors related to the student's prerequisite knowledge and information processing skills related to the use of knowledge. Le Roux and Adler (2015) investigated how linguistic features of practical problems represent mathematics, act textually by relating texts and identifying people. They reported that a text may be included or excluded or given significance in representing objects and activities in the practical problem. Depending on how the learner understands and interprets the text, it can diverge from what it is expected to represent and in so doing produce a 'hybrid' text.

Implications for mathematics learning

The South African FET Mathematics curriculum covers 10 main content areas: Functions, Number Patterns, Sequences and Series, Finance, Growth and Decay, Algebra, Differential Calculus, Probability, Euclidean Geometry and Measurement, Analytical Geometry, Trigonometry and Statistics (Department of Basic Education, 2011). These are the non-arbitrary, esoteric domain content that learners are supposed to acquire by the end of three years of FET. According to the Department of Basic Education (2011), one of the specific aims of the Mathematics curriculum is 'to be able to use contextual problems relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible' (p. 13). This objective provides an example of the connections between the mathematical and non-mathematical contexts that the curriculum aims at promoting. In this study we analysed learners' perspectives of connections between mathematics and their English literature book, *Animal Farm*. The assumption was that they had acquired adequate subject matter knowledge and skills to enable them make connections, see, identify and interpret mathematics from what they read based on the intended curriculum. However, the analysis in this study showed otherwise.

Mwakapenda (2008) argued that connections are central to the way the discipline of mathematics, its learning outcomes and assessment standards are conceptualised. The notions of representation and integration are found to be key aspects in understanding connections in mathematics, making links within itself and other disciplines. Mathematics is not about reasoning for its own sake; it is concerned with processes that are connected to activities and problems of the social, physical and mathematical worlds involving human practices in all cultures. However, connections in mathematics cannot be easily made by someone who lacks the conceptual understanding of mathematical concepts and procedures and relations between concepts and procedures

(Kilpatrick et al., 2001). Donoghue (2001) proposed that a strong mathematics background helps students to make connections among mathematical ideas and also between mathematics and other content learning areas. This raises the question of whether secondary school learners are achieving the necessary conceptual understanding to enable them to make connections between mathematics and what they read. Can they make connections between mathematics and 'contextual problems relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible?' (Department of Basic Education, 2011, p. 13). This has an implication on the way learners are taught mathematics especially to acquire conceptual understanding. The learners' inability to make connections between mathematics and what they read showed their lack of understanding of mathematical concepts including the basic number system. With this deficiency, how do we expect them to learn the more complex ten topics outlined for the FET Mathematics curriculum?

Boaler (2013) showed that when mathematics is opened up broader mathematics is taught, mathematics that includes problem-solving, reasoning, representing ideas in multiple forms and asking questions, improving learners' performance and encouraging them to study mathematics at advanced levels. Mathematical problems that demand connection making and creativity are more engaging for learners of all levels. When all aspects of mathematics are encouraged, rather than procedural fluency alone, many more learners participate in the learning process, leading to higher achievement. Boaler referred to this opening and broadening of the mathematics taught in classrooms as *mathematical democratisation.* Narrow mathematics teaching combined with low and stereotyped expectations for learners produce low achievement in mathematics.

In this article, we have examined the interconnection between two education practices: reading and mathematics. In particular, we have examined how these two practices come together in activities of learning mathematics and seeing mathematical ideas within the context of reading texts that may be considered non-mathematical, as in the case of *Animal Farm*. We have presented our analysis of learners' understanding of mathematical ideas by looking at the context of the reading materials (*Animal Farm*) available to them. Considered in this way, our study is at the interconnection of the domain of mathematics and the domain of language (everyday ordinary public language). Several studies have emphasised the importance of recognising this problematic interface in mathematics teaching and learning (Barwell, 2014; Moschkovich, 2008; Planas & Civil, 2013; Setati, 2008). Our analysis has shown that learners were not able to see mathematics embedded in *Animal Farm*. That is, they were largely unable to see mathematics in spaces that may be isolated from traditional environments in which they learnt mathematics. We argue that the reason for this finding is due to the fact that mathematics learning and language learning occur as separate practices. In particular, we contend that this finding is due largely to the inability of mathematics teaching to draw on the non-mathematical domain, the domain that is more easily available and accessible to learners. Our argument concurs with contextualisation perspectives advanced by Lakoff and Nuñez (2000) in relation to the interface between mathematical cognition and everyday reality. Lakoff and Nuñez have explored the question 'How much of mathematical understanding makes use of the same kinds of conceptual mechanisms that are used in the understanding of ordinary non-mathematical domains?' (p. 28). Our finding suggests that meaningful mathematics teaching and learning need to connect with and make use of everyday understandings that are located in spaces and domains that may be considered non-mathematical.

Conclusion

In this article, we have addressed the interconnection between two education practices: reading and mathematics. We have reviewed the literature related to reading and reading mathematically. We have examined how these two practices come together in activities of learning mathematics and seeing mathematical ideas within the context of *Animal Farm*, a textbook that may be considered non-mathematical. We explored the extent to which Grades 10–12 mathematics learners were able to see mathematics in *Animal Farm*. The analysis showed that learners were able to see mathematics in *Animal Farm* only when they were given excerpts that had mathematics words and applications related to the concept of number. We have observed that *Animal Farm* falls into the public domain of knowledge. We have argued that high school mathematics knowledge (esoteric domain) is largely inconsistent with the public domain knowledge. The learners' inability to see mathematics in *Animal Farm* points to the fact that school mathematics learning and teaching do not necessarily prepare learners to be able to see mathematics in spaces such as *Animal Farm*. Ability to see mathematics in such spaces requires a recontextualisation of mathematics knowledge beyond what may be accessible based on exposure to environments in which learners traditionally learn mathematics.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

L.M. carried out the investigation as part of her doctoral research. She wrote the initial draft of the manuscript. W.M. was the research supervisor. He read through the draft and made revisions to ensure that the manuscript met submission requirements.

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