

Opening mathematics texts: A critical discourse analysis of probability problems in mathematics textbook

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Abstrak Artikel ini menyelidiki sifat masalah peluang yang disajikan dalam buku teks matematika dengan menggunakan perspektif sosio-politik dan analisis wacana kritis yang diambil dari ahli bahasa kritis terkenal Norman Fairclough. Secara khusus, makalah ini menganalisis bagaimana siswa diposisikan oleh masalah yang disajikan dalam teks, untuk mengetahui peran penulis dan siswa sebagai pembaca, serta untuk mendapatkan wawasan tentang konsekuensi yang mungkin terjadi pada siswa. Merujuk pada model tiga dimensi Fairclough untuk analisis wacana kritis sebagai kerangka kerja untuk mempelajari hubungan antara teks tertulis dari masalah peluang dalam buku teks, praktik diskursif yang terkait, dan praktik sosial yang merupakan bagian dari praktik diskursif, artikel ini menunjukkan bahwa penulis buku teks cenderung otoriter dengan mengarahkan siswa tentang apa yang harus dilakukan dan bagaimana melakukan kegiatan berkaitan dengan konsep peluang (matematika). Analisis juga menunjukkan bahwa penggunaan masalah berbasis kehidupan sehari-hari dalam teks menunjukkan upaya penulis untuk menyajikan konsep peluang yang lebih relevan dan dapat diakses oleh siswa. Artikel ini menunjukkan kegunaan model tiga dimensi Fairclough sebagai kerangka kerja untuk menganalisis masalah peluang yang disajikan dalam buku teks matematika.

Kata kunci *Peluang, Analisis wacana kritis, Analisis buku teks matematika, Model tiga dimensi Fairclough*

Abstract This article investigates the nature of probability problems presented in mathematics textbook using the socio-political perspective and critical discourse analysis drawn from well-known critical linguists Norman Fairclough. Specifically, the paper analyzed how the students are positioned by the problems presented in the text, to find out the role of authors and student readers, and to gain insight about the possible consequences for students. Drawing on Fairclough's three-dimensional model for critical discourse analysis as a framework for studying the relationship between the written text of probability problems in the textbook, the associated discursive practices, and the social practice to which the discursive practices form part, the article argues that the textbook authors tend to be authoritative by directing students about what to do and how to do the probability (mathematical) activities. The analysis also shows that the use of real-word problems in the text points out the attempts of the authors to present the probability concepts more relevant and accessible to the student readers. The article demonstrates the usefulness of Fairclough's three-dimensional model as a framework for analyzing probability problems presented in the mathematics textbook.

Keywords *Probability, Critical discourse analysis, Mathematics textbook analysis, Fairclough's three-dimensional model*

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Introduction

There has been a considerable amount of research about the importance of language in mathematics teaching and learning in both mathematics education and applied linguistics community (e.g., Barwell, 2005; Foster & Inglis, 2017; Riccomini et al., 2015). Much of the previous research focusing on the relationship between mathematics and language aimed to explain the teaching and learning of mathematics as it happens in naturalistic classroom settings (Smit et al., 2016). However, the setting of the work presented in this paper is different from much of the work on the previous research about language and mathematics, in which it focuses on investigating the nature of real-world probability problems presented in the mathematics textbook. To the best of my knowledge, this is the first study investigating real-world probability problems presented in the school mathematics textbook using critical discourse analysis.

Mathematics textbooks, as already known, are a common feature of many mathematics classrooms all over the world, and their content and structure play an important role in students' learning and understanding of the subjects. Research done by Hiebert et al. (2003) found that teachers in many countries rely heavily on mathematics textbooks or worksheets of some kind in which they used mathematics textbooks in at least 90 percent of their lessons. Furthermore, most of the research on mathematics textbook analysis focused on the content and structure of the text. Sönerhed (2011) found that of the twenty-one studies on mathematics textbook analysis, 90% of them are about content analysis and a few of them are about both content analysis and the use of textbooks in relation to curriculum. Taking a different approach, this paper examined the nature of probability problems presented in mathematics textbook using the socio-political perspective and critical discourse analysis drawn from well-known critical linguists Norman Fairclough. Specifically, the paper analyzed how the students are positioned by the problems presented in the text, to find out the role of authors and student readers, and to gain insight about the possible consequences for students.

Methods

Critical discourse analysis

The mathematics textbook was analyzed through a Critical Discourse Analysis (hereafter CDA). CDA is a multidisciplinary and interdisciplinary research tool to study linguistic discourse that views language as a form of social practice (Fairclough, 1992). Fairclough's three-dimensional model for critical discourse analysis will be used as a framework for studying the relationship between the written text of probability problems in the textbook, the associated discursive practices (production, distribution, and consumption of the text) and the social practice to which the discursive practices form part.

Discursive practice (production, distribution, and consumption of the text)

Discursive practice, as indicated in Fairclough's three-dimensional framework, involves process of production, distribution, and consumption of the text. In terms of production, Fairclough (1992) suggested that the concept of "text producer" can be more complicated than it may seem. The producer of the text of probability problems analyzed in this paper is taken to be the author of the mathematics textbook from which the problem was originally selected and the curriculum designers who design the curriculum and instructional approach that is used to create the problems for the textbook. The 'consumer' or the 'interpreter' of the probability

problems in the textbook is taken to be the student who is working and solving the problems. According to Fairclough (1992: 134), text producers “interpellate” interpreting subjects who are capable of making the relevant assumptions and connections about the text, and hence yield coherent readings of the text. So, in relation to probability problems in the textbook, the producers of the problem text will have a particular student in mind when creating the problems.

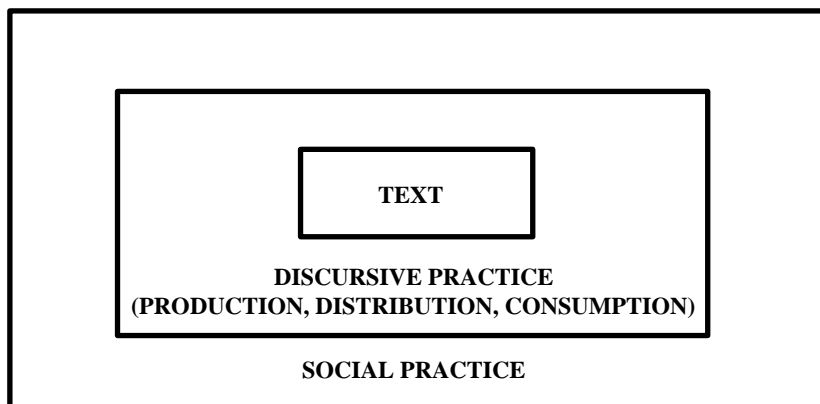


Figure 1. Fairclough's three-dimensional framework (1992: 73)

Text as action, representation, identification

By studying the level of discursive practice of the text that involves process of production, distribution, and consumption it is possible for me to consider the three major types of meaning of a text. Fairclough (2003: 27) proposed three major types of text meanings: ‘Action’ refers to how the text enact social relations; ‘Representation’ refers to what aspects of the world (the physical world, the social world, the mental world) that the text represents; and ‘Identification’ refers to what the text says about the attitudes, desires and values of participants.

The concept of intertextuality

In order to explore the processes of text production, distribution, and consumption on the level of discursive practice, I choose to use Fairclough's concept of intertextuality in which he argued that texts are full of other already produced texts. According to Fairclough (1992) intertextuality “sees texts historically as transforming the past – existing conventions and prior texts – into the present”. Intertextuality is concerned with how texts draw upon, incorporate, recontextualize and dialogue with other texts (Fairclough, 2003). The inner level of Fairclough's three-dimensional framework, the written text, will be analyzed to identify whether the texts are formed by other texts as suggested by Fairclough (1992). The concept of intertextuality will be used to identify the elements of the written texts that constitute the discursive practice. Fairclough (1992, 2003) distinguishes some of these related elements such as genres, discourse, styles, activity types, and registers. These interconnected elements can indicate how language can be used in a particular view of social life. Fairclough (2003) said that these elements could be connected to the three major types of text meanings (action, representation, and identification).

The textbook and probability problem texts

This paper analyzed the textbook from the series of Britannica Mathematics in Context titled Great Predictions. This book is one of the products resulting from the Mathematics in Context (hereafter MiC) project, which was developed by the Wisconsin Center for Education Research, School of Education, University of Wisconsin–Madison and Freudenthal Institute at the University of Utrecht, The Netherlands, with the support of the National Science Foundation Grant. The MiC project was resulted from a research collaboration between the US and Dutch mathematics education researchers to develop a middle-school curriculum materials that combined three different things: NCTM Curriculum and Evaluation Standards, the research base on a problem-oriented approach to the teaching of mathematics, and the Dutch realistic mathematics education approach. The MiC curriculum is organized in four mathematical strands: number, algebra, geometry and measurement, and data analysis and probability. The book that is used in this paper, great predictions, is categorized under the data analysis and probability strand.

In order to make it clear about the analysis, I present one of typical probability problems that are used in the textbook. The probability problems that are presented in the textbook share a particular format but differ in terms of their contexts. The problem presented below is about dying trees in the forested area where students are asked to estimate the number of dying trees given the specific situation.

In a forested area near Snow Creek, an average of 12 trees per 10 acres died from severe weather conditions over the last several years. But this year from January to August, forest rangers reported about 42 dead or dying trees per 10 acres.

2. a. The forest near Snow Creek is about 5,000 acres. How many trees would you normally expect to die from storms in the area?
- b. Explain whether you think the foresters should be concerned about the health of the trees.

Figure 2. The dying tree problem (Roodhardt et al., 2006, p. 2)

Analysis of text

I use Fairclough's (1992, 2003) method of Critical Discourse Analysis (CDA) to investigate the micro- and macro-level concepts of the probability problems presented in the text. In terms of micro-level concept, the following sections analyzed the text of probability problems presented in the MiC textbook based on Fairclough's three major types of text meanings. Whereas, in macro-level concept, the probability problem text was analyzed from socio-political perspectives using Fairclough's (2003) related elements: discourse, genre and style.

Action

In analyzing the action function of a text, I use three linguistic forms: imperatives, personal pronouns, and modality. Imperatives or commands such as determine, suppose, explain, and define tell the students what to do and attract their attention or activity. Rotman (1988) proposed the notion of inclusive and exclusive imperatives when examining imperatives of mathematics text. He defined that inclusive imperatives such as consider, define, and prove “demands that speaker and hearer institute and inhabit world or that they share some specific argued conviction about an item in such a world” (p. 9). Rotman argued that readers are constructed to think when reading the inclusive imperatives. In contrast, exclusive imperatives such as use, make, and count “dictate that certain operations meaningful in an already shared world be executed” (p. 9). Exclusive imperatives, Rotman claimed, construct reader to scribe. He went further that people need to scribe and think to do mathematics.

Personal pronouns, especially first-person and second-person pronouns, play an important role in the construction of action function of a text. Morgan (1996) argued that first-person pronouns such as I and we “may indicate the author's personal involvement with the activity portrayed in the text” (p. 5). The second-person pronoun, Morgan suggested, may address the reader directly about the mathematics presented in the text. The last linguistic form, modality, is defined as “indications of the degree of likelihood, probability, weight or authority the speaker attaches to the utterance” (Hodge & Kress (1993: p. 9) cited in Herbel-Eisenmann (2007)). Modality can be found in the “use of modal auxiliary verbs (must, will, could, etc.), adverbs (certainly, possibly), or adjectives (e.g., I am sure that...)” (Morgan, 1996, p. 6). The use of term ‘hedges’ to describe the words associated with uncertainty is commonly used by linguists. In mathematics textbooks, hedges such as “might”, “may” and “about” are common and these hedges raise questions about the degree of certainty about the things that are being discussed in the text. These two forms of language – personal pronouns and modality – can be used as a tool for understanding of how students are positioned with respect to mathematics (Herbel-Eisenmann & Wagner, 2007).

In analyzing the representation and identification functions of a probability problem text, I adopted linguistics analysis developed by Le Roux and Adler (2016, following Fairclough) that analyses the meaning of linguistic features using the discourse community. In this sense, I am interested to find out about how objects are presented, and people are identified (by nouns, pronouns, and articles), how activities are represented (by verbs), how time is represented (by adverbs) and how the text acts to link parts of the text (using conjunctions and articles).

Mathematical discourse vs everyday discourse

When analyzing mathematics textbooks, it is very important to differentiate between everyday discourse and mathematical discourse as one of the main goals of mathematics textbook is to encourage students to move from every day, informal ways of mathematical knowledge into more academic, conceptual ways of understanding mathematics. The notion of mathematical register proposed by Halliday (1978) can be used to understand the meaning of mathematical discourse. Halliday defined mathematical register as:

a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings. We can refer to a ‘mathematics register’, in the sense of the meanings that belong to the language of mathematics (the

mathematical use of natural language, that is: not mathematics itself), and that a language must express if it is being used for mathematical purposes (p. 195).

In this definition, Halliday pointed out to meanings, styles, and modes of argument. Through the notion of mathematical register, we understand that language constructs mathematical knowledge different from it constructs other academic subjects (Schleppegrell, 2007). In this analysis, however, I follow the view of Sfard proposing that mathematics is a special form of discourse. Sfard (2008:161) argued that mathematical discourses “are made distinct by their tools, that is, words and visual means, and by the form and outcomes of their processes, that is, the routines and endorsed narratives that they produce.”

Findings and Discussion

Imperatives in Great Predictions textbook

Overall, the 69-page student edition of MiC Great Predictions book consists of 15,417 words. Imperative words such as *explain* occurred 32 times, *suppose* occurred 9 times, and *determine* occurred 3 times as shown in the Table 1 below.

Table 1. Frequency of imperative words in the MiC Great Prediction text

Imperative words	Frequency
Use	51
Make	36
Find	34
Explain	30
Estimate	19
Copy	11
Suppose	9
Complete	8
Describe	7
Organize	6
Write	6
Draw	5
Determine	3

It can be seen that the most common imperative words include use, make, explain and estimate. Most of the imperative words in text require students to actively participate in the activities or experiments given in the text and also to explain or articulate their thinking and reasoning. Looking at the type of imperatives used in the text, I found that 151 of the 225 (about 67%) are exclusive imperatives. This fact shows that the authors tend to use authoritative in which they explicitly tell the students what to do and how to do it. This finding is in line with much of previous research showing that exclusive imperative words are common in mathematics textbooks (e.g., Herbel-Eisenmann, 2007).

Personal pronouns in Great Predictions textbook

The use of first-person pronouns is very rare in this textbook. There are only 2 instances where the plural first-person pronoun “we” is found, whereas the singular one “I” is entirely absent in this textbook. The use of first-person pronoun “we” in this mathematics unit such as

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“we can call this” could suggest that the author is speaking with the authority of mathematics community. However, the second-person pronouns occurred frequently in the text with 224 instances. For example, “In this section, you studied...” appears that the author is addressing reader to notice particular probability ideas from the text. Furthermore, the authors of MiC Great Predictions textbook used this kind of control to emphasize the mathematics, in this case probability concepts, that they hope or assume is constructed by the students (Herbel-Eisenmann & Wagner, 2007). Morgan (1996) argued that the absence of first-person pronouns obscure the presence of human beings in the text which distances the authors from the readers, creating a formal relationship between them.

Modality in Great Predictions textbook

The use of modality in the form of hedged verbs such as may, probably, and might are quite rare in this textbook with only 20 instances. Further investigation found that a combination of hedged verb and pronoun “you” are even smaller with only 3 instances. This indicates that the word “you” is mostly associated with a high degree of certainty verbs. However, the modal auxiliary verb occurred several times in the text such as “will” (84 times), “can” (52 times), “would” (47 times), “should” (10 times), “could” (8 times). This suggests that the authors showed their knowledge of probability problems with strong conviction and where the concept of probability is to be used.

Representation and identification

Looking at the probability problems presented in the text, it can be seen that the use of words acts textually to build a narrative about the objects discussed in the problems. Furthermore, most of the objects in the narrative of the texts are identified as a quantifiable collective such as ‘42 dead or dying trees’ and ‘a bunch of original fish’. In the dying trees problem, the dying trees are represented using different types of words such as died (verb), dying (adjective), and dead (noun/adjectives).

As the probability problem texts are presented in the form of narrative, the students are identified to use the linguistic features to follow the narrative. The people in the narrative text are presented personally related to the context of the texts such as forest rangers, households, and fish farmers. The use of pronouns he and she also suggest that students can identify their gender.

Herbel-Eisenmann and Wagner (2007) pointed out that the use of pictures with verbal text might impact the reader’s experience of the text, such as the use of ‘generic’ drawings and ‘particular’ photographs. They added that, for example, a drawing of a man might represent any man, whereas a photograph of a man is only representing one particular man portrayed in the image. In this MiC Great Predictions textbook, the authors use both generic drawings and particular photographs. The authors of Great Predictions textbook use 5 photographs and 4 generic drawings with people in them. Of all of these images, only one image showing a person doing mathematics. This image is a generic drawing, which means the portrayed person is generic, and it shows a man conducting a probability (mathematics) experiment (Figure 2). The use of this generic drawing might be understood as the authors’ invitation to the readers to imagine themselves conducting the experiment. The activity played by the man in the image can also affect readers’ sense of how mathematics, in this case probability, is related to people.

Furthermore, the portrait of a man in this image may also suggest a gender bias in which showing a stereotype of “male is more than female in mathematics.”



Figure 3. A man doing probability (mathematics) experiment (Roodhardt et al., 2006, p. 5)

Discourse, Genre, and Style

Mathematical discourse

A mathematical discourse is a way of using language (written and spoken language, visual images, and gestures) to represent the activities and objects in mathematics (Sfard, 2008). The fact that the MiC Great Predictions textbook is lacking first-person pronouns (singular and plural) indicates that the authors are trying to conceal the presence of human beings in the text. This is in line with the notion of “obfuscation of agency” proposed by Herbel-Eisenmann (2007) which means that the textbook portrays probability concepts (or mathematics in general) as a discipline that acts independently of humans. The authors’ style of writing the textbook is also authoritative in which most of the imperative words in the text are exclusive. The use of exclusive imperative constructs in this text, as noted by Rotman (1988), suggests the readers to be a scribbler who performs actions.

Mathematical genres

Genre is also a key to the analysis of mathematics textbooks. Le Roux and Adler (2016) defined a genre as “a recognizable way of using language to enact relations between people and between texts” (p. 234). Examples of mathematical genres are the mathematical word problem, the mathematics lecture, and the turn-taking practices (Le Roux & Adler, 2016). By following the argument of Gerofsky (1996) that classifies mathematical word problem as a genre, I found that in the MiC Great Predictions textbook, the authors seem to use mathematical word problem as a genre in producing the text. Gerofsky (1996: 37) emphasized that most word problems, from ancient or modern resources, follow the same three-component structure of ‘set-up’, ‘information’ and ‘question’.

Taking a dying tree problem from the MiC Great Predictions textbook (figure 3) as an example, it can be seen that the problem text perfectly matches with the three-component structure of mathematical word problem. In the problem, a ‘set-up’ and an ‘information’ component, is made by presenting the characters and condition of a forest at risk as well as the information needed to solve the problem in the first, second and third sentences. The next following sentence in the problem is a question presented to the students. Furthermore, the textual features of mathematical word problems presented in the MiC Great Predictions textbook suggest that they have no ‘truth value’ although some of the problems seem to refer to the real-

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word problems (Gerofsky, 1996). In her argument, Gerofsky went further to say that ‘word problems in mathematics education are written in imitation not of life but of other word problems’ (Gerofsky, 1999: 37).

Authoritative style

Style in mathematics textbook analysis is defined by Le Roux and Adler (2016: 234) as ‘how language is used to be a particular type of person such as a student or lecturer in a mathematics practice’. As the authors of the textbook use many exclusive imperative words, it implies that they tend to be authoritative in the style of writing the text. Herbel-Eisenmann (2007) argued that the authors’ role in authoritative style is to engage students into mathematical community by controlling their activity using commands.

Conclusion

In this paper, I have presented the use of Fairclough's three-dimensional model for Critical Discourse Analysis (CDA) to investigate the micro- and macro-level concepts of the probability problems in the MiC Great Predictions textbook. The analysis shows that the textbook authors tend to be authoritative by directing students about what to do and how to do the probability (mathematical) activities. This finding is in line with the previous research conducted by Herbel-Eisenmann (2007) and supports the argument that authoritative is a common mathematics textbook framing. Moreover, adopting a particular approach such as realistic mathematics education may put the authors of the textbook in the difficult situation as they have particular mathematical ideas in mind that students need to learn and do not have access about students’ actual prior knowledge (Herbel-Eisenmann, 2007).

The use of real-word problems in the text also points out the attempts of the authors to present the probability concepts more relevant and accessible to the student readers. Presenting the probability problems in the form of narrative along with the use of generic drawings to help student readers imagine themselves of conducting the experiment or activities suggest that the authors are trying to move away from procedural approach towards more conceptual understanding. Following Cobb (in Sfard et al., 1998: 46), these textual and drawing features perform an action function to encourage a ‘conceptual discourse’ (a conversation in which the reasons for the calculations are made explicit) rather than a ‘calculational discourse’ (a conversation in which the primary topic is the calculation processes). This result is also similar to the work of Le Roux (2008) in investigating mathematical problem presented in the course material for a first-year university course in mathematics at a South African university.

The result of this study is also in line with the notion of *depersonalization* within mathematics textbooks proposed by Herbel-Eisenmann and Wagner (2007). They argued that mathematization, the moves between personal and personal, are at the heart of mathematics, and school mathematics textbooks should recognize and facilitate the mathematization within students’ mathematics learning. Although the analysis presented in this paper is limited by the socially constrained nature of my interpretations, it does demonstrate the usefulness of Fairclough's three-dimensional model as a framework for analyzing probability problems presented in the mathematics textbook.

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