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Descriptive Analysis of the Graphic Representations of Science Textbooks

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ABSTRACT

Textbooks are primary teaching aids, sources from which students obtain knowledge of science domain. Due to this fact, curriculum developers in the field emphasize the crucial role of analysing the contents of science textbooks in improving science education. Scientific domain knowledge relies on graphical representations for the manifestation of itself. Content analysis of the representations therefore entails the necessity of the systematic reading and categorizing of a body of visual representations, including diagrams, drawings, photos, and text that appeared in these science teaching and learning materials. This paper examined ten UAE primary science textbooks and practical books using an author-improved graphical analysis grid. From the descriptive analysis, it was found that general science was the illustrated topic area for fundamental level of science. The most frequently used graphical type is the iconic. Female images outnumber the male images. Results also showed that indigenous graphics were dominant over foreign graphics. The study also found the majority of visual representations in the textbooks were designed to convey static information and they are in close relationship with the textual representations. Yet most of the graphical images were indexed and captioned that served specific cognitive functions. The results also suggest graphic representations need to be treated as an important visual tool that textbook authors should use them wisely to have the domain knowledge conveyed in various topic areas.

Keywords: graphic representations, coding scheme, content analysis

INTRODUCTION

Textbooks play a crucial role in the science teaching and learning. As all science subjects seek to provide representations and explanations for natural phenomena so as to describe the causal relationships and the complexity of the natural world (Gilbert, 2007). For this reason, science educators consider textbooks as instructional resources that support teachers in planning and delivering science instruction to meet local and national curricular standards. Textbook authors thus enjoyed the freedom to manifest the national curricula and examination specifications (Martinez-Gracia, Gil-Quilez and Osada, 2006). As a major source of information in teaching and learning of a particular science subject, the quality and accuracy of the textbook content is crucial for their educational effectiveness.

Textbook researchers aimed at exploring different aspects of textbook features. The research territories may include the treatment of socio-scientific and controversial issues, analysis of representational information, portrayal and convey of knowledge (Orgill, 2013), nature of science (e.g., Abd-El-Khalick et al., 2017), gender issues (e.g., Yasin et al., 2012), comprehensibility of text (e.g., Kloser, 2016), language pattern (e.g., Muspratt and Freebody, 2013), demonstration of indigenous knowledge (Rillero, 2013), and cultural and religious sensibility (e.g., Wiseman, 2014). Various forms of analytical tools have been developed: questionnaires, rubrics, grids, criteria, rating scheme, protocols, and coding of the indicators.

Criteria were formulated for the analysis of texts and various modes of presentations, such as illustrations, photos, maps, tables and exercises. A guidebook proposed by the UNESCO provided practical advice for textbook reviewers in adopting both quantitative and qualitative methods (Pingel, 2010). It suggested examining the proportion of facts and views and examiners' interpretation. The American Association for the Advancement of Science, (AAAS) Project 2061 developed protocols evaluating the instructional effectiveness of science textbooks. Science educators observed when students learn science topics; there is a need to emphasize deep conceptual understanding rather than factual memorization. As such, a wide repertoire of content-specific instructional supports that promote understanding among students from diverse backgrounds, interests, and abilities (Koppal and Caldwell, 2004).

Existing literature recognized the the role of graphical representations in constructivist learning, which is not only to transmit information but also to enable students conduct their own investigation. Studies explained the role of graphical displays in learning and thus effective graphical designing principles should be synthesized. By examination of three theoretical perspectives on visual learning, Vekiri (2002) concluded that dual *coding theory*, *visual argument*, and *conjoint retention* are compatible although each theory has its own assumptions. Vekiri also claimed that graphics are effective learning tools only when they allow learners to interpret and integrate information with minimum cognitive processing. Learner's differentiation such as prior subject knowledge, visuospatial ability, and learning strategies could influence graphic processing and interact with graphical design to mediate its effects.

In particular, studies on engaging visual representations in science books could be roughly divided into two perspectives (Liu and Khine, 2016). The first approach mainly focuses on the instructional effectives of visual displays brought to the individual learning. A majority of studies followed this vein and examined the leaners' visual learning. Slough et al. (2010) quantified the type and quality of the graphical representations in middle school textbooks in the United States and examined how they interacted with the texts. An instrument named Graphical Analysis Protocol (GAP) designed by Slough's research team to analyse the graphic types the interaction with the textual material. In their findings, they reported most graphics were static, and analytic forms of graphics serve decorative purpose in nature. Moreover, they found about one third of the graphs were not spatially or semantically related to the text. Irez (2010) examined five secondary school biology textbooks and examined the treatment of nature of science. Lee (2010) examined the design and use of representations changed over the six decades in the USA, and argued graphs used in the textbooks become increasingly iconic. It was found science was portrayed as a collection of facts rather than of a dynamic process of generating and testing alternative explanations about the nature of science. The study identified one problem in the textbooks that potentially generate alternative conceptions about science as the scientific domains was portrayed as congregation of facts rather than dynamic processes.

The second approach considers the school books as cultural objects that may have an impact on the representational teaching and learning activities. Since textbooks represent the national curricular and the uniqueness of cultural identity. Researchers of this orientation believed that textbooks are developed to carry the national perspectives and culture (Izquierdo and Gouvea, 2008). There are also science educators insist on incorporating indigenous knowledge and local cultural of the society if to make textbooks effective in their own contexts (Ninnes, 2000). As for gender issues, Kahveci (2010) conducted a quantitative study to investigate gender equity, questioning level, science vocabulary load, and readability level. The author concluded that the textbooks included unfair gender representations, a considerably higher number of input-level and processing than output level questions, and high load of science terminology.

Reading visual displays for the scientific understanding could be a challenging task. More recent attention has focused on the analysis of specific textbook designing attributes when different visual modes of representations are engaged. Previous research into the content analysis of diagrams usage in science textbooks focused on the designing features by examining the relations between images and teachers' instructional practice (Pozzer and Roth, 2003). In a longitudinal study by Lee (2010), the author examined the extent to which changes in representations in textbooks published in the US over the past six decades. It was found that high-fidelity images, such as photographs are more likely to be used than the schematic and explanatory images to promote the familiarization to students. In explaining the criteria for evaluating the quality of science textbooks, Devetak and Vogrinc (2013) noted that visual materials are sometime used to stimulate recall of prior information. Although many variables regarding graphic features were taken into consideration, the researchers failed to extract the overall graphical/representational of primary science textbooks.

Later, textbook studies tend to build connections between visual mode of representations with other variables, such as students' achievement or teachers' instruction. Liu and Treagust (2013) conducted a content analysis on diagrams used in the Western Australia science textbooks. They explored the distribution patterns of different types of diagrams in secondary science and biology textbooks and the uniformity of the frequency of usage.

Through observing teachers' classroom instruction, Liu and Treagust (2013) proposed a series of teaching practices facilitating science teaching when diagrammatic representations are used. More recently, Liu and Khine (2016) performed a descriptive statistical analysis on the distribution of diagrams contained in Bahrain primary science textbooks and workbooks. They tested statistical difference between different book categories, suggestions were also provided for teachers to improve the diagrammatic teaching efficacy. In another empirical study, Renkl and Scheiter (2017) identified the challenges learners may encounter when dealing with visual displays. They further elaborated the supportive interventions and evidence about learning outcomes. All the above studies unanimously emphasized the role of different means of instructional interventions (textbooks or teachers' teaching) in either reducing the visual displays' complexity or increasing the individuals' prerequisites for an effective visual learning.

Previous studies failed to specify the functionalities of different graphical types used in the textbooks. In identifying different types of graphs, a coding scheme was created according to the taxonomy proposed by Hegarty, Carpenter, and Just (2016) that classified graphics used in science teaching context into three types, which include: Iconic diagrams, schematic diagrams, and charts and graphs. Iconic diagrams are realistic pictures or drawings of concrete objects. They are effective in helping student recognize the appearance and structure that are available to visual inspection. An example of iconic diagram could be a drawing or a photo of an insect. The iconic sketches provide visible outlines that could help to identify the shape of the insect. Compared to iconic diagrams, schematic diagrams are rather abstract representations, such as phylogenic trees or electric circuit. Schematic diagrams are highly abstracted from the real-world entities but only preserve the physical relationships of the target information. Consequently, interpretation of a schematic diagram requires learners to decipher the abstract content of the diagram and make a connection to the target concept. The third category, charts and graphs, presents the relationships of quantitative data. For example, a line graph can display the change in the human population over the years, and a pie chart can show the percentage of carbon dioxide in air. It is often necessary for the reader to identify all independent variables before making an interpretation because abstract meanings and numerical data embedded into charts and graphs.

The study also includes Augmented Reality (AR) diagrams into the coding scheme, because the textbooks contain virtual reality images that were designed and produced by multimedia printing technology. AR diagrams can be thought of as the "middle ground" between completely synthetic and completely real. The information conveyed through the augmented reality images could help perform real world tasks (Renkl and Scheiter, 2017). All diagrams in the ten school books were analysed according to the four diagrammatic types – iconic, schematic, charts and graphs, and augmented reality.

RESEARCH OBJECTIVES

The overwhelming majority of scientific concepts rely on the illustration of diagrams for effective teaching and learning. Although visual displays have great potential to foster learning, they also pose substantial demands on learners. As the literature calls for more research to examine the information on textbook alignment and to work out new content analysis standards (Hegarty et al., 1991). Meanwhile, under the belief that diagrams were not randomly used by textbook authors, researchers of this study aim to explore the inherent rules that graphics by which textbook writers and science educators use them for the purpose of facilitating students' conceptual learning. Well-designed science learning materials are believed to have the potential in facilitating students' conceptual learning. Through analysing the diagrammatical usage in textbooks, this study could set an example and to provide methodological options for future textbook studies. The researchers of this study sought to explore a number of properties inherent in the graphic displays in UAE primary science books. The investigation of graphic representations in UAE context may provide more suggestions and experiences on the instructional usage for further book studies. As been previously mentioned, textbook quality has been correlated directly and indirectly to the success of educational reform and enhancement of students' understanding (Azuma, 1997). Curriculum of the primary science is the starting point for higher level of science learning. Undoubtedly, the learning at the higher level of science demands a gradual build-up of the previous learning. The critical analysis of graphical representations in primary science textbooks serves as an important strategy to reflect on how the designing features of representations are aligned with school science teaching and learning.

Research Questions

The research aim of the study was clarified as to centre on the overall usage of graphics across textbooks and practical books, rather than gain a profound understanding of a certain scientific topic explained by certain representational mode(s). The aim of this study was to explore the distributions and frequencies of graphic representations in the primary science schoolbooks. In addition, the original coding scheme was applied in a new context. Therefore, a number of research questions were formulated in related to the categories contained in the coding scheme:

(1) What are the frequencies of the graphics among the science topic areas?
(2) How various forms of graphical representations distributed in textbooks and practical books?
(3) What is the distribution of the gender representations of graphics in the sampled textbooks and practical books?
(4) How was the ethnic information distributed in the textbooks and practical books?
(5) How do the graphic representations relate to the text? The frequency of indexing relation between a diagram and text.
(6) How do the graphic representations relate to the text? The frequency of captioning relation of illustrations.
(7) What are the functional connections between the graphics and the written text (*decoration or relation*)?
(8) What was the quality feature (dynamic or static) of the graphical representations in the textbooks and practical books?

THEORETICAL FOUNDATION

Conceptual change perspectives of teaching and learning have provided a powerful framework for the research in science education as well as instructional design (Polikoff, Zhou and Campbell, 2015). Over the past decades, cognitive development approaches to conceptual change have undergone a shift from Piagetian development psychology that emphasizes stage-dependent and domain-general conceptual learning to other paradigms such as Ausubel's (1968) assimilation, Vygotskian perspectives (Strike and Posner, 1982). Ausubel (Cheng and Gilbert, 2009; Eilam and Poyas, 2010) believes the most important factor influences learning is what the learners already knows and hence to teach accordingly. Piaget's (Chamblisss and Calfree, 1989)argument emphasizes the interplay of assimilation and accommodation in classifying students' conceptions on explications of their thoughts and science concepts.

It is therefore evident to note conceptual change theory emphasizes the crucial roles of active engagement and students' existing knowing play in the individual learning. Textbook as a ubiquitous instructional material used in science teaching and learning, the effectiveness of students' learning process could be supported by addressing the defining features of students' individual's active engagement and the diagrammatic distribution in the primary science curriculum. Learning science with diagrams is grounded in the primary curriculum. Learning science with graphics is grounded in the conceptualisation of knowledge as a tentative human construction widely known as constructivism that insists conceptualisation is reflected in constructing the new knowledge on a prior conceptual scaffold. In this study, all visual representations were considered as constructive learning tools that could facilitate leaners' conceptual changing process.

RESEARCH DESIGN

Sample

The sample consisted of all Science Students' Textbooks and Practical Activity Books adopted in all government schools in the UAE that typically cover 5 years of primary instruction. Primary textbooks were selected as the sample in this study was due to the importance of preliminary level of schooling is the crucial stage for science learning. All these ten books were selected and analysed in the study are currently used in the UAE primary schools. **Table 1** lists the titles that were covered in this study.

Table 1. List of textbooks under study

No	Level	Title
1	Primary Grade 1	Science Around You 1 (Student Book)
2	Primary Grade 2	Science Around You 2 (Student Book)
3	Primary Grade 3	Science Around You 3 (Student Book)
4	Primary Grade 4	Science Around You 4 (Student Book)
5	Primary Grade 5	Science Around You 5 (Student Book)
6	Primary Grade 1	Science Around You 1 (Practical Activity Book)
7	Primary Grade 2	Science Around You 2 (Practical Activity Book)
8	Primary Grade 3	Science Around You 3 (Practical Activity Book)
9	Primary Grade 4	Science Around You 4 (Practical Activity Book)
10	Primary Grade 5	Science Around You 5 (Practical Activity Book)

Method

Visual analysis is a systematic, observational method that allows the quantification of samples of observable content classified into distinct categories (Slough et al., 2010). By using frequency test, the authors of this study conducted a quantitative content analysis that consists of three research phases including: 1) defining the modes of representation to be analysed， 2) compiling the coding scheme to be used to code the graphics, and 3) encoding the graphics and to gain inter-coder reliability. According to the research framework by Bell, research process of this study could be divided into three steps:

The main task in the first phase is to formulate a series of research questions and the criteria to explicitly define what is to be understood as 'visual contents'. Particularly, the graphical types contained by the school books were classified, and the classification provided a basis for the further scientific observation of their appearances in different topic areas or themes.

During phase two, the authors compiled a code scheme and determined the related representational constructs to be examined. The instrument Graphical Analysis Protocol designed by Slough et al was taken as the original coding scheme, with changes made to highlight the uniqueness of the scientific instruction in UAE. The GAP instrument provides major key perspectives that organize the representational features of graphics to be examined. There are eight categories in the scheme, that are graphic types, function, topic area, quality, ethnic representation, gender representation, type and relation to text. **Table 2** lists the research categories with detailed descriptions. The coding scheme was validated by two science education specialists. After the coding scheme being revised, the criteria for coding were discussed among the authors and a group of science teachers. Categories in the revised scheme was also checked to make sure to be relevant to the research question. Methodologically, categories were also checked to meet the requirements of being 'Exhaustive' and 'Exclusive' in a quantitative content research (Cheng and Gilbert, 2009; Eilam and Poyas, 2010). 'Exhaustive' requires every aspect of the images must be covered by the coding category. 'Exclusive' requires no overlapping between the categories.

Table 2. The coding scheme used in the study (adapted from the original scheme by Slough et al (Duit and Treagust, 2012))

Research Category		Description
I – Topic Area		
Life Science	Plant	A plant photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
	Animal	An animal photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
	Human	A human photo or drawing, female or male
Environmental Science		An environmental photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
General		A general-science photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
Earth Science		An earth science photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
Physical Science		A chemistry or physics photo or drawing of indigenous (local Arabic) or foreign origin (outside the Arabic world)
II – Graphical Types		
Iconic		Photos and pictures that depict the concrete objects in which spatial relations are isomorphic to those in the referent object.
Schematic		Diagrams abstracted from real-world entities but do not preserve the physical relations presented in the source information.
Charts and Graphs		Depict quantitative and numerical data.
Augmented Reality		'Middle ground' between completely synthetic and completely real.
III – Ethnic Representation		
Indigenous		Local photograph (gulf states or Arabic) or drawing
Foreign		Non-local photograph or drawing
IV – Gender Representation		
Female		Female human photograph or drawing
Male		Male human photograph or drawing
V – Indexing		
None		Photograph or drawing is not mentioned in text
Indexed		Photograph or drawing is mentioned in text
VI – Captioning		
No caption		No title or description under graph or drawing
Captioned		A title or description is written under graph or drawing
VII – Quality		
Dynamic		Use series of images to show change over time in graph or drawing
Static		No change with time in graph or drawing
VIII – Function		
Decoration		Does not support text, if taken out does not cause any difference in understanding of the written text
Related to Text		Important to text written, if taken out will affect understanding of text

Having agreed on the diagram coding scheme, the authors in total reviewed a sample of diagrams (approximately 10% of the total) from a range of the textbooks resulting in more than 96% agreement with the classification in order to enhance the validity and reliability of the analysis.

The encoding and data analysis were conducted in phase three. All illustrations appeared in the UAE science textbooks and practical books grade 1 to 5 were coded and analysed with the developed coding scheme. Coding of images strictly comply with the description of each research category. The visual content was analysed by taking into account the context in which the scientific concept was demonstrated before the final categorization. In order to enhance the validity and reliability of the analysis procedure, the coding result was cross-checked by two well-experienced science researchers. At last, the main author reviewed and re-entered the data and performed the statistical analysis. The visual content in the school books were calculated and the data for each category were tabulated for each chapter in every textbook and practical book. Descriptive statistics was processed by SPSS software for each variable were conducted.

RESULTS AND DATA INTERPRETATION

An overall statistics regarding the number of pages and diagrams analysed, as well as results by research questions.

(1) What are the frequencies of the graphics among the science topic areas?

According to the results shown in **Table 4**, the General Science is the scientific domain that contained the largest quantity of graphics (778), followed by 531 graphics in Life Science topic, 210 graphics were found in Environmental Science, 187 in Earth Science, and 184 in Physical Science. Meanwhile, with the increase of the years of schooling, scientific topics manifested different tendencies of graphical usage in both textbooks and practical books:

The Life Science topic is composed of three broad sub-topics. Graphics used in the topic of Plant remained relatively stable between Textbook 1 (33.3%) and Textbook 2 (32.3%), the percentage dropped sharply to 5.1% in Textbook 5; however, it was noteworthy to see that graphs regarding plants were not used in a large quantity in practical books. The percentage dropped from 3% in Practical Book 1 to 1% in Practical Book 4. With no graphics were found in Practical Book 2, Practical Book 4 and Practical Book 5. The graphics relating to Animal showed a slight fluctuation from 27.2% in Textbook 1 to 9% in Textbook 4, and lastly rose to 12.6% in Textbook 5. The percentage in Practical books showed a slight downward tendency, from 10% in Practical Book 1 to 7% in Practical Book 3. The percentage of graphics used in depicting Human showed a significant decrease, from 23.8% in Textbook 1 to 8.5% in Textbook 5. An overall increase tendency could be found in the Practical books, from 4.8% (Practical Book 1) to 12.2% (Practical Book 4).

For Environmental Science, the percentages of graphical usage demonstrated an overall fluctuation in Textbooks, with a sharp decrease from Textbook 1 (34.8%) to Textbook 3 (6.7%), and then increased to 21.4% in Textbook 5; A steady decrease of the graphic usage could be seen in Practical books, from 3.3% in Practical Book 1 to 0.4% in Practical Book 3.

For General science, the percentage of graphical usage increased slightly from 11.3% in Textbook 1 to 18.3% in Textbook 5; The percentage of graphical usage remained a relatively stable, from 3.5% (Practical Book 1) to 3% (Practical Book 5).

In Earth Science, there is an increase in the graphic usage from Textbook 1 (10.7%) to Textbook 5 (28.3%). Textbooks of Physical Science demonstrated an dramatic increase in their use of graphs, from 58.2% in Textbook 1 to 3.2% in Textbook 5; On the contrary, there was a significant increase across the practical books, from2.7% in Practical Book 1 to 6.5% in Practical Book 5.

Table 4 derived from **Table 3** and indicated graphical distribution in topic areas and from grade 1 to 5. The results show that general science topic has the largest quantity of graphics (41.2%), followed life science topic (28.1%), and then environment science (11.1%), earth science (9.9%), and lastly physical science (9.7%). However, no matter what topic area is, textbooks contain more illustrations than practical books in each grade. As for the graphics used in different grades, grade 1 has the most number of graphics (27.2%), followed by grade 3 (19.9%), grade 2 (19.5%), grade 4 (15.9%) and grade 5 (17.5%). The graphic usage differs in each grade. The most frequently used and least used types are life science (35.3%) and Earth Science (5%) in grade 1; General Science (42.4%) and Earth Science (6%) in grade 2: General science (55.7%) and Earth Science (4%) in grade 3; General Science (43.8%) and Earth Science (5.7%); and General Science (50%) and Physical Science (1.8%).

Table 3. Frequencies of graphics in various topic areas for textbooks and practical books grade 1 to 5

Grade	TOPIC AREA										Total	
	Life Science		Environmental Science		General Science		Earth Science		Physical Science			
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Grade 1	182	35.3%	80	15.5%	115	22.3%	26	5%	112	21.7%	515	27.2%
Grade 2	133	36%	53	14.4%	157	42.5%	6	1.6%	20	5.4%	369	19.5%
Grade 3	79	21%	15	4%	210	55.7%	56	14.9%	17	4.5%	377	19.9%
Grade 4	84	28.1%	17	5.7%	131	43.8%	38	12.7%	29	10%	299	15.9%
Grade 5	53	16.1%	45	13.6%	165	50%	61	18.5%	6	1.8%	330	17.5%
Total	531	28.1%	210	11.1%	778	41.2%	187	9.9%	184	9.7%	1890	100%

Table 4. Summary of graphics in topic areas and across grade 1-5

Book Type and Grade	TOPIC AREA													
	Life Science						Environmental Science		General Science		Earth Science		Physical Science	
	Plant		Animal		Human									
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Textbook 1	33	33.3	73	27.2	39	23.8	73	34.8	88	11.3	20	10.7	107	58.2
Practical Book 1	3	3	26	10	8	4.8	7	3.3	27	3.5	6	3.2	5	2.7
Textbook 2	32	32.3	57	21.3	30	18.3	47	22.4	143	18.4	6	3.2	17	9.2
Practical Book 2	0		14	5.2	0		6	2.9	14	1.8	0		3	1.6
Textbook 3	23	23.2	38	14	3	1.8	14	6.7	169	21.7	51	27.3	14	7.6
Practical Book 3	2	2	2	7	11	6.7	1	0.4	41	5.3	5	2.7	3	1.6
Textbook 4	1	1	24	9	39	23.8	17	8.1	104	13.4	31	16.6	17	9.2
Practical Book 4	0		0		20	12.2	0		27	3.5	7	3.7	12	6.5
Textbook 5	5	5.1	34	12.6	14	8.5	45	21.4	142	18.3	53	28.3	6	3.2
Practical Book 5	0		0		0		0		23	3	8	4.3	0	
Total	99		268		164		210		778		187		184	

(2) How various modes of graphical representations distributed in textbooks and practical books?

The graphics in all the ten primary science Textbooks and Practical Books were examined and classified into iconic, schematic, charts & graphs, and augmented reality. Analysis were then performed to see how these above mentioned representational types were used in the ten school books, either textbooks or practical books. Results about the Textbook 1 to 5 are shown in **Table 5**; Graphical usage in Practical Book 1 to 4 was summarized in **Table 6**. **Table 7** summarized the maximum and minimum used graphic types in each year of schooling.

Results showed that: iconic diagrams were the most common form of graphics. Iconic diagrams accounted for 95.6%, 89.8%, 92%, 80.8%, 82.2%, and 88.9% in Textbook 1 to 4 respectively. While schematic diagrams came second at 4.1%, 7.8%, 6.4%, 17.1%, and 15.8% in each of the four textbooks, from Textbook 1 to 4. Charts & Graphs account for 0.2%, 0.6%, 1.6%, 2.1%, and 1.7% in Textbook 1 to 4. Augmented reality type has the least amount of graphic, with 1.8% in Textbook 2 and 0.3% in Textbook 5.

As for the graphic distribution of Practical Books, a similar pattern was found as in their paired textbooks. The most common graphic form is the iconic diagrams. Its proportions account for 83.5%, 91.7%, 75%, 50%, 29% and 68.5% in Practical Book 1 to 5. With schematic diagrams at 16.5%, 5.6%, 12.5%, 33.3%, 67.7%, and 23.9% in the five Practical Books respectively. The proportions of charts & graphs are relatively low, as in 0%, 2.8%, 12.5%, 16.7%, 3.2%, and 7.6% respectively. Besides, it is noteworthy that augmented reality graphs do not appear in the five Practical Books.

Table 5. Distribution of different diagrammatic representations for grades 1 to 5 textbooks

Diagrammatic Type	Grade										Total	
	Textbook 1		Textbook 2		Textbook 3		Textbook 4		Textbook 5			
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Iconic	372	95.6	299	89.8	286	92	189	80.8	245	82.2	1391	88.9
Schematic	16	4.1	26	7.8	20	6.4	40	17.1	47	15.8	149	9.5
Charts & Graphs	1	0.2	2	0.6	5	1.6	5	2.1	5	1.7	18	1.2
Augmented Reality	0		6	1.8	0		0		1	0.3	7	0.4
Total	389		333		311		234		298		1565	

Table 6. Distribution of different diagrammatic representations for grades 1 to 5 practical books

Diagrammatic Type	Grade										Total	
	Practical book 1		Practical book 2		Practical book 3		Practical book 4		Practical book 5			
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Iconic	66	83.5	33	91.7	48	75	33	50	9	29	189	68.5
Schematic	13	16.5	2	5.6	8	12.5	22	33.3	21	67.7	66	23.9
Charts & Graphs	0		1	2.8	8	12.5	11	16.7	1	3.2	21	7.6
Augmented Reality	0		0		0		0		0		0	
Total	79		36		64		66		31		276	

Table 7. The maximum and minimum of graphic types found in each grade

Grade	Book Type			
	Textbook		Practical Books	
	Max	Min	Max	Min
Grade 1	Iconic (95.6%)	Charts & Graphs (0.2%)	Iconic (83.5%)	Schematic (16.5%)
Grade 2	Iconic (89.8%)	Charts & Graphs (0.6%)	Iconic (91.7%)	Charts & Graphs (2.8%)
Grade 3	Iconic (92%)	Charts & Graphs (1.6%)	Iconic (75%)	Schematic/Charts & Graphs (12.5%)
Grade 4	Iconic (80.8%)	Charts & Graphs (2.1%)	Iconic (50%)	Charts & Graphs (16.7%)
Grade 5	Iconic (82.2%)	Augmented Reality (0.3%)	Schematic (67.7%)	Charts & Graphs (3.2%)

Table 8. The gender representations of graphics for textbooks and practical books

Books	Gender						Total
	Male Image		Female Image		Combination		
Textbook 1	15	24.2%	37	59.7%	10	16.1%	62
Textbook 2	12	28.6%	28	66.7%	2	4.7%	42
Textbook 3	9	32.1%	19	67.9%	0	0	28
Textbook 4	18	50%	18	50%	0	0	36
Textbook 5	4	25%	10	62.5%	2	12.5%	16
Practical book 1	0		1	100%	0		1
Practical book 2	0		0		0		0
Practical book 3	0		0		0		0
Practical book 4	0		0		0		0
Practical book 5	0		0		0		0

(3) What is the distribution of the gender representations of graphics in the sampled textbooks and practical books?

The findings to the above question is summarized in **Table 8**, which shows that female images tend to appear more frequently than male images in the school books. (Female images account for 59.7% for Textbook 1, 66.7% for Textbook 2, 67.9% for Textbook 3, 50% for Textbook 4, and 62.5%for Textbook 5). In addition, Textbooks contain more human images than Practical Books (184 to 1 in quantity respectively). However, portrait of human can barely be found in Practical Books. Compared with textbooks, there is only one graph found to be containing a human figure in Practical Book 1.

Although female images tend to be more frequently selected, gender preference as appeared in the images was not obviously emphasized in science teaching and learning. In most occasions, a human image was just employed to demonstrate as human intervention or operation is required in a scientific process, like an experiment.

(4) How was the ethnic information distributed in the textbooks and practical books?

As can be seen from **Table 9**, the majority of ethnic information resides in the graphics contained by Textbooks. While practical books have less ethnical content. The indigenous information is more preferable to be used in the explanation of a concept.

The indigenous elements can be identified as people's dressing, geographical environment, climate condition etc. The 'self-centric' way of using visual displays may help eliminate students' difficulties in understanding a concept. However, ethnic identities can rarely be found in practical books. **Figure 1** shows the images coded as indigenous and foreign.

Table 9. Distribution of the ethnic information in the textbooks and practical books

Books	Ethnic				Total
	Indigenous		Foreign		
Textbook 1	104	78.8%	28	21.2%	132
Textbook 2	65	80.2%	16	19.8%	81
Textbook 3	0		0		0
Textbook 4	10	100%	0		10
Textbook 5	10	83.3%	2	16.7%	12
Practical book 1	6	60%	4	40%	10
Practical book 2	0		0		0
Practical book 3	0		0		0
Practical book 4	0		0		0
Practical book 5	0		0		0

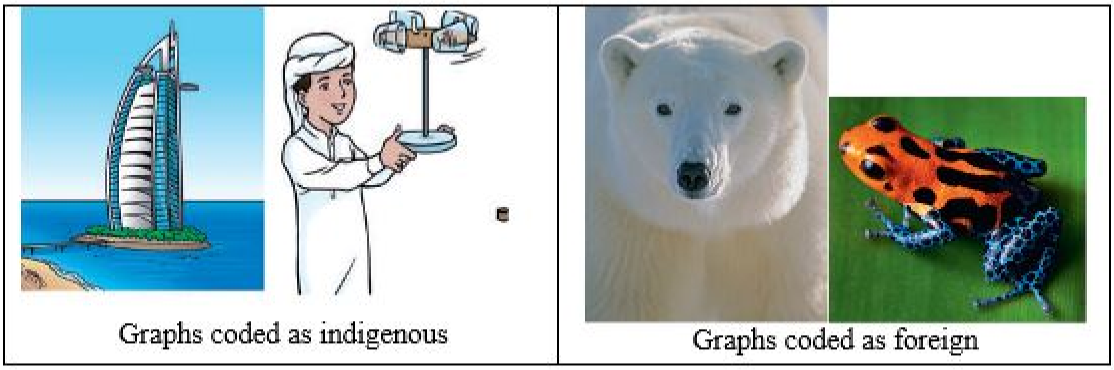

Figure 1. Graphs coded as indigenous and foreign origin

Table 10. The indexing relation between graphs and text in textbooks

Textbooks	Indexing				Total
	Not-indexed		Indexed		
Textbook 1	34	8.9%	348	91.1%	382
Textbook 2	18	5.5%	309	94.5%	327
Textbook 3	0		303	100%	303
Textbook 4	5	2.2%	227	97.8%	232
Textbook 5	24	8.1%	274	91.9%	298
Average	16.2	4.9%	292.2	95.1%	308.4

Table 11. The indexing relation between graphs and text in practical books

Practical Books	Indexing				Total
	Not-indexed		Indexed		
Practical book 1	23	29.5%	53	70.5%	78
Practical book 2	1	2.8%	35	97.2%	36
Practical book 3	3	4.5%	63	95.5%	66
Practical book 4	7	24.1%	22	75.9%	29
Practical book 5	18	58.1%	13	41.9%	31
Average	10.4	23.8%	37.2	76.2%	48

(5) How do the graphic representations relate to the text? The frequency of indexing relation between a diagram and text.

An indexing relation refers to a situation in which the diagram and the text are mutually complementary in explaining each other. As the results shown in **Table 10** and **Table 11**, the majority of graphics were in indexing connection with the wordy information beside. In average, 95.1% of the graphics in textbooks and 76.2% of them in practical books are coded as indexed. However, the percentage of not indexed in practical books is higher than that of textbooks (23.8% to 4.9%).

Table 12. Captioning relation in the textbooks

Textbooks	Caption				Total
	Not-Captioned		Captioned		
Textbook 1	38	9.9%	344	90.1%	382
Textbook 2	50	18.4%	222	81.6%	272
Textbook 3	49	16.3%	252	83.7%	301
Textbook 4	79	34.2%	152	65.8%	231
Textbook 5	92	30.9%	206	69.1%	298
Average	61.6	21.9%	235.2	78.1%	296.8

Table 13. Captioning in the practical books

Practical Books	Caption				Total
	Not-Captioned		Captioned		
Practical Book 1	16	19.3%	67	90.7%	83
Practical Book 2	7	20%	28	80%	35
Practical Book 3	39	59.1%	27	40.9%	66
Practical Book 4	18	27.7%	47	72.3%	65
Practical Book 5	5	16.1%	26	83.9%	31
Average	85	30.4%	195	69.6%	280

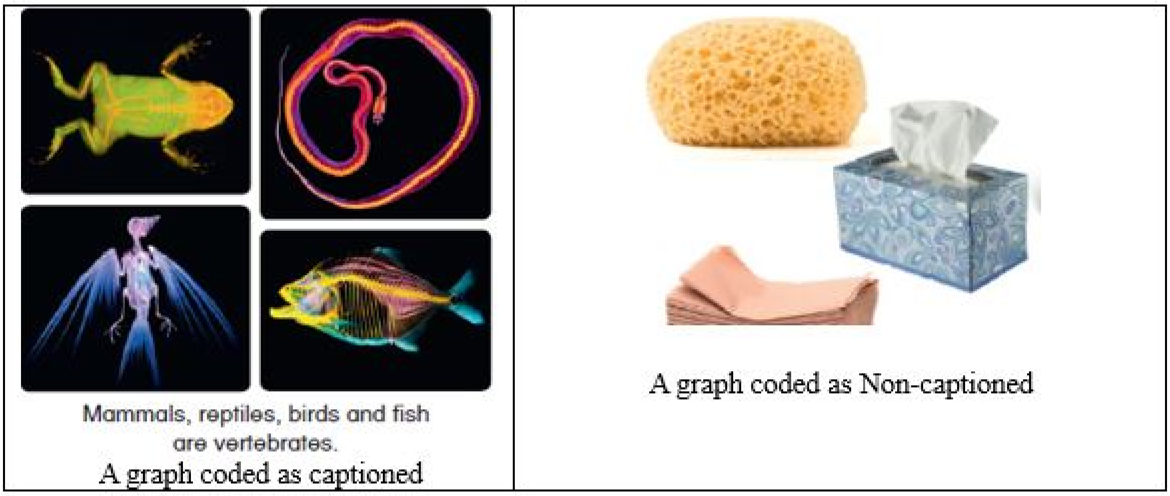

Figure 2. Captioned and non-captioned graphs

(6) How do the graphic representations relate to the text? The frequency of captioning relation of illustrations

A captioning relation refers to a brief description in written language provided to accompany the corresponding illustration. As can be seen from **Table 12** and **Table 13**, captioned illustration (78.1%, 69.6%) outnumber the not-captioned ones (21.9%, 30.4%) in textbooks and practical book categories in average.

Figure 2 shows the captioned and non-captioned graphs respectively. The caption 'Mammals, reptiles, birds and fish are vertebrates' was provided under the graphics facilitating students' understanding. However, the non-captioned graph on the right does not have any description or title underneath. These photos show various types of absorbent materials listed as examples. Without any explanations, students were asked to choose which is suitable for absorbing water.

(7) What was the quality feature (dynamic or static) of the graphical representations in the textbooks and practical books?

Table 14 and **Table 15** show the frequencies of the quality feature of graphical representations occurring in the school books. There are more static graphs than dynamic graphs in both Textbooks and Practical Books. With 79.1% are static graphs and 20.9% are dynamic graphs in Textbooks; 73.5% are static graphs and 26.5% are dynamic graphs in Practical Books.

Table 14. Frequencies of quality feature (dynamic or static) in the textbooks

Textbooks	Quality				Total
	Dynamic		Static		
Textbook 1	67	17.9%	307	82.1%	374
Textbook 2	38	11.5%	293	88.5%	331
Textbook 3	73	24.2%	229	75.8%	302
Textbook 4	61	26.3%	171	73.6%	232
Textbook 5	82	27.5%	216	72.5%	298
Average	64.2	20.9%	243.2	79.1%	307.4

Table 15. Frequencies of quality feature (*dynamic or static*) in the practical books

Practical Books	Quality				Total
	Dynamic		Static		
Practical Book 1	11	13.4%	71	86.6%	82
Practical Book 2	2	5.6%	34	94.4%	36
Practical Book 3	8	12.3%	57	87.7%	65
Practical Book 4	37	56.9%	28	43.1%	65
Practical Book 5	16	51.6%	15	48.3%	31
Average	14.8	26.5%	41	73.5%	55.8

Table 16. Frequencies of the functional connections in textbooks

Textbooks	Function				Total
	Decoration		Relation		
Textbook 1	10	2.6%	373	97.4%	383
Textbook 2	19	5.7%	313	94.3%	332
Textbook 3	0		299	100%	299
Textbook 4	1	0.4%	229	99.6%	230
Textbook 5	1	0.3%	297	99.7%	298
Average	6.2	2%	302.2	98%	308.4

Table 17. Frequencies of the functional connections in practical books

Practical Books	Function				Total
	Decoration		Relation		
Practical Book 1	3	3.6%	80	96.4%	83
Practical Book 2	0		36	100%	36
Practical Book 3	0		65	100%	65
Practical Book 4	1	1.5%	64	98.5%	65
Practical Book 5	2	6.7%	28	93.3%	30
Average	1.2	2.2%	54.6	97.8%	55.8

The majority of the graphs in both textbooks and practical books were used to convey static information. As the conceptual knowledge illustrated by 79.1% and 73.5% of the graphs were found to be static.

(8) What are the functional connections between the graphics and the written text (*decoration or relation*)?

Table 16 and **Table 17** illustrate the functional connections in textbooks and practical books. The majority of the functional connections between graphs and its related text in textbooks and practical books belong to relation function (98% and 97.8% respectively). Only a very few of the graphs were coded as the decoration function (2% and 2.2% respectively).

DISCUSSION

In this study, a descriptive statistical analysis was performed in regard with the type, function and another quality features of the graphical representations contained by UAE primary science textbooks and practical books. The results suggest that all the four types of the graphical representations were identified in the ten science books. With majority of graphical types were found to be used in all topic area. Some general features of the graphical usage could be summarized as follow:

In UAE primary science books, the general science topic (41.2%) contains the largest quantity of graphics, followed by life science (28.1%), environmental science (11.1%), earth science (9.9%), and physical science (9.7%) comes to the last (Refer to the results in **Table 3**). Prior study that have also noted the importance of using visual graphics in illustrating general science content, especially for the fundamental level of science learners. In the study, researchers examined the graphical representations in twelve Bahrain cycle-2 primary science books and workbooks, the results suggested about 70% of graphics belong to general science, 36% to life science topic area, 10% to earth science and 31% to environmental science, 3% to earth science and 31% to physical science (Ausubel, 1968). The proportions of the topic areas may vary in the school books from country to country, one general implication could be drawn is that general science is a domain in which textbook authors tend to use more visual representations to illustrate the conceptual knowledge being taught.

As for the selection of representational modes, the most frequently used visual type is the iconic, then the schematic, followed by charts & graphs, and lastly the augmented reality. This pattern applies to both textbooks and practical books. However, augmented reality graphs could rarely be found in practical books. Moreover, female images are more frequently used in describing the human intervention of a scientific process, for example, a scene in which female teachers are doing experiments with (female) students. In addition, textbook authors tend to have more indigenous elements in the explanation of concepts. Compared with the foreign elements, the indigenous elements are more preferable to be used in the graphical design. The above finding also correlates with a recent study (Vygotsky, 1978), in which iconic diagrams were identified as the most frequently used diagram type, the least used diagram type is Chart & Graphs, Augmented Reality graphics were rarely used in primary workbooks in another middle east country. It is also noteworthy seeing researchers of earlier studies also emphasized the importance of teaching diagrammatic literacy to improve students' learning of science concepts (Gilbert, 2007; Liu and Treagust, 2013; Novick, 2006). An iconic diagram was defined as an accurate depiction of concrete objections in which spatial relations in the diagram are isomorphic to those in the referent object (Piaget, 1971). The results of this study found empirical evidences supporting the advantages that iconic graphs have in the visual cognitive process. In particular, iconic diagrams are more often used in the beginning science learning in which is omorphic interplay need to be built between the graphic depiction and the concrete referent objects.

As for the relations between graphical and textual representations, the coding scheme summarized information into three aspects: *Indexing* – all most all of the graphs and text were mutually explaining each other (95.1% for textbooks and 76.2% for practical books); *Captioning* – most of the graphics were captioned, which means, a brief textual description was provided; *Functioning* – the logical and semantic relation between the visual and textual representations were further classified as being decorational or relational. The data shows the functioning relation belongs to the relational type, that is, the graphs were not simply provided to be appealing to the teachers and students. Though conceptual frameworks were proposed for depicting the multiple representational learning (Bell, 2001, p. 14), these frameworks depicts the leaners' cognitive process in such a subtle manner that can hardly to be applied in book analysis studies. Especially when voluminous of graphical and textual representations are posed together, which could deteriorate the reliability of coding. One of another obvious findings to emerge from this study is engaging more than one mode of representations in its coding scheme, the three classified functions (*Indexing, Captioning,* and *Functioning*) would be more suitable for book studies.

This study has certain limitations that could be considered in future research:

(a) In addition to the results from quantitative analysis, textbook users' (teacher/students) opinions could have been sought. Their opinions might provide a brand new perspective viewing the graphical usage. The actual uses of different modes of visual representations were observed especially in real science instructional context, the observations were considered helpful in triangulating the findings.

(b) The analysis of graphics could also have included items regarding specific drawing conventions, such as colouring, arrows and etc. Though those visual conventions alone are not sufficient for students to make sense of the information in graphics, knowing how learners refer to those conventions may also provide a means of analysing textbook usage of graphics.

(c) There may be more properties inherent in the graphical representations that should have been included in the coding scheme. Especially when new types of visual representations emerge along with the development of the printing technology, countries all over the world have different science teaching context. Those features may of great value to the improvement of the coding instrument.

Future studies could investigate (a) the cognitive relationships between different modes of graphic representations and other representational modes such as text, (b) the instructional use of different graphics in classroom settings, and (c) students' learning efficacies when reading different modes of graphics.

CONCLUSIONS

Previous studies into content analysis of science textbooks about visual representation usage focused on characterizing different functional features of visualizations by examining the relationship among the visual displays as well as teachers' instructional practices (2010). However, this study did not aim to investigate students' exact conceptual learning via different modes of visual displays. Guided by the improved coding scheme, this study set out to determine the patterns in which graphical representations distributed in the UAE primary science books.

The analysis of the ten science books may provide science educators with insights on the distributional manner that graphic representations have been organized in these books.

Research findings of this study could generally be divided into three aspects regarding the graphic usage:

One of the most significant findings to emerge from this research is analysing the graphical distributions among a number of scientific topic areas. The results shed light on the general visual usage of the science textbooks and practical books. However, the frequency does not equal to the level of importance of each subject area. In addition, it is neither ideal nor possible for all topic areas to have equivalent number of graphs. To some degree, the finding echoes UAE primary science curriculum, in which content areas like general science and life science might play a pivotal role in the science learning.

The second research objective moves on to the selection of graphical types in the illustration of domain knowledge. Various modes of graphical representations were found in the textbooks and practical books of each grade. The overall graphical selection was in accordance with the primary level of science teaching and learning, as iconic graphs are advantageous in presenting the information that is more tangible, concrete, and intelligible to the learners' background knowledge. It is also noteworthy to see that the higher the grade of science learning, the more frequently schematic graphs to be used. Human images were more likely to be used for instructional purpose, while less portraits of human were found in practical books. It is also observed that female images tend to appear more frequently than male images in the school books.

The visual illustrations in the ten UAE science books were also found to be accommodating to both indigenous and foreign elements. The indigenous graphs outnumber the foreign ones, as primary level of science teaching might require learners' interpretation of the concepts to be taught and their prior knowing.

Some other strengths that UAE textbooks have in facilitating students' learning. Such as, many items in practical books that need students to draw. Students' drawing may not only sever as a method to demonstrate their learning, it could also be a way for evaluating the individual conceptual learning. In textbooks, the graphical and textual representations supplement each other through description of the scientific facts as well as raising questions. In other words, graphs are always companied by a short passage entitled "Fact" describing the content of the image in an objective way. Besides, some questions may also be provided for the guidance of students' interpretation. The "Fact + Questions" pattern would help the book authors skilfully avoid the religious controversies that students may encounter during the science learning process.

Although an extent of the graphs were designed without caption, the function and content of the graphs were in consistent pattern. The topic may exert a guidance towards student's understanding of the graphs, because students may perceive its possible implication.

The coding scheme may not be able to serve as a universal instrument for classifying and analysing the graphical representations contained in textbooks. For more items could be added to fit the actual and indigenous science learning materials. However, findings summarized in the study provide suggestions that teachers should evaluate the visual material before its application in the classroom teaching. It also implies the importance of graphic usage that authors and curriculum developers should take into account when developing educational material. Nevertheless, in terms of methodological aspects, this study also provides empirical evidences to develop the 'Coding Scheme' that could be used for further textbook studies regarding visual usage. It is hoped that more items could be included into the original coding instrument Graphical Analysis Protocol (GAP) by Slough et al. An improved instrument could be used to identify and analyse more and other features of graphical representations or especially the interactions between different modes of representational learning and representational attributes. For instance, colour vs. black printing, the drawing and the graphical compositions – lines, arrows, shapes and etc.

Previous studies also tend to analyse two or more modes of representations or a number of spatial conventions under one representation that could promote conceptual learning (Khine, 2013). This study also provided practical advice for teachers and textbook authors when including different modes of visual representations in the everyday science teaching. Without any doubt, well-designed and visual-friendly learning materials are believed to exert a positive effective in helping students understand the difficult concepts and to avoid misconceptions. This study is considered of a benefit to teachers, textbook authors and curriculum developers in producing reform-oriented science textbooks, which would help in improving the quality of science learning in UAE. Although a large number of textbook studies in the literature focused on the graphics used in secondary and tertiary level of science education, preliminary textbooks deserve more attention.

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