

An analysis of intrasemiotic and intersemiotic relations of textual and visual modes for the topic of Forces in Namibian Grade 8 school science textbooks

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Abstract

Science education in Namibia receives much attention from the Government of the Republic of Namibia, but learners' performance remains poor in Physical Science topics such as Forces and Matter. Although the majority of Namibian learners rely heavily on school textbooks as learning aids, there is a paucity of research on the nature of their textual meaning potential. School science textbooks are multimodal with semiotic modes such as the textual/written and visual modes. The Systemic Functional Linguistics' textual metafunction focuses on the devices or relations these modes could enact within or across each other for producing a cohesive piece of text. Sense-relations across the textual and visual modes in school science textbooks potentially contribute to strengthen cohesion and thus greater textual meaning-potential than afforded by sense relations within these modes alone. This study builds on the discourse perspective on science education by analysing the intrasemiotic and intersemiotic sense relations within and across the textual and visual modes for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks. It entailed a qualitative case study framed by Systemic Functional Linguistics more generally, and the notion of intersemiotic complementarity in particular.

The results from this study indicate which sense relations were currently playing a stronger role in strengthening cohesion for the topic of Forces. Synonymy and repetition were found to be the most frequently-occurring sense relations within the textual mode while antonymy, collocation and synonymy were the most frequently-occurring sense relations within the visual mode. The main finding of the study was that intersemiotic complementarity in Physical Sciences textbooks contributed to strengthened cohesion and thus textual meaning potential in the topic of Forces through the sense relations of intersemiotic collocation and intersemiotic repetition. The study recommends that textbook developers strengthen currently under-utilised relations within and across modes, in order to strengthen textual meaning-potential for the topic of Forces. The study also recommended that the Namibian science textbook publication criteria should include textual-visual intersemiotic complementarity as one of the evaluation criteria for school science textbooks.

Keywords: forces; semiotic modes; multimodal school science textbooks; intersemiotic complementarity; Systemic Functional Linguistics; intrasemiotic

Introduction

Science education in Namibia receives much attention as evident in Namibia's National Textbook policy highlighting the sciences as critical subjects (Ministry of Education, 2008). Strong emphasis is placed on learners' understanding of the physical and biological world (Ministry of Education, Arts & Culture, 2015a). Despite such attention and emphasis, the problem of poor learners' performance in subjects such as Physical Sciences persists. Namibia's national results for Grade 10 Physical Science indicated the percentage of learners who scored A-C symbols in 2015, 2016 and 2017 as 28.3%, 32.2% and 30.0% respectively (Ministry of Education, Arts & Culture, 2015-2017). 'Forces' is one example of a Physical Sciences topic in which learners experience challenges (Ministry of Education,

2015-2016). Due to the visual nature of the topic, many teachers and learners utilise textbooks when covering it. This is no surprise considering that school science textbooks play a significant role as mediating tools in facilitating learners' meaning-making of scientific knowledge (Ndumanya, Ramnarain, & Wu, 2021).

Martinec (1998, p. 161) explains that "textual meaning is about the devices which the semiotic modes have for producing a cohesive piece of text rather than a random collection of acts" and that this applies to all semiotic systems, "whether it be that of action, language, images, music, or an inter-semiotic one". Due to the multimodal nature of science and in line with school science textbooks worldwide (Wanselin, Danielsson, & Wikman,

2021), Namibian school science textbook discourse involves both textual and visual modes. The cohesive devices in question can thus exist within individual modes (intrasemiotically) or between modes (intersemiotically). The particular cohesion achieved across modes in a text such as textbooks, empirically reveals its specific intersemiotic texture. Liu and O'Halloran (2009) single out intersemiotic texture as a property of coherent multimodal texts crucial for coherence.

While it is important to have an understanding of how semiotic modes work together to help the learners make meaning of science, insufficient research has been carried out on the nature of the meaning relations between modes in explaining the “features that make multimodal text visually and verbally coherent” (Royce, 2007, p. 63). There is a knowledge-gap in the literature pertaining to textual-visual cohesive relations even though such relations can possibly strengthen the textual meaning potential of Namibian school science textbooks. This is particularly problematic in African countries such as South Africa and Namibia, where there is a history of strong reliance on science textbooks due to most learners studying science in the medium of a second language – often by teachers who are also not proficient in this language (Alexander, 2001). The knowledge gap, together with learners’ overall poor performance in the topic of Forces, provided a strong rationale for analysing intrasemiotic and intersemiotic sense relations for the topic of Forces in Namibian Grade 8 physical sciences textbooks.

The research questions which drove this study were:

1. What is the nature of the *intrasemiotic* sense relations for the topic of Forces in Grade 8 Physical Sciences textbooks within the textual and visual modes?
2. How are the textual and visual modes for the topic of Forces related in terms of *intersemiotic* complementarity?

It was anticipated that the findings of this study would inform school science textbooks developers in terms of how textual meaning could be strengthened within and across the written/textual and visual modes. Furthermore, the results might have the potential to empirically inform Namibian science textbook

criteria focused on by Namibian textbook evaluation panels.

Review of literature

The topic of Forces

The topic of Forces in the Namibian Junior Secondary Phase (JSP) Physical Sciences syllabus for Grade 8 is divided into five sub-topics: “The nature and effects of Forces”; “Weight and Mass”; “Work”; “Energy”; and “Friction” (Ministry of Education, Arts and Culture, 2015a, p. 20). The acquisition of knowledge and skills in these sub-topics by learners is important for the reasons stipulated by Namibia’s Ministry of Education, Arts and Culture (2015a): firstly, they help learners foster an understanding of the interaction of human beings and the environment; and secondly, they help learners understand the physical and biological world around them. Although significant, these sub-topics have proven to be a challenge to the success of the Namibian science education curriculum, as indicated by learners performing poorly in them (Ministry of Education, 2015).

School science textbooks as discourse artefacts in Bernstein’s Pedagogic Device

Basil Bernstein, one of the most influential theorists on the sociology of education (Singh, 2002), introduced the notion of the pedagogic device as a possible explanation for the relative stability of formal education systems across contexts. The Pedagogic Device is explained as a “process by which discipline-specific expert knowledge is converted or pedagogised” (Singh, 2002, p. 572), i.e. made suitable for the learning process. The model provided by the pedagogic device is useful for this study because it situates textbooks theoretically in the broader educational landscape. From the perspective of the pedagogic device, school science textbooks are curriculum artefacts of the recontextualisation field which lays between the knowledge production and knowledge reproduction fields. The field of recontextualisation according to Bernstein (1990) comprises two sub-fields: The Official Recontextualising Field (ORF), and the Pedagogic Recontextualising Field (PRF). The PRF consists of textbook publishing houses, professional teacher associations, and other non-governmental educational institutions. Thus, the work of developing and publishing school science textbooks (such as the ones explored in this study), lies within the PRF. Multimodal school

science textbook discourse is thus a pedagogic recontextualisation of the multimodal discourse of scientists in the knowledge production field, for use by teachers and learners in the knowledge reproduction field. This highlights the significant role of science textbooks in science education of developing countries such as Namibia.

The significance of science textbooks within the school curriculum

School science textbooks are considered globally to be important agents of school curriculum implementation. The importance of school science textbooks in general within the education system is recognised by many scholars (Ndumanya et al., 2021). School science textbooks influence science teachers' implementation of a school curriculum (McNeill, Berland, & Pelletizer, 2017). During the school closures due to the COVID-19 pandemic from 2020 to 2021 and with the resulting expectation of increased independent study by learners in countries like Namibia where online learning is constrained by Wi-Fi limitations, their significant role in mediating learning was magnified. In effect, many science learners in contexts of poor Wi-Fi infrastructure or access such as Namibia and for whom online learning was thus not an option, would have experienced school science teachers being largely replaced by school science textbooks as the primary avenue of science discourse.

Cohesions across the Textual and Visual modes in school science textbooks

Some scholars define semiotics as the study of meaning-making through signs (Jamani, 2011). The field of semiotics aims to characterise the different kinds of signs that compose different semiotic resources (Machin, 2016). According to Jamani (2011), the textual and visual modes are examples of semiotic resources contributing to the meaning potential of scientific texts. Each semiotic modality expresses a slightly different meaning (Roehrich, 2016). There is meaning that the textual mode can individually afford that the visual mode alone cannot, and vice versa (Roehrich, 2016). For example, the textual mode plays a significant role in facilitating symbolism (Machin, 2016).

Hsu and Yang (2007) cautioned that school science textbooks often contain unique terminologies that differ from everyday language. The textual mode is thus

indispensable in differentiating between every day and scientific discourse. In terms of the visual mode, Machin (2016) highlighted their iconic nature in resembling the objects being depicted. Visuals in school textbooks can shape readers' sensory perceptions of the represented world (Haiyan, 2018). Roehrich (2016) highlights that the visual mode allows for communication that is impossible with words alone. This is why abstract concepts in science textbooks are often described and explained via visual representations (Wanselin et al., 2021). The different modes can complement each other due to the additive nature of their meaning affordances (Royce, 2002).

The relation between semiotic modes such as the visual and textual is reported by Siefkes (2015) as a relatively under-explored area of multimodality research. The connection between semiotic modes is related to cohesion (Jones, 2012). Ali (2021, p. 277) describes cohesion as "the relation of meaning, the connection or the ties which exist within a text and provide the semantic unity required in the structure of that text". Cohesion is of utmost importance in science textbooks because it pertains to all the metafunctions (ideational, interpersonal, and textual) of semiotic systems according to Systemic Functional Linguistics. Cohesive relations thus also contribute to textual meaning potential of the textual/written and visual modes (Roehrich, 2016).

Theoretical framework

Intrasemiotic and intersemiotic sense relations

The theoretical orientation of this study drew from Systemic Functional Linguistics (SFL) theory devised by Halliday (1978). SFL considers language to be a social semiotic system, and initially focused primarily on spoken language and the associated written text (Halliday, 1978). SFL proposes that the meaning-making functions of language are categorised into three metafunctions: the ideational, the interpersonal, and the textual. The current study did not focus on power relations involved in the language use and so the interpersonal metafunction was not relevant. The ideational metafunction refers to the content function of semiotic modes (Halliday, 2007) and the textual metafunction "concerns organisation of the text and how meaning is presented to make it coherent" (Wanselin et al., 2021, p. 3) – it is thus the textual metafunctions which is of strongest

relevance to the current study.

Later interest in exploring how different semiotic modes interact in multimodal texts resulted in the evolution of Systemic-Functional Multimodal Discourse Analysis (SF-MDA) (O'Halloran, 2008). The SF-MDA approach to language and other semiotic modes, particularly in terms of their metafunctional meanings, offered a framework by which the textual and visual modes appearing in Namibian school science could be analysed. The textual metafunction can be explored in terms of the cohesion that occurs between the written/textual and visual modes, achieved through the six sense relations highlighted by Royce (2002, 2007): repetition (when the meaning of two semiotic modes is exactly the same), synonymy (when the meaning of two semiotic modes is similar), antonymy (when the meanings from two semiotic modes is in opposition), hyponymy (classification of the meaning relations between the general class and its sub-classes), meronymy (classification of the meaning relations between a whole and its constituent parts), and collocation (concerned with the relationship of semiotic modes that regularly co-occur). For the study reported in this paper, these sense relations were explored within and across the textual and visual modes for the topic of Forces in three Namibian Grade 8 Physical Sciences textbooks in order to address the research questions. These are: *Platinum Physical Science Grade 8 Learner's Book* (Haimbangu, Poulton, & Rehder, 2016), *Living Physical Science Grade 8 Learner's Book* (Jones, Larceda, & Roebert, 2016), and *Solid Foundations Physical Science Grade 8 Learner's Book* (Van Niekerk, 2016).

Intersemiotic complementarity

Intersemiotic complementarity is an approach of SF-MDA for studies involving the analysis of multiple modes, and some recent studies used intersemiotic complementarity for exploring meaning potential of multimodal texts (Nakakuwa & Jawahar, 2020; Royce, 2007). In order to understand how the visual and verbal modes work together in a multimodal text, Royce developed the framework to analyse the intersemiotic complementarity between the visual message elements (VMEs) and lexical items in printed text. According to Royce (2002, p. 191), "the visual and verbal modes complement each other to realise an intersemiotically coherent multimodal text". Of particular relevance to

the object of analysis in the study reported in this paper – textbooks, he suggests "that the intersemiotic resources used to realise this complementarity can be readily explored for pedagogical purposes" (Royce, 2002, p. 191).

Research design

Research methods

This study entailed a qualitative case study of three Namibian Grade 8 school science textbooks in order to explore *intrasemiotic* and *intersemiotic* relations of the textual and visual modes. The selected Physical Sciences textbooks that constituted the data in this study were explored in-depth via document analysis. In the document analysis method, existing documents are the source of data (Bertram & Christiansen, 2015) making it different from other methods of collecting data such as interviews, which requires data to be elicited by the researcher for the purpose of the research (Pennington, 2017).

Research site, objects of analysis, and sampling

The study was carried out in Namibia and the objects of analysis were Namibian Grade 8 Physical Sciences textbooks. These textbooks were developed and evaluated following the most recent curriculum changes in the country. For all textbooks submitted for evaluation to subject panels (including Physical Sciences textbooks), a maximum of three of the best titles per subject per grade are approved (Ministry of Education, Arts and Culture, 2019). In Namibia, an approved textbook is "one which has been evaluated by the National Institute for Educational Development (NIED) in accordance with the specialised procedures, methodology, criteria and mark schemes for the revised curriculum" (Ministry of Education, Arts and Culture, 2015b, p. 4). Current criteria do not include intersemiotic complementarity.

The sample for the study included three Grade 8 Physical Sciences textbooks endorsed by the Namibian government at the time of this study being conducted (referred to in this paper as Textbook A, Textbook B and Textbook C). These textbooks were selected purposively because of the defining characteristic of their being endorsed by the government following a formal evaluation process conducted by NIED's textbook evaluation panel. The sampling was also purposive in terms of the focus on Grade 8, because the implementation of Namibia's revised curriculum for Grade 8

started in 2017 when this study began (Ministry of Education, Arts and Culture, 2015a). In addition, the study focused only on the topic of Forces because of its significance in Physical Sciences, coupled with the poor performance of learners in it (Ministry of Education, 2015).

Approach to data analysis

The analysis of data in this study was undertaken in three phases. The first phase aimed at providing a description of the textual and visual modes in terms of the common features of science discourse. Examples of these common features are keywords highlighted in bold face, and photographs and diagrams as types of representations occurring in the textbook section on Forces. The second phase dealt with analysis of *intrasemiotic* sense relations within each of the textual and visual modes for the topic of Forces. The researcher used both deductive and inductive approaches in developing the codes to analyse the *intrasemiotic* sense relations within the textual and visual modes. The deductive approach to data analysis involves an advance formulation of categories of information required from the data (Bertram & Christiansen, 2015). An inductive approach to data analysis is primarily a form of pattern recognition in data where themes or concepts are derived from the readings and interpretation of raw data without the restraints imposed by theory (Cohen, Manion, & Morrison, 2011).

The information that related to words,

concepts, and other textual elements were coded as *words*. Information relating to letters, mathematical operations, and numerical values were coded as *symbolic letters*, *mathematical symbols*, and *numerical values* respectively. In addition, the information relating to the use of arrows was coded as *arrows*. The words referred to as keywords in the Physical Sciences textbooks and which appear in bold font, highlighted in colour, or written in italics were coded as *technical words*. The diagrams and photographs were coded as *visuals*. Some diagrams and photographs in the topic of Forces for the three Physical Sciences textbooks were paired. The paired diagrams and photographs were coded as *paired visuals*. The diagrams and photographs in the topic of Forces that appeared singularly were coded as *singular visuals*. Phase Three focused on analysis of *intersemiotic* complementarity between the textual and visual modes for the topic of Forces.

Results and discussion

What is the nature of the intrasemiotic sense relations within the textual mode for the topic of Forces in Physical Sciences textbooks?

The results as shown in Figure 1 revealed that synonymy and repetition were the most frequently occurring sense relations within the textual mode. This suggested that the cohesive affordances of these sense relations were prioritised (whether knowingly or not) over others in facilitating meaning-making for the topic of Forces.

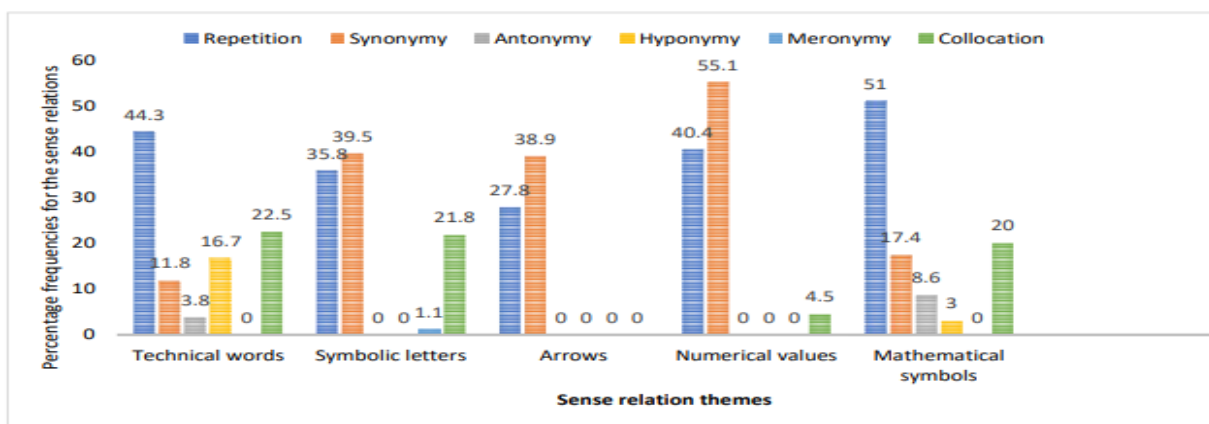


Figure 1: The average percentage frequencies of the sense relations for the textual mode themes

Synonymy occurred most frequently for the sense relation themes “symbolic letters”, “arrows”, and “numerical values” in the Physical Sciences textbooks. Examples of synonymy identified for the sense relation theme “symbolic letters” for the three Physical

Sciences textbooks included the textual elements *N* and *newton*, *m* and *mass*, *g* and *gravitational field strength*, and *w* and *weight*. The frequent occurrence of synonymy within the textual mode of the topic Forces is beneficial, in light of the fact that synonymy

helps avoid monotonous sentences in addition to being a cohesive device (Sidabutar, 2021). However, it was found that synonymy occurred less frequently for technical words that appeared in bold font, highlighted in colour, or written in italics. Learners as the main readers of these textbooks would stand a better chance of learning the vocabulary of science (Webb, 2007) if synonymy occurred with a higher frequency for technical words. The results suggest that learners could be missing out on this opportunity. This is a possible contributing factor to learners performing poorly in the topic of Forces.

The results for repetition indicated that it occurred most frequently for the sense relation themes “technical words” and “mathematical symbols”. Examples of repetition identified for the sense relation theme “technical words” encompassed the textual elements *contact force*, *non-contact force*, *mass*, *weight*, and *kinetic energy*. This study adds science textbooks to the range of data sources (telephone conversations, English and Spanish conversations, and non-narrative texts) reported by Malah (2015) for which repetition is reported as the most frequent form of cohesion. The results also indicated that collocation, hyponymy, antonymy, and meronymy were the least frequently occurring sense relations within the textual mode. Their low occurrences have implications for science education in terms of the missed opportunities for the cohesive affordances of these sense relations. Examples of collocation identified for the sense relation theme “technical words” for the three Physical Sciences textbooks include the textual elements, *contact force*, which is used together with other words such as, *pull*, *push*, *mass*, *weight*, and *gravitational field strength*. Examples of hyponymy

identified for the sense relation theme “technical words” included the textual elements, *contact force* > *frictional force* (meaning that *contact force* is the hypernym of *frictional force*) and *strain potential energy* < *potential energy* (meaning that *strain potential energy* is a hyponym of *potential energy*). Examples of antonymy identified for the sense relation theme “technical words” include the textual elements, *contact force* and *non-contact force*, *renewable energy sources* and *non-renewable energy sources*, as well as *gravity* and *upward force*. Examples of meronymy were identified only in one of the three Physical Sciences textbooks in the sense relation theme “symbolic letters”. The examples included the textual elements, *N* < *force meter* (meaning *N* is a meronym of *force meter*). The examples provided from the textual mode illustrate the same 6 sense-relations subsequently explored for the visual mode and across the textual and visual modes.

What is the nature of the intrasemiotic sense relations within the visual mode for the topic of Forces in Physical Sciences textbooks?

The results as shown in Figure 2 indicated that the sense relations which occurred most frequently within the visual mode were antonymy, collocation, and synonymy. This suggested that the cohesive affordances of these sense relations were prioritised (whether knowingly or not) over others in meaning potential for the topic of Forces. The results indicated that antonymy occurred most frequently between visuals containing arrows. This result suggested that arrows played a significant role in the meaning potential for the topic of Forces in the three Physical Sciences textbooks.

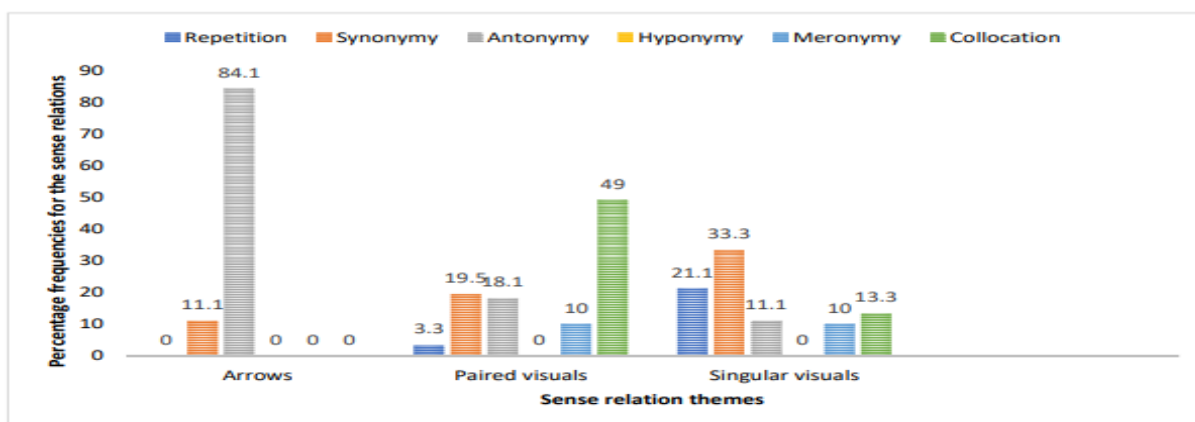


Figure 2: The average percentage frequencies for the sense relations within the visual mode themes

The results revealed collocation as the sense relation occurring most frequently for the visuals that were paired. The results showed that synonymy is sense relation which occurred most frequently for the visuals that appeared singularly. When visuals that were related in meaning appeared independently of each other in a textbook, the intrasemiotic visual cohesion might be weaker since the relationship between the visuals needed to be made by the learner themselves. Some learners would likely not realise the full meaning potential of such separate visuals, resulting in negative consequences for the overall meaning potential of the textbook.

How are the textual and visual modes for the topic of Forces related in terms of intersemiotic complementarity?

The results as shown in Figure 3 indicated that the occurrence of *intersemiotic* sense relations for the topic of Forces across the three Physical Sciences textbooks differs. While *intersemiotic* repetition occurred most frequently between

the textual and visual mode for the topic of Forces in Textbook A, *intersemiotic* collocation was the most frequently used sense relation in Textbook B and C. This difference in the occurrence of these *intersemiotic* sense relations suggested that it could be based on authors’ or publishers’ understandings of which sense relations provided the best cohesive affordances in communicating scientific knowledge for the topic of Forces. For example, as stated earlier, repetition was the most direct form of cohesion and this could account for this sense relation being the one most frequently used in Textbook A. For Textbooks B and C, the results suggested that there were missed opportunities for the cohesive affordances of repetition in supporting the learning content in the topic of Forces. The results further suggested that Textbook B and C considered *intersemiotic* collocation, which was also a contributor to cohesion, as significant for cohesion and thus meaning between the textual and visual modes for the topic of Forces.

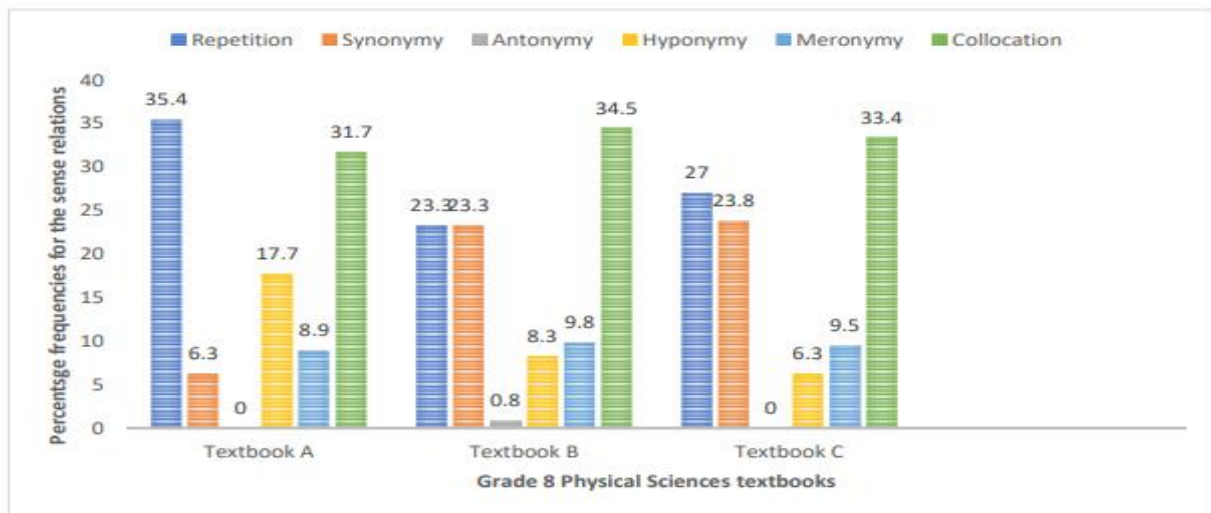


Figure 3: Percentage frequencies for the sense relations identified between the textual and visual modes in all three textbooks

On the other hand, the low occurrence of *intersemiotic* collocation in Textbook A meant that fewer opportunities were provided for the cohesive affordances of this sense relation in the topic of Forces. Overall, the results indicated that both the textual and visual modes in the topic of Forces complemented each other towards strengthening cohesion and thus textual meaning potential. These results provided empirical insight into Namibian science textbooks in terms of their *intersemiotic* texture - highlighted by Yiu and

O’Halloran (2009, p. 365) as “an essential property of multisemiotic texts”.

Conclusion

It is believed that science learning materials (such as textbooks) which are well-designed have the potential to facilitate conceptual learning (Khine & Liu, 2017). Ryu et al. (2021) recommend that text features such as cohesion should to be carefully considered during textbook development. The study reported in this paper which explored intrasemiotic and

intersemiotic cohesion in three Namibian Grade 8 science textbooks, contributed to the broader discussion on cohesion towards textual meaning in science textbooks. The results from this study indicated that particular sense relations were currently playing a stronger role than others in strengthening intrasemiotic cohesion for the topic of Forces, within the Physical Sciences textbooks. While synonymy and repetition are the most frequently occurring sense relations contributing to cohesion within the textual mode, antonymy, collocation and synonymy are the most frequently occurring sense relations contributing to cohesion within the visual mode. There is thus room for science textbook developers to draw more strongly on the cohesive affordances of intrasemiotic collocation (especially for arrows and numeric values), hyponymy (for symbolic letters, arrows and numeric values in particular), and meronymy (across all sense relation themes) for text about Forces. Furthermore, textbook developers should draw more strongly on the cohesive affordances of intrasemiotic meronymy (especially for arrows) and hyponymy (across all sense-relation themes) for visuals about Forces.

The findings of the study further revealed that intersemiotic complementarity between the textual and visual modes in Physical Sciences textbooks increased the overall number of sense relations possible from the text and visuals. The greater total number of sense relations (due to the instances of intersemiotic collocation and intersemiotic repetition identified in this study), strengthens cohesion for the topic of Forces beyond just the cohesive affordances of intrasemiotic sense relations with the textual and visual modes. In terms of the pedagogic device, these findings illustrated the particular intersemiotic texture by which the Pedagogic Recontextualising Field currently allows for specialised scientific knowledge on Forces to be pedagogised cohesively.

Recommendations

The study recommends that textbook developers draw strongly more strongly on the cohesive affordances of intersemiotic: synonymy, antonymy, hyponymy and meronymy, in order to strengthen the intersemiotic texture for the topic of Forces in three Namibian Grade 8 science textbooks. Due to the separate cohesive affordances of the textual and visual modes being strengthened by

sense relations that occur across these modes, the study also recommends that school science textbook selection panels include textual-visual intersemiotic complementarity as a textbook evaluation criterion.

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