Textbooks: An Investigation of their Visual Attractiveness

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The visual attractiveness of two Queensland mathematics textbooks is examined. Diagrams were categorized according to their type, and each type was examined in terms of perceptual precedence. Series A textbook was found to have one third of diagrams of a cosmetic type, commanding 40% of the perceptual precedence. Such diagrams have no relevance to the subject matter, and therefore the potential to distract a student. Series B textbook was found to have combination diagrams in abundance that demanded perceptual precedence. Each diagram of this type has two or more functions and the potential to be effective in developing mathematical understanding. It is recommended that further research be conducted into student uses and perception of diagrams so as to inform authors and illustrators.

Recently, a State Primary School in Queensland abandoned one series of mathematics textbook, Series A (Boswell, 1998) appropriate for Years 1 to 7 inclusive, because the teachers felt the series was not meeting its claims of promoting mathematical understanding, knowledge and skills appropriate to the learner. In the views of the teachers, most students were not stimulated by the series, and as a result, additional materials (over and above those one would normally expect a classroom teacher to employ) had to be generated to compensate for the shortfalls of the series. Series B (Parker, McSeveny, Collard & Thomas, 2000) was selected to replace Series A as the teacher's felt both series covered the same curriculum content from the Year 1-10 Mathematics Syllabus. However, Series B had clearer explanations and a more visually attractive format than Series A.

The purpose of this paper is to investigate this notion of the visual attractiveness of the two series. I will concentrate my attention on the function of the diagrams as primary transmitters of visual information in their own right. Both teachers and textbook authors and illustrators use diagrams frequently on the assumption they make things easier for students to understand (Henderson, 1999). It is worth a close investigation of the use of diagrams in textbooks, as they may not be as useful as one may think.

Diagrams as Visual Information Transmitters

In many circumstances in mathematics (such as in early numeration and geometry), diagrams are traditionally used as the main transmitters of information with the "written text being absent or sparingly used in a support role as captions or labels" (Lowe, 1986, p. 8). Diagrams are a fundamental component of today's textbooks. As outlined by Hannus and Hyönä (1999), diagrams serve a number of functions: (a) attention guiding – to attract a student to pay more attention to the material in general, and specifically to the illustrated contents, (b) affective – to develop interest and motivation towards the textbook material, (c) cognitive – to improve learning by enhancing comprehension and memory, and (d) compensatory – to improve the learning achievement of poor readers. Diagrams may also be particulary efficient in providing spatial information difficult to express in words (Levie & Lentz, 1982). Levie and Lentz (1982) suggested, on the basis of their seminal review of the literature, that in order for diagrams to be effective and to obtain improvement in

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learning, they needed to be directly relevant to the text content. Gombrich (1974) pointed out that the educational intention of the illustrator is not always matched by the viewer. It may not be a simple question of comprehension by the viewer, but rather a question of the generated meaning matching the intended meaning.

A review of the research literature indicates that diagrams can play at least four interrelated roles:

1. *Identification* - Diagrams that point out or identify parts of things (Cook & Mayer, 1988, Charles & Nason, 2001) (e.g., geometry diagrams of a circle upon which the names of the diameter, radius and circumference are labelled (Iding, 2000; Kidman, 2000; Lowe, 1993)).
2. *Comparison* - Diagrams that compare one kind of thing to another (Lemke, 1999; Hunter, Crismore & Pearson, 1987; Winn, 1989). (e.g., two different kinds of time-pieces, analogue and digital, might appear next to each other).
3. *Sequence* - Diagrams that point out stages in a chain of events (Cook & Mayer, 1988; Hunter, Crismore & Pearson, 1987). Typical examples would be diagrams of a sporting race showing the ordinal finish.
4. *Combination* - Diagrams that combine two or more of the above functions (Cook & Mayer, 1988; Hunter, Crismore & Pearson, 1987; Iding, 2000; Lowe, 1993; Winn, 1989). (e.g., a scaled map provides more than one view - an additional cross-section or enlarged view (i.e., comparison). Aspects of the map can be labeled (i.e., identification) and the pathway to follow can be indicated via the use of arrows (i.e., sequence).

As outlined above, diagrams have different purposes and roles. Along with each purpose and role, a different interpretation and set of spatial skills for understanding also needs to be considered. Hannus and Hyönä (1999) outlined five cognitive processes necessary for the comprehension of an illustrated textbook: (a) to comprehend abstract concepts and principles, (b) to decide in which sequence the text and diagrams are studied, (c) to distinguish between relevant and irrelevant diagrams, (d) to decide which diagrams are related to each other, and (e) to integrate related pieces of diagrams and text into a coherent internal representation. It can be seen from this list, that an intellectually high-achieving child is more likely to carry out such integrative processes than a low-achieving child.

In a study investigating both high and low-ability children, Reid and Beverage (1990) found the less able children spent more time studying diagrams and accessed them more frequently than the higher ability children. This was particularly so for low-spatial-ability children presumably because they had more difficulty forming spatial representations (Hegarty, Carpenter, & Just, 1991). Low-ability learners did not seem to spontaneously construct elaborate mental structures of text materials, but did so in the presence of a diagram (Reid & Beverage, 1990). In terms of an authentic textbook with several diagrams (i.e., 3-5) per page, the diagrams distracted children's attention away from the content, and thus hampered successful learning (Harber, 1983).

The value of a diagram, or a set of diagrams, may increase with increasing detail, but a point has to be reached where any additional detail or diagrams, becomes a distraction to the viewer from the key concept of the author (Henderson, 1999). Because a learner often learns as much from a diagram as from text, it is essential that the visual components of textbooks are not merely insertions, but actually relate facts or understandings (Dowd, 1990). Cox (1996) found that logically inappropriate material, (i.e., analogies and illustrations) should be eliminated, as such material is distracting. Such distractions "reduce the impact of a lesson, and increase the chance of misunderstandings developing" (Cox, 1996, p. 24). Excessive and unrelated diagrams are both a handicap and a disincentive to continue the study of the subject, something we obviously want to avoid in mathematics. Students experience problems in the processing of diagrams when (a) all aspects of a diagram and text have equal perceptual status, and (b) "visual prominence to information that is actually of low salience with respect to the presented content" (Lowe, 1996, 240).

Textbooks as Learning Materials

The textbooks being considered in this paper are authentic textbooks, as classified by Willows, Borwick and Hayvern (1981), in that they typically contain more than one diagram per page and the diagrams often cover a significant proportion of the page. In order to effectively use such a textbook, a child would need to decide as to which diagram they should attend to and which diagram they ought to ignore, when to study each diagram and what information they need to extract from each diagram (Hannus & Hyönä, 1999). A textbook can therefore be a highly complex teaching item for a child, especially if there is an absence of text to diagram links.

Methods and Data Analysis

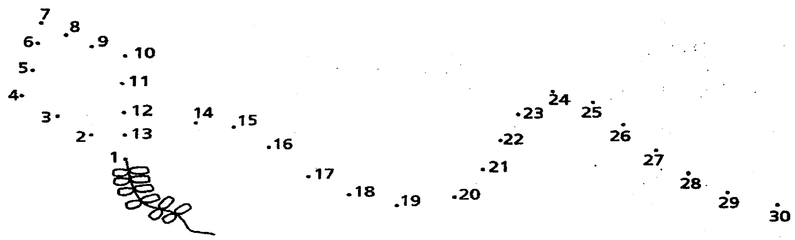
Two methodologies were developed for investigating the visual attractiveness of the two series of textbooks. The data comprised the entire set of diagrams contained in eight mathematics textbooks, four from each of Series A and B (Years 1, 3, 5 and 7). All diagrams were classified according to the role each played. The frequency of diagrams across the Years 1, 3, 5 and 7 textbooks were then averaged and tabulated for each series. Averages were calculated in order to obtain an overview of each series for comparison purposes, as it was Series A in general, the teachers were dissatisfied with, rather than individual year levels.

In a second methodology, four classes of children, one class from Years 1, 3, 5 and 7 (a total of 115 students), participated in an 'initial perception' experiment for each series of text book. Each child was asked to randomly select a page in the Series A textbook, relevant to their year level, and to 'tick' the diagram that initially caught their attention. This was to identify the pre-attentive stage, a stage that occurs "within the very first few moments of seeing the picture before we start to process it in a deliberate, systematic way" (Lowe, 1996, 239). The child then placed a 'postit note' on the page as a marker. This was then repeated nine times giving a total of 10 random pages per child, per class for Series A. The 'initial perception' experiment was then repeated for Series B. Each 'ticked' diagram in each textbook in each series was then classified according to the role each played. The frequency of diagrams across the Years 1, 3, 5 and 7 textbooks were then tabulated for each series.

Results and Discussion

It was necessary to create two additional classifications in order to accommodate *all* diagrams. It was found that the four types of diagrams (identification, comparison, sequence and combination) compiled from the literature related only to those diagrams comprising a pedagogical role. Diagrams in the forms of novel presentation of numbers and cartoon drawings also needed to be accommodated, so the classifications of illustrative and cosmetic diagrams were included. Figure 1 provides examples of diagrams in each classification.

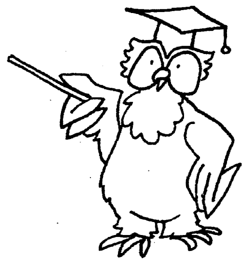
Join the dots to complete the picture. Name, colour and decorate the shape.



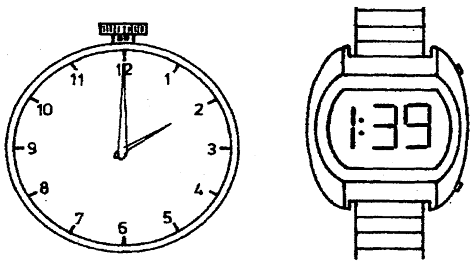
(a) Sequence (Series A)

Arrange these containers in order from **largest** capacity to **smallest** capacity.

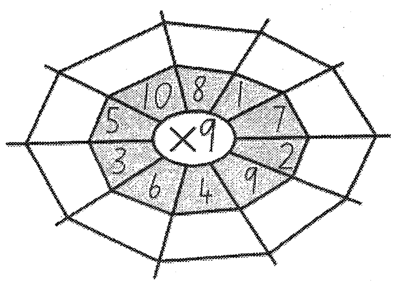
(b) Combination (Series A)



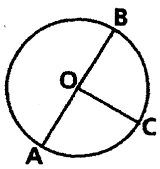
(c) Cosmetic (Series A)



(d) Comparison (Series B)



(e) Illustration (Series B)



The **radius** is the distance from the centre to any point on the circumference.
AO = OB = CO

(f) Identification (Series B)

Figure 1. Examples of diagram types.

Table 1 shows the average frequency and percentage of each type of diagram for Series A and B. Table 1 indicates a clear difference in the average number of diagrams per series. Series A has, on average, an additional 137 diagrams to Series B. When one considers the average number of pages per textbook in Series A (165 pages), this equates to approximately 1 extra diagram per page. Having one more or one less diagram per page ought not to be a major deciding factor of the visual attractiveness between two series, except when the type of diagram is considered.

A difference in the proportion of cosmetic diagrams between the two series was found. Nearly one third of all diagrams in Series A were of a cosmetic type. Figure 1(c) gives an example of such a diagram. This cartoon of an owl has no relationship to the mathematical activity of completing a multiplication grid, yet they (the owl and the grid) are presented side by side on the page, with equal space being allocated to each. Series B has only 18% of diagrams falling into this 'cosmetic' category.

Table 1
Frequency of Each Diagram Type for Series A and B

		Identification	Comparison	Sequence	Combination	Illustration	Cosmetic	Total
Series A	f	122	104	18	120	70	201	635
	%	19	16.5	3	19	11	31.5	100
Series B	f	66	98	34	160	50	90	498
	%	13	20	7	32	10	18	100

Whilst Series B has its share of cartoon characters, the majority are similar to the one shown in Figure 2. Such cartoons carry an educational message relating to the mathematical activity on the page, and so have been classified into one of the other categories depending on the message. Series B has fewer irrelevant cosmetic diagrams than Series A, and this may have been an influencing factor of the visual attractiveness between the two series.

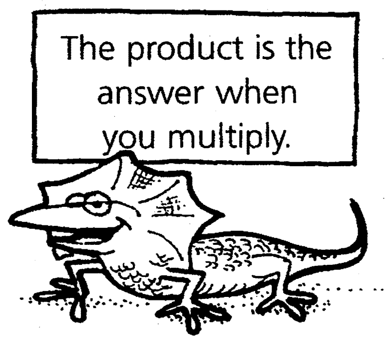


Figure 2. Example of a cartoon from Series B.

Neither series seems to include many diagrams of the sequence type. Perhaps the authors and illustrators do not think mathematical concepts like ordering or chain of events are suited to diagrammatical instruction. Of the 52 diagrams of the sequence type presented in the two series, only one was identified as to having any form of saliency in the 'initial perception' experiment. Table 2 shows the frequency and percentage of each type of diagram for Series A and B for the 'initial perception' experiment.

In order to capture the pre-attentive precedence of diagram types, an 'initial perception' experiment was conducted with 115 students on both series of textbooks. The experiment exposed the types of diagrams that had displays, symbols or characteristics that took perceptual precedence over other diagrams due to distinctive visual characteristics. As Table 2 indicates, 40% of perceptual precedence in Series A was allocated to the cosmetic type of diagrams. As the cosmetic diagrams are not related to the subject matter in the textbook, such a high perceptual precedence is of concern. For a child to turn to a page in a textbook and be visually drawn to a diagram of no relevance to the lesson, it has to be distracting. It appears that the cosmetic diagrams have the potential to "reduce the impact of a lesson, and increase the chance of misunderstandings developing" (Cox, 1996, p. 24). Excessive and logically inappropriate diagrams are both a handicap and a disincentive to begin work, something to be avoided in mathematics. Series B has a far lower percentage of cosmetic diagrams, and would therefore have more potential than Series A in getting a lesson off to a reasonable start. The diagrams that present a combination of functions appear to capture the pre-attentive precedence in Series B. Why this is the case is unclear from the study, but it is interesting to speculate that the detail contained in such diagrams improves their perceptual precedence in a similar way that the value of a diagram, may increase with increasing detail (Henderson, 1999).

Table 2
Frequency and Percentage of each Diagram Type for Series A and B for the 'Initial Perception' Experiment

		Identification	Comparison	Sequence	Combination	Illustration	Cosmetic	Total
Series A	f	225	120	1	300	54	450	1150
	%	19.5	10.5	0	26	5	39	100
Series B	f	370	243	0	467	30	40	1150
	%	32.5	20	0	41	3	3.5	100

There are a number of interesting observations between Table 1 and Table 2. Table 1 indicates that for both series', the combination diagrams have approximately 20% to 30% frequency, yet they have a higher perceptual precedence, especially for Series B. A similar finding relates to the identification diagrams in Series B.

The inverse situation occurs for comparison (Series A) and illustrating (Series A and B) diagrams. For these two categories, there appears to a greater frequency of diagrams in either series', but they do not have great perceptual precedence. A possible explanation for this may lie in the placement of the diagrams on the page.

Conclusion and Implications for Further Research

The teachers may well have been justified in selecting Series B over Series A on the basis of visual attractiveness and stimulatory material for their students. Series A has almost one third of its diagrams in the cosmetic category, meaning these diagrams are totally unrelated to the content of the material. Another problem with Series A is that these cosmetic diagrams are commanding almost 40% of the initial perceptual precedence. Potentially, these cosmetic diagrams could distract many students and therefore have a negative impact on the start of the lesson. The teachers felt their students were not being stimulated mathematically, by Series A, and the distraction potential of the cosmetic diagrams may be responsible. If this is the case, then the teachers ought to be satisfied with their selection of Series B. Series B has a marked reduction in the number of cosmetic diagrams, and these few diagrams have low initial perceptual precedence. Combination diagrams rated very highly in initial perceptual precedence for Series B. Such diagrams have more than one purpose in portraying mathematical meaning, and so, coupled with high initial perceptual precedence, they have potential to be good aids in developing mathematical understanding. Thus it appears that the visual attractiveness of Series B, over Series A, may lie in the decreased number of cosmetic diagrams, and increased proportion and perceptual precedence of combination diagrams.

Further research is recommended. An analysis of the diagrams in textbooks is necessary to give authors and illustrators some understanding of what is thought to influence the way diagrammatic information is being processed by students. Authors and illustrators would be more able to design effective textbooks if they had some understanding of that information from the student perspective. Authors and illustrators need to be aware of what the students have to deal with when presented with a textbook. With this knowledge, an author and illustrator can be more analytical in the design of the textbooks. Therefore, an investigation into establishing the differences between pre-attentive and attentive (deliberate and systematic) processing of diagrams is recommended. Such an investigation could determine perceptual characteristics of a diagram such as the size, shape and overall arrangement favorable to its effectiveness, but that are not noticed in pre-attentive processing. Knowledge of these visual characteristics could result in improved diagrams so as to direct student attention in initial moments to salient aspects of a page and it's diagram thus improving subsequent progress of mathematical understanding.

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