



Content Analysis of The Diagrammatic Representations of Primary Science Textbooks

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•Received 8 February 2015•Revised 14 October 2015 •Accepted 20 November 2015

Science education research emphasizes the irreplaceable value of textbooks in students' acquisition of scientific knowledge. Illustrations such as diagrams contained in science books are crucial modes of visual representations that facilitate learners' conceptual learning. Through classifying, coding, and analysing diagrams from twenty science textbooks and workbooks used by Bahrain primary science curriculum, the aim of the study is to find out the distributional pattern and illustration characters of different diagrammatic types in the Bahrain's primary science books. Descriptive statistical analysis was carried out. A one-way ANOVA test was performed to check if there are any distributional differences between textbook and workbook categories. Findings of the study summarized the characteristics of diagrammatic usage in the Bahrain primary science books. The textbook analysis method used in the research also provided some insights for researchers interested in analysing the usage of diagrams and other illustrations in science learning contexts.

Keywords: Content analysis, diagrams, primary textbooks, science education

INTRODUCTION

Textbooks are important teaching aids and sources from which students of all schooling years obtain knowledge. Trends in International Mathematics and Science Study (TIMSS 2007) showed that in average about 40% of teaching time in every lesson is used by teachers to teach by textbooks (JapeljPavešič, Svetlik, Kozina, Rožman, &Šteblaj, 2008). Science educators unanimously agree that textbooks are used as a major source of information in teaching science, the quality and accuracy of the content is crucial for their educational effectiveness. And the inadequate and the inconsistency of science knowledge presented in them could affect students'

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interpretation of scientific concepts. As all science subjects seek to provide representations and explanations for natural phenomena in order to describe the causal relationships and the complexity of the natural world (Gilbert, 2007). In the learning process, books serve to facilitate student linking understanding between the real world entities, phenomena and scientific theories (Ahtineva, 2005). Such descriptions of complex scientific entities or phenomena have usually been chosen to correspond to the learners' formation of visual perceptions about what happened in the real world. It is therefore science textbooks are being used as a major illustration tool, their content knowledge and the way being demonstrated are crucial for the quality of individual learning.

Generally speaking, research on engaging visual displays in science education have largely been conducted from two approaches: The first approach mainly focuses on cognition located in individual minds and mediates between individual's notions and experience (Roth, Pozzer-Ardenghi & Han, 2005). According to this notion, visual representation usage could either be used as one of the constitutional factors leading to effective learning or evaluating learners' conceptual learning facilitated by interpreting the illustrations. The second approach places the emphasis on the role of culture and social practice, and looks at the school books as cultural objects in representational teaching and learning activities (Izquierdo & Gouvea, 2008). Studies of this type value the cultural diversity in the science syllabus, and maintain that researchers need to deftly and appropriately deal with the cultural differences in which they are working.

Despite previous studies acclaimed the learning efficacy brought by reading illustrations, few studies focused on diagrams as an integrated representation mode and its application across a wide range of scientific teaching and learning contexts, especially at the primary level. This study aims to find out the distribution pattern of various diagrammatic types being used in the primary science textbooks.

RATIONALE AND PURPOSE

In the large majority of science classrooms, textbooks reflect the curriculum that stipulating what is taught and learned about science (Chiappetta, Ganesh, Lee, & Phillips, 2006). Science curriculum of the primary is the starting point for higher level of science learning. Undoubtedly, the learning goals stipulated in higher level of schooling demand a gradual build-up of the previous learning. The critical analysis of primary science textbooks serves as an important strategy to reflect on how they are aligned with the principles and standards of the Bahrain science curriculum. The crucial role of pre-existing knowledge been found in the general learning performance indicated by science researchers (Ausubel, 1968; Strike & Posner, 1982). This study is considered of a benefit to curriculum developers and textbook authors in improving the quality of science textbooks used in Bahrain.

The overwhelming majority of scientific contents rely on the illustration of diagrams for effective teaching and learning. Well designed and visual-friendly textbooks are believed to help students to understand the difficult concepts and to

State of the literature

- In the learning process, books facilitate learners to link understanding between the real-world and scientific theories.
- To improve the textbook learning efficacy, more visual images are needed to augment the text.
- A few studies focused on diagrams as an integrated representation mode in scientific teaching and learning contexts.

Contribution of this paper to the literature

- After examining 3125 diagrams in 1955 pages, it was found that within the four categories of diagrams, iconic diagrams are most prevalent.
- The junior year books contain more iconic diagrams and senior textbooks include other three types of diagrams.
- The study provides some insights on the methods to be used in textbook analysis.

avoid scientific misconceptions (Khine, 2013). They are also expected to raise students' interests in learning science and contribute to the further meaningful learning. Although a great number of textbook studies in the literature focused on the graphics used in secondary and tertiary level of education, preliminary level of science textbooks deserve more attention. In addition, previous studies tend to more analyse various visual representations modes as an integrated approach or investigate some specific spatial conventions under one representation that could promote students' learning. The notion of investigating one particular representational mode may be absent.

The researchers of this study aim to explore the properties inherent in the diagrammatic displays in primary school science books. Under the belief that diagrams were not randomly used by textbook authors, instead, there must be rules in which science educators use them for the purpose of facilitating students' conceptual change. Based on the diagrammatic typology proposed by earlier studies (Hegarty et al., 1991; Azuma, 1997), this study examined those four diagrammatic types contained in the primary textbooks and the findings may provide some suggestions on the instructional usage of diagrams for further studies.

LITERATURE REVIEW

The understanding of visualization may be a demanding task as they depict scientific phenomena and processes that are invisible to the naked eye (Liu & Treagust, 2013). Previous studies emphasized students may have difficulties interpreting illustrations in the textbooks caused by visual conventions such as colour coding and arrows (Pozzer & Roth, 2003; Hurley & Novick, 2010). Well-illustrated science textbooks therefore have been widely acknowledged to have more visual friendly representations that facilitate the interpretation of domain knowledge (eg. Novick, 2006). The basic principle of analogical reasoning and constructivistic learning also imply that learners map a well-known domain (previous) to a new one (target) by keeping their familiar relationships (Gentner, 1998; Newton, 2003).

The multimodal information generated by combinations of both representations create challenges to learners as well. Peeck (1993) argued that drawing students' attention does little to support processing of pictorial representations, teachers should also place a picture before the text that may activate learners' existing background knowledge. Given the findings, Peeck suggested illustrators should let students work on some illustration related tasks.

A large number of the studies explored the possibility that readers interchangeably sought information from both the textual representations and graphic representation to achieve an effective learning. Agrawal et al (2011) suggests that for the improvement of textbook learning efficacy, more visual images are needed to augment the text. Information from both representations complement each other to help students achieve better learning effects. Researchers also found that extended captions could facilitate the learning of graphics (Bernard, 1990; Reinking, Hayes, & McEneaney, 1988). Other researchers value learners' differences in interpreting representations. Some educators stressed that text and images follow parallel relations, they more or less presenting the same information but possibly appealing to different readers (Martinec & Salway, 2005). In addition, the labelling verbal information can also contribute to students' conceptual interpretation. Mayer and Gallini (1990) observed students learn more from illustrations in which both the elements of the diagram and the function of those elements are labelled. The above findings suggested that text and visual means of representations need to be appropriately integrated in introducing abstract concepts in science (Vinisha & Ramadas, 2013).

Science textbooks may have different ways organizing multimodal representations. A study by Slough et al (2010) covered the use of graphical representation in sixth grade science textbooks in the USA. They found that one third of the graphic images are decorative in nature, and another one third was not related to the text beside. Carvalho et al (2011) examined the images used in teaching environmental science textbooks used in 14 western and eastern European and non-European countries. They found that eastern European countries tend to have more texts than images in their books, where as non-Europe textbooks have more images than text. In particular, researchers investigated the efficacy of various types of visual representations in promoting students' learning of scientific information. For example, Pozzer and Roth (2003) reported that students may have difficulties interpreting illustrations in the textbooks, especially when multiple visual conventions are combined, such as, colour coding, real or broken lines, and arrows are used without explanation.

The foci of textbook research could also be placed on learners' conceptual learning process facilitated by interpreting visuals used in the illustration of science books. 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 practices (Mevarech & Stern, 1997; Pozzer - Ardenghi & Roth, 2005). As illustrations in science textbooks are extremely varied, as they play different roles in demonstrating domain knowledge. Among all illustrations, diagrams were found critically important in demonstrating both abstract and concrete information (Pozzer - Ardenghi & Roth, 2005). It is worth noticing the fact that diagrams have been placed in the middle of the continuum. Bridging the concrete and abstract information implies that diagrams not only could reduce the amount of cognitive load but also limit the ambiguity for understanding science concepts.

In everyday science teaching environment, students need to learn through concrete hands-on experiences, experiments and practical works, and instructional activities that based on a conceptual theme in which the mathematical or scientific thinking could take place. Teachers therefore need to have the authority and the ability to critically select the most appropriate materials and to take the decision about when, where and how to make them useful for his/her teaching (Wang, 1998). Lee (2010) examined the visual representations used in the US textbooks over the past six decades. Lee found that high-fidelity images, like photographs are more often used than the schematic and explanatory images to promote the familiarization to students. Hurly and Novick (2010) emphasized the construction of diagrammatic conventions that are related to students' perceptual features.

THEORETICAL FOUNDATION

Conceptual change views of teaching and learning processes in science have provided a powerful framework for the research on teaching and learning as well as instructional design since the late 1970s (Treagust & Duit, 2008). Over the past three 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 assimilation (Assubel, 1968), Vygotskian perspectives (Vygotsky, 1978). Ausubel's (1968) believes the most important factor that influences learning is what the learner already knows and hence to teach accordingly. Piaget's (1964) argument insists 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 tool 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 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 framework. In this study, diagrams are considered constructive learning tools that facilitate learners' conceptual changing process.

RESEARCH DESIGN

Sample

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. The sample consisted of a total number of twenty primary students' textbooks and workbooks adopted in all government schools in the Kingdom of Bahrain. The twenty books (ten textbooks and ten workbooks) were selected and analysed in this study are currently used in the primary schools. These textbooks were designed for the two-semester per schooling year, and there is one textbook and one affiliated workbook for each semester. Table 1 lists the books that were included in this study.

Coding scheme

The diagram coding scheme was created according to the typology proposed by Hegarty, Carpenter, and Just (1991) that classified diagrams used in science teaching context into three types, that are iconic, schematic, and charts and graphs. Iconic diagrams are effective in helping students recognize the physical appearance that are available to visual inspection. An example of iconic diagram could be a hand-drawing or a photo of a horse. The iconic sketches provide visible outlines that could help to refer to the shape of this animal. Schematic diagrams are highly abstracted from the real-world entities but only preserve the physical relationships of the target information. For instance, a chart showing the human digestive system, magnetic fields. Charts and graphs depict a set of related, typically numerical meaning through readers' interpretation of independent variables. A pie chart can show the percentage

Table 1. Books included in the study

No	Books	Type	Pages
1	Primary 1 - I	Textbook	128
2	Primary 1 - I	Workbook	40
3	Primary 1 - II	Textbook	126
4	Primary 1 - II	Workbook	33
5	Primary 2 - I	Textbook	120
6	Primary 2 - I	Workbook	52
7	Primary 2 - II	Textbook	126
8	Primary 2 - II	Workbook	53
9	Primary 3 - I	Textbook	138
10	Primary 3 - I	Workbook	54
11	Primary 3 - II	Textbook	148
12	Primary 3 - II	Workbook	54
14	Primary 4 - I	Textbook	164
13	Primary 4 - I	Workbook	51
16	Primary 4 - II	Textbook	164
15	Primary 4 - II	Workbook	52
17	Primary 5 - I	Textbook	161
18	Primary 5 - I	Workbook	65
19	Primary 5 - II	Textbook	169
20	Primary 5 - II	Workbook	57
	Total		1955

of oxygen constitute in the air. To understand charts and graphs, it is necessary for the reader to identify all independent variables because abstract meanings and numerical data embedded into charts and graphs.

The study also included Augmented Reality (AR) diagrams into the coding scheme, because the textbooks contain virtual reality images that were designed and produced by multimedia technology. AR diagrams can be thought of as the “middle ground” between completely synthetic and completely real (Azuma, 1997). The information conveyed through the augmented reality images could help perform real-world tasks. All diagrams in the twelve school books were analysed according to the four diagrammatic types – iconic, schematic, charts and graphs, and augmented reality.

Research questions

The aim of this study includes to examine the nature and extent of the use of illustrations in science textbooks for Year 1 – 5 and the workbooks in Bahrain primary schools. Weiss, Banilower, McMahon, and Smith (2001) reported that 95% of teachers rely on textbooks to organize and deliver instruction and assign homework. All the books were divided into two groups (textbooks and workbooks) because they have different instructional purposes. While the former has prominent didactic effects, through which learners could interpret the content knowledge; the latter are usually used as a training materials, which require students to complete the practice questions. Taken together, data from both book groups were used to respond the following research questions:

- (1) How are different categories of visual illustrations distributed in the primary textbooks and workbooks?
- (2) What are the trends of the illustration usage in these science books?
- (3) Has each diagrammatic type been organized in a consistent approach in both textbooks and workbooks?
- (4) Any implications could be drawn so as to guide primary teachers to optimize their diagrammatic teaching?

Method

Content analysis in this research entails a systematic coding and categorizing of the diagrams, drawings, charts and photos been included in these primary science textbooks. The analysis of the study operates under the positivist approach, in which diagrammatic displays and their distributional pattern were examined through mathematical measures. To have a more profound understanding of the illustrations' usage in a number of school books, an interpretive paradigm and quantitative non-experimental research design was incorporated in the study (Cohen, Manion, & Morrison, 2011). Interpretive research attempts to understand the meaning perspective of the participants, such as in the search for patterns of meaning-in-action and for building up new theories (Patton, 1980). Interpretive research describes people acting in events and provides the reader with a depiction in enough detail to show that the author's conclusions make sense. It allows researchers to describe the research topic that the research focused on.

Content analysis is defined as a “research technique for making replicable and valid inference from texts to the contexts of their use” (Krippendorff, 2004, p.18). This type of content analysis is traditionally quantitative in nature and its data collection begins with predetermined codes and categories. Accordingly, diagrams contained in these textbooks were counted and coded into four types: Iconic, Schematic, Charts & Graphs, and Augmented Reality. Descriptive statistics were computed so as to investigate how diagrams of each type are distributed in the books. The research procedure is listed as follow: Firstly, all the diagrams in the twenty textbooks were

coded. The criterion for coding followed the taxonomy proposed by Hegarty et al, (1991). Secondly, the means of diagrams for each page of textbooks were calculated. In addition to that, the frequency test was performed so as to identify the distributional differences of the four diagrammatic types. The above information is helpful to understand the different diagrams in each book. Thirdly, a one-way ANOVA test was conducted to examine any differences between the mean diagrammatic usages in the two school book categories. Lastly, the trends of diagrammatic use across different book categories were demonstrated. The trends demonstrate the distributions of diagrams from a longitudinal perspective, showing how diagrams are used along with the growing school years.

Having agreed on the diagram coding scheme, the three authors independently reviewed a sample of 300 diagrams (approximately 10% of the total) from a range of the text books resulting in more than 94% agreement with the classification in order to enhance the validity and reliability of the analysis.

RESULTS AND DISCUSSION

Prevalence of diagrams

Content analysis was conducted to investigate all types of diagrams included in the textbooks. Descriptive statistics was applied to calculate the total number of diagrams in each book, the quantity and proportion of each diagram type in the book as well as those information in each grade. The results were summarized as follow:

1. Bahrain primary science textbooks contain a great amount of diagrammatic illustrations. There are 3125 diagrams in a total number of 1444 pages of textbooks. There is also an obvious difference in the mean of the total number of diagrams for each type of diagram, varying from 0.12 (Charts and Graphs) to 1.75 (Iconic Diagrams). Among the ten textbooks, book Primary 5 – I has the most diagrams (2.46) on each page, while book Primary 3 – II has the least diagrams (1.8) on each page of the book. For all the ten course books, there are on average 2.16 diagrams per page used for explaining the scientific expertise.

2. Bahrain primary science workbooks also contain large amount of diagrams, but textbooks contain more diagrams than workbooks. Particularly, 1065 diagrams were found in a total number of 511 pages of workbooks. The ten workbooks demonstrate difference in the average diagrams used on each page, ranged from 1.49 (Primary 2-II) to 3.2 (Primary 1-II). There are on average 2.08 diagrams per page used in the ten workbooks.

3. In general, the four categories of diagrams were all identified in both textbooks and workbooks. However, iconic diagrams were identified as the most frequently used diagram type, it accounts for 81% of diagrams in the textbooks and 85% in the workbooks. While the least used diagram type is Charts & Graphs, which accounts for 5.5% in the textbook. The lowest percentage for Augmented Reality was only 1% of the diagram usage in the workbooks. Furthermore, the means and ranges of different diagram usage in the two textbook categories are depicted in Table 2.

Distribution differences

Bahrain primary science curriculum adopts a holistic approach that covers a number of science and mathematics subjects. Such as, arithmetic math, physics, chemistry, biology. The differences in the distributing of diagrammatic illustrations were also identified by the content analysis. The distribution differences of diagrams not only exist between book categories: textbooks and workbooks, but also within the grades of science learning. The reason for this is each type of diagram has its unique characteristics in conveying certain type of visual information. As such, the

Table 2. Means and ranges of the diagram usage in the textbooks and workbooks

Book Type	Number of books	Iconic		Schematic		Charts and Graphs		Augmented Reality		Total	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Textbooks	10	253.4	208-302	23.7	5-67	17.4	2-31	18.9	2-39	312.5	249-396
Workbooks	10	91	69-116	3	0-15	11.9	7-15	0.9	0-2	106.5	79-132

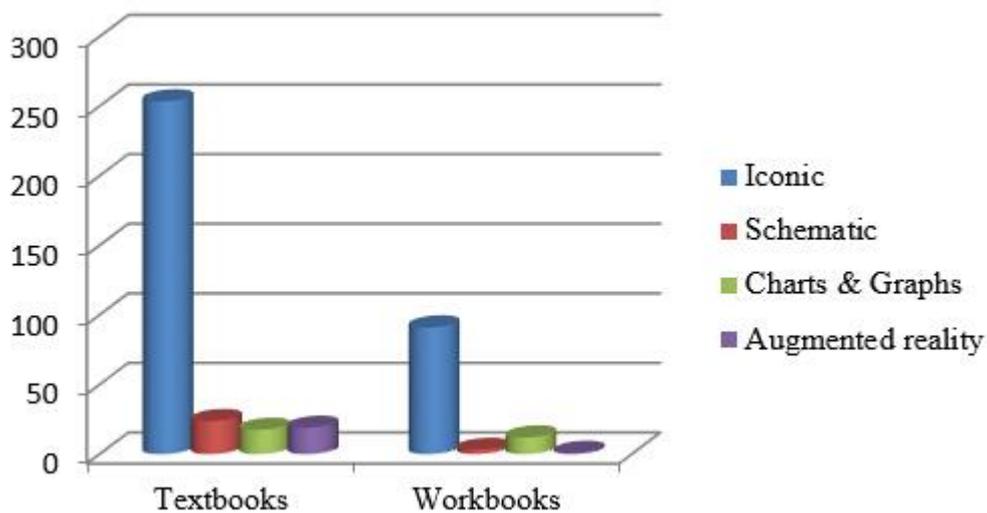


Figure 1. Means of diagram inclusions in the two book categories

four types of diagrams were selectively used by textbook authors according to the content knowledge being taught.

As the distributional differences exist in the two book groups mentioned above, the means of diagrammatic usage for each book category were calculated. Therefore, it is noteworthy to know if there were statistical differences between the mean diagrammatic usages of the textbook and workbooks. The means of diagram inclusion in the two book categories are shown in Figure 1.

The four types of diagrams might have played different roles in primary science teaching and learning. The average number of diagrams in each textbook was different, though some books have a small quantity of certain type of diagram while some have a larger quantity of other type. Therefore, the authors would like to find out if the diagrams were distributed with similar pattern in textbooks and workbooks. Based on the calculation of the means of diagrammatic usage in each book, a one-way ANOVA test was conducted as so to determine if there is any statistical difference between each type of diagram in the two book categories. Results indicate that the usages of four types of diagrams were not found differentiate greatly as they were used in textbook and workbooks. Iconic diagrams ($F=1.30$, $p=0.60$), schematic diagrams ($F=4.22$, $p=0.09$), charts and graphs ($F=0.96$, $p=0.57$), augmented reality ($F=1.93$, $p=0.22$). In other words, diagrams in Bahrain primary science books might have been used in a consistent method to facilitate the illustration of the scientific concepts embedded.

Figure 2 and Figure 3 show the percentages of diagram usage in workbook and textbooks. As the results shown in the two figures, iconic images constitute 81% and 85% of the diagram usage in textbooks and workbooks respectively. The proportion of iconic diagrams in workbooks is higher than it in the textbooks (81% vs. 85%), though iconic diagrams account for the majority of diagrammatic usage in both textbooks and workbooks. It is therefore noticeable that iconic diagrams account for

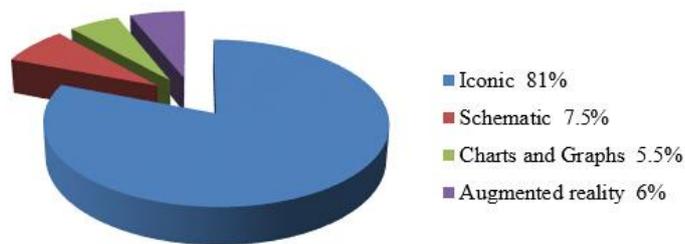


Figure 2. Percentage of diagram usage in workbooks

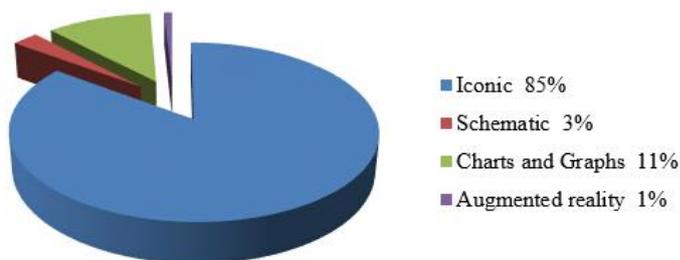


Figure 3. Percentage of diagram usage in textbooks

the most diagrammatic usage in both book categories. This finding correlates with the early findings that iconic diagrams are more often used in the beginning science learning, in which the isomorphic connections need to be built between the graphic depiction and the concrete referent objects in the real society (Liu & Treagust, 2013). The primary science learners may depend more on photographs, pictures for understanding what the scientific and biological entities and phenomena look like.

The second frequently used diagram type(s) is the schematic diagrams (7.5%) in the textbooks and the charts and graphs (11%) in the workbooks. In textbooks, diagrams are more often employed for the purpose of demonstrating the content knowledge. The didactic advantages of schematic diagrams were used by textbook authors to explain why and how a scientific concept functions in such a way (Tomczak, 2005). To illustrate simplified complex situations could be considered as one of the major roles of schematic diagrams, which usually provide concise depiction of the abstract structure so as to make learners understand the concepts more easily. In workbooks, charts and graphs are more used for the purpose of evaluating students' learning. Because quantitative information could be drawn from charts and graphs that include pie charts, line graphs, etc. To get the correct answer, students have to make their calculation by referring to their understanding of concepts being taught (Liu & Treagust, 2013).

The least frequently used diagram type(s) are Charts and Graphs (5.5%) in the textbooks and Augmented Reality (1%) in workbooks. The above data is also found in line with realistic situation in which diagrams are distributed, that is, textbooks may need more illustrations to serve its didactic purpose, whereas Charts and Graphs tend to serve the assessing purpose better. That is the reason why the least amount of Charts and Graphs found in the textbooks and Augmented Reality in workbooks respectively. The statistic results also support to make the claim that Augmented Reality (6%) tend to be used more often than Charts and Graphs in textbooks. Similarly, workbooks seem to contain less Augmented Reality images so as to maintain their assessment intention.

Trends across textbook types

The diagrammatic compositions in the two textbook categories will be discussed in this section. The differences in percentages of diagram types between in textbooks and workbooks will be reported as follow: In the textbooks, from Primary 1 - I to Primary 5 - II the percentage of iconic diagrams decreased from 92.16% to 66.67%. However, the other three diagram types demonstrated an increasing tendency in general – the percentage of schematic diagrams reached 16.92% in grade five; Charts and graphs reached 6.57%; Augmented reality peaked at 9.85% in the end. As the learners progress to the senior years of schooling, they are less likely to be exposed to learn from iconic diagrams.

The trends displayed in Figure 4 within the primary science workbooks show that the percentage of iconic diagrams dropped from 84.38% to 73.21%; schematic diagrams showed an increasing trend increasing from 3.13% to 13.39%, though no schematic diagrams were found in Primary 2-II, Primary 3-I, and Primary 4 -II. The amount of charts and graphs remain unchanged at about 10%. An obvious increase can be found in the type of augmented reality, from 3.13% to 13.39%.

The overall trends in the prevalence of the four diagrammatic types in these primary science textbooks reflect variations in the likely advantage of different diagrammatic types for learning various scientific contents. It is evident that primary textbooks tend to contain more iconic diagrams in the junior year textbooks; however, senior textbooks appear to include the other three types of diagrams more frequently with increased scientific content as shown in.

DISCUSSION

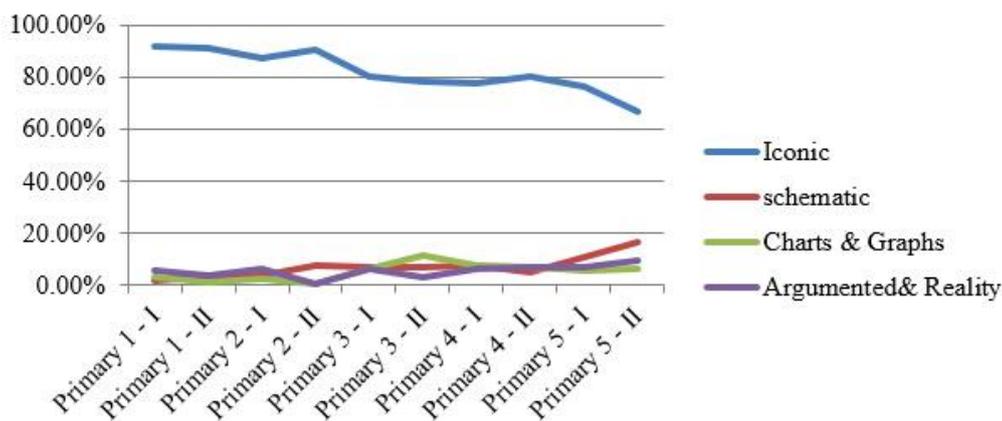


Figure 4. Trends across the primary school textbooks

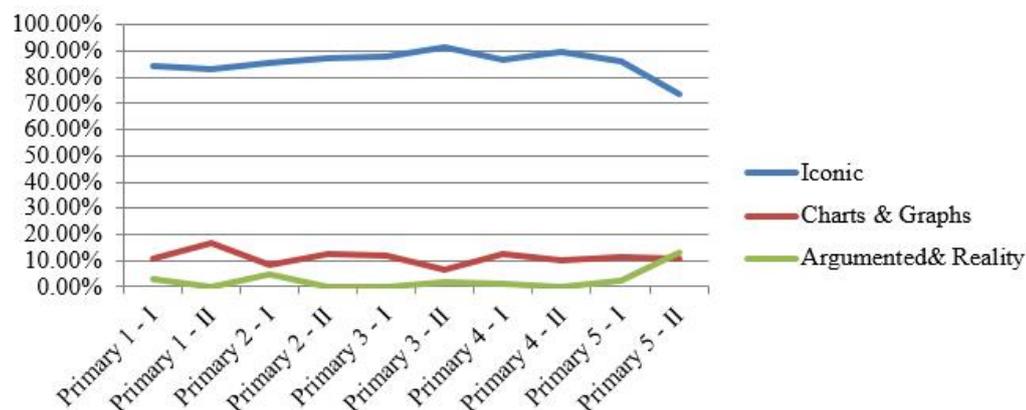


Figure 5. Development trends within the workbooks

The examination of the overall twenty books contained in textbooks and workbooks used in the primary level of science education enabled a response to the research question about the distribution of diagrams in different book categories. The results of the content analysis indicated that a large amount of diagrams are included in both textbooks and workbooks. It is thus can be assumed that diagrams served as an important tool to present for preliminary learners to learn science knowledge and other educational purposes.

The distribution of diagrams in these textbooks could also reflect how science teachers engage the diagrams in their teaching. As the functional roles of diagrams have been discussed in the early studies, the diagrams in each book may serve as a tool for the purpose of explaining, assessing, and presenting the scientific domains to pupils. Therefore, diagrams contained by the sample science books have the following features as to undertake the roles mentioned above. The case in Bahrain acclaimed one important notion from the early studies, that is, diagrams could serve as a conceptual changing tool that bridging known and unknown for learners.

A great amount of diagrams have been used in the primary level of science teaching. On average, there are about 2.2 diagrams used in the textbooks and 2.0 diagrams in the workbooks for the purposes of explaining, presenting or evaluating the scientific domain. Obviously, the results confirmed that primary level of science education demands large quantity of diagrams to facilitate students' learning. While previous studies may focus more on the explanatory function of diagrams, this study argued that diagrams could also be used for other purposes, such as introducing a context and assessing students' learning.

Compared with the other three types of diagrams, iconic type is the most frequently used in both textbook and workbook groups. One possible reason could be that more pictures and photos are used so as to make learners to be better drawing references from the real world entities. Workbooks tend to include more charts and graphs that may be used as a tool to examine learners' conceptual learning, especially when arithmetic calculations and association between variables are involved.

In general, more schematic diagrams tend to be used more for senior grades of students to make sense of complicate scientific knowledge. Similar trend also applies to the workbooks. Though iconic diagrams are the most diagrammatic type exposed to the students, schematic diagrams have a larger proportion in the primary science teaching and learning.

Though schematic and augmented reality diagrams demonstrate an upward tendency in their usage. Augmented reality is the least used diagrammatic type in the workbooks (1%), though a larger proportion of its usage can be found in the textbooks (6%). Augmented reality diagrams are less likely to be used for its assessing purposes. Textbooks in each category were also compared as to see if there are any significant changes in the growing years of science learning. The results of one-way ANOVA test suggest that textbooks and workbooks have consistent methods of usage, that is, the textbook authors bear a same philosophy in organizing each diagrammatic types in teaching and learning. We may come to the conclusion that the preliminary science learners need to count on more iconic type of diagrams to help linking their pre-existing knowledge. However, fewer iconic diagrams are included when pupils become much senior.

The novelty of this study also lies in comparing different book categories. This study may provide science educators with some insights on the methods to be used in textbook studies.

This study has certain limitations that future studies could avoid:

(a) Textbook authors' opinions should have been sought so as to explore diagrammatic usage at a profound level. Though these reasons alone are not sufficient to make speculation generated from the quantitative analysis.

(b) There may be other methods that are more suitable for analysing the diagrammatic distributions. Diagrams could also be analysed according to the science subjects to get a further understanding of the representational roles that diagrams play in conveying domain knowledge. For instance, the diagrams used in teaching human life could be very different with the ones used in natural science topics.

(c) Specific diagrammatic conventions could have been taken into consideration, such as colouring, location, and even gender and cultural factors. Though conventions alone are not sufficient for students to understand the information contained by diagrams, knowing how students refer to conventions may also provide another approach for analysing diagrammatic usage.

Each of these three suggestions for future research could enhance the validity of the research findings.

CONCLUSIONS

The aim of this study is not about measuring students' learning efficacy that could be influenced by diagrams' drawing conventions such as colouring, labels and caption. With the notion that diagrams have been used as crucial tool in portraying complicated scientific domain. The study analysed the distribution of diagrams in different book categories. As one of important findings of this textbook analysis research is the diagrams' distributional pattern including the frequencies, trends, and methods of having scientific content knowledge to be visualized by elementary learners.

Iconic diagrams keep rich details of the information been contained, learners therefore have less difficulty in understanding the scientific entities and phenomena been demonstrated. Iconic diagrams tend to be the easiest diagram type for learners who have limited background information or before proceeding to more complicated domain knowledge. This could be one of the reasons that more photos and drawings are used in the primary science teaching. It is then reasonable to assume that increasing conceptual understanding and reading skills are necessary for interpreting abstract concepts. The depiction provided by iconic diagrams could lay foundation for individuals' more advanced learning.

Understanding schematic diagrams relies on effective diagrammatic reading skills (Tomczak, 2005). Because the learners have to make sense of the embedded information by means of interpreting the graphic composition elements and rules such as arrows, spatial distances and etc. Getting familiar with these graphic conventions should enable readers to see the representation of scientific concepts from an abstract angle. Students have to move from the recognition of the phenomena to the formation of mental models by relating the domain-specific knowledge and the diagrammatic representations. In science books, schematic diagrams are more inclined to be used for explaining the concepts for students at later levels of schooling.

Compared with the above two types of diagrams, charts and graphs could be the most intellectually demanding type because knowledge of conventions is necessary but not sufficient for comprehending graphs (Hegarty et al, 1991). Students may have to equip themselves with domain knowledge, mathematical knowledge, and graphic composition for the complete learning of charts and graphs. For example, a pupil has to figure out the numerical proportion composed in a pie chart and then compare the size of the each sector. In other words, individuals understand the scientific domain by figuring out how mathematical variables are related to each other.

Augmented reality could be used to annotate objects and environments with public or private information. Applications using public information assume the availability of public databases to draw upon. For example, a picture like display could demonstrate information of the street view of a gymnasium with traffic flows around.

Augmented and Reality might therefore be used to create a hypothetical view that how the building of a gymnasium would change the traffic. An advantage of learning with AR is that virtual lines and objects could aid navigation and scene understanding as the poor visibility could affect the interpretation.

In this study, the descriptive statistical analysis was performed to examine the diagram prevalence and their distributional trends across textbook groups. The results of the study suggest that the four diagram types were found in each elementary science book, and a distributional pattern could also be summarized to demonstrate the diagrammatic usage among different years of schooling. Though this study did not aim to discuss the correlation between scientific topic areas and diagrams or the connections between diagrams and other graphic representations, the findings contribute to the literature in several aspects: First, it updated Novak's diagrammatic typology by including augmented reality graphs in examining recent science textbooks. Second, it provided empirical findings focusing on the diagrammatic usage at the primary level of science education of textbooks. Third, it contributed another approach for textbook research.

This research raised the questions about the pedagogical value of including diagrams in science books. Future studies could focus on: (a) How these four types of diagram are used in teachers' teaching to provide a holistic investigation of the instructional use of diagrams; (b) Comparing the different learning effects generated when students are exposed to different diagram types.

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