Supporting students to make judgements using real-life data

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Introduction

Numeracy in schools is becoming an increasingly important part of mathematics learning and teaching. This is because we want students to engage with mathematical concepts more deeply, use mathematics to make sense of their environment and make decisions that are based on the analysis of mathematical information. In order to be numerate, students must be able to acquire mathematical concepts and procedures, and apply these flexibly in a range of real life contexts. The school mathematics curriculum provides a number of strands of mathematics from which students can draw from, such as geometry and algebra in order to exhibit their numeracy skills. In the present study, numeracy is investigated from the perspective of students' abilities to gather, display and interpret data—an area of numeracy that has been broadly referred to as *statistical literacy* (Watson, 2011). A statistically literate student can be expected to demonstrate an ability to use statistical concepts to make sense of his or her immediate environment. This area of students' numeracy continues to be challenging for many students (Shaughnessy, 2007).

In this paper we draw on our recent research that focuses on the interpretative aspects of real-life data and generating ideas for activities that would better engage children in the complex and somewhat more demanding area of statistical literacy. We do this firstly by advancing a model of phases that we suggest students go through from being able to draw a graph to being able to interpret a graph and make decisions. Secondly, we present findings from an authentic real-life context that we investigated in order to examine the usefulness of the phases outlined in our model. Finally we examine possible strategies for classroom practice.

Phases in data handling

When students learn about data they can be expected to go through a number of phases. We regard the following four phases as being the key components of the process underlining data representation and interpretation.

- Phase 1: Construction of graphs using a given set of decontextualised data.
  In this phase students generally translate numbers given in a table to graphs. This process is indicative of their understanding of how to draw different types of graphs. Including the construction and labelling of titles, scales, legends and axes, etc. These are necessary building blocks for the construction of graphs in early phases of learning to represent data.
- Phase 2: Extraction and Tabulation/organisation of data from a real-life context (contextualised data).
  This second phase involves students having to extract data from the context and then organising or tabulating the data before constructing an appropriate graph. A critical element in this phase is to be able to make sense of the data and understand how it could be organised.
- Phase 3: Construction of different types of graphs using organised data from Phase 2.
  In this phase students explore the construction of different types of graphs using the same data. As their experience in drawing graphs matures the emphasis on graphs shifts from being able to draw a graph to making judgement about the type of graph being drawn and whether it is appropriate for the information they have.
- Phase 4: Interpreting information from the graph.
  Using graphs to draw conclusions and make sense of their data is the fourth phase. Drawing reasonable conclusions is predicated on students' ability to observe the numerical data in its graphical form. Beyond that the students should be able to look at their graph and unearth visible patterns that convey something about the context. They need to give an overall interpretation and comment with understanding about the background of the information looking between variables and making comparisons. The demands at this point get more complicated when students have to extract information from real-life contexts that is multi-dimensional. These latter skills constitute more advanced thinking in data handling and children continue to experience difficulties in these areas.

Example of an authentic context: Breakfast cereal analysis

We used a breakfast context to examine Year 7 students' knowledge and skills at the more demanding end of the skills spectrum for graphing. In this activity, students had to focus on nutritional information that was highlighted on four breakfast cereal boxes (Figure 1). Following this, they were instructed to construct a graph that they believed would best represent the highlighted information for the purpose of making decisions recommending cereal for their friends.

The data that appear on the breakfast cereals were discrete in nature, and thus our expectation was that students would draw graphs that are appropriate for the representation of discrete data, such as bar charts and column graphs, etc.

After drawing their chosen graph(s), students were asked a series of semi-structured questions based on the graph(s) that they had drawn. These semi-structured questions were developed with a focus on supporting students to talk about the graphs that they had drawn, why they had drawn these graphs, and to interpret with a view to arriving at a

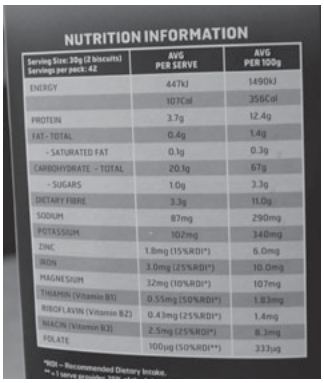

Figure 1. Breakfast cereal box with highlighted information.

decision about which cereal is the best cereal to recommend to their friends for breakfast. In answering the question about the quality of the breakfast cereals, students were directed to focus on the graph(s) that they had drawn.

Semi-structured questions

- Can you tell me what type of graph(s) you have drawn? Why have you chosen to draw this type of graph?
- What can you see is important in the graph(s) you have drawn? Why is this important?
- Using your graph(s), if you had to recommend one of these breakfast cereals to your friends, which cereal would you recommend? Why?

A model solution

Before presenting students responses we provide one possible approach (Figure 2) that a year 7 student could have adopted that meets the standards outlined in the statistics and probability strand (ACARA, 2011). This example contains all of the necessary information students would need in order to be able to interpret the breakfast cereal information and draw a reasonable conclusion about the quality of the breakfast cereals in their recommendations.

On the left hand side of Figure 2 is a table of the highlighted information from the breakfast cereal boxes; an example of Phase 2: Extraction and tabulation of real-life data. The rows of the table represent the dietary information contents and the columns represent the types of breakfast cereals,

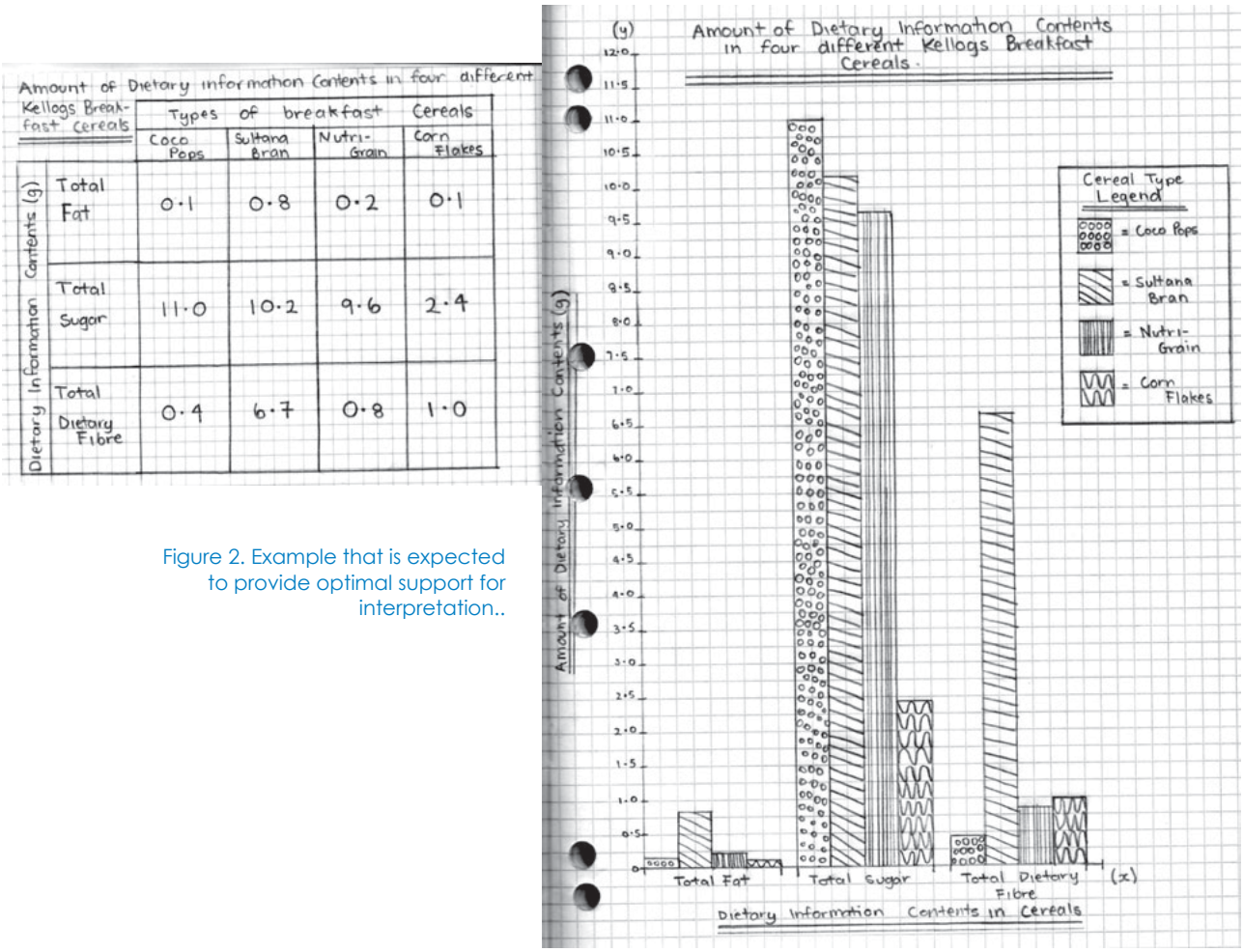

Figure 2. Example that is expected to provide optimal support for interpretation..

this is one way students could tabulate/organise the data given from a real-life context. On the right hand side of Figure 2 is a clustered column graph that shows all of the information from the table in a single graph; an example of Phase 3: Construction of a graph using organised data. The clustering within this graph allows for an easy comparison of individual cereals and overall comparison of dietary information contents and this can assist with the interpretation of the graph (Phase 4).

Our findings

Finding 1: Year 7 students are capable of drawing graphs

All Year 7 students that participated in this activity were capable of drawing a graph. Although this is a positive outcome, the details of the graphs that they had drawn did not always represent the given information accurately. For example, students struggled with scale, alignment of points within their graph(s), labelling and drawing appropriate graphs for the given information. Figure 3, details graphs that were drawn by a student to represent the breakfast cereal information. This particular student drew a line graph without realising it was not appropriate for the data they were given, the student's scale began with the number 2 although there were values below 2 in the data set, and although each graph was partially labelled it may not be enough information for someone who did not know what each graph was about to understand what the student is trying to convey.

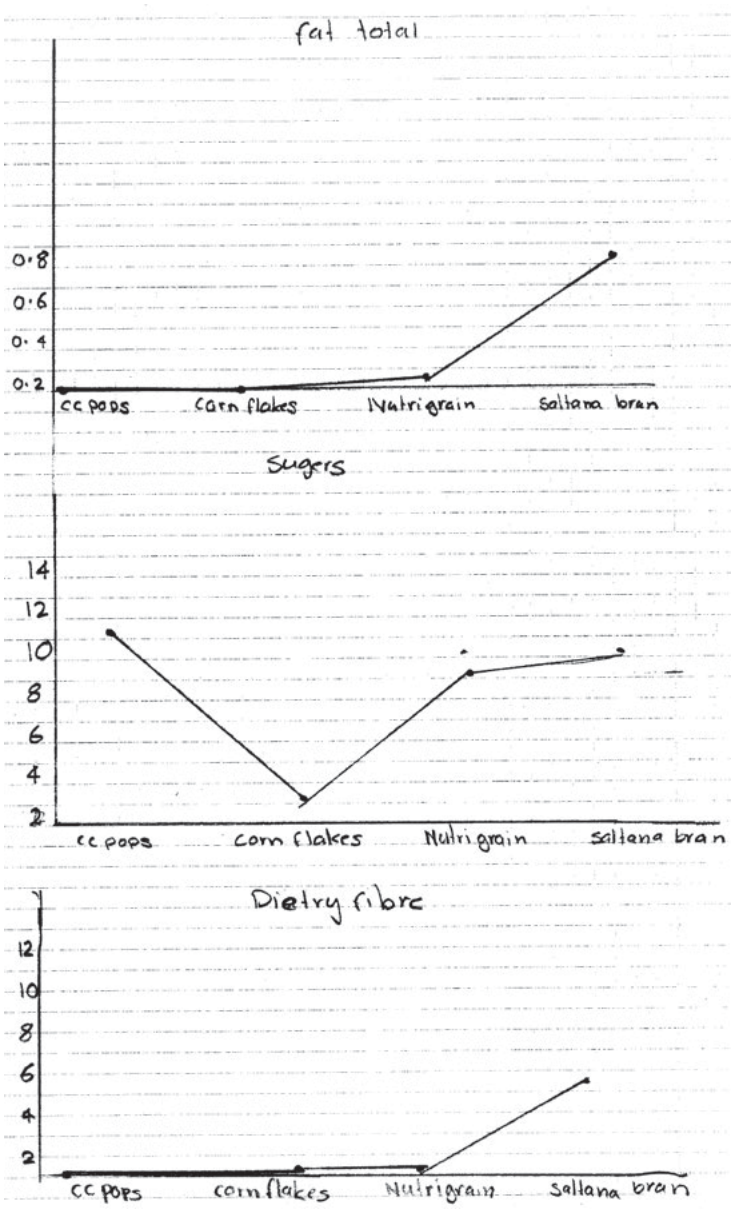

Figure 3. Graphs constructed by a Year 7 student to represent breakfast cereal data

Finding 2: The majority of Year 7 students drew more than one graph.

The majority of graphs drawn by Year 7 students were not appropriate in order to look for patterns and make judgements about the quality of cereals. This is due to the fact that the students tended to draw disjointed graphs for each of the cereals whereas a clustered graph (as seen in Figure 2) would have been more

appropriate. Although each graph has different dietary content amounts for each cereal box, drawing individual graphs for a data set that contains multiple information, limits students' abilities in interpreting information.

Figure 4, is an example of why individual graphs can be limiting to students' abilities of interpretation. If we look at it closely, we can see why this student, although able to represent the majority of information accurately (ignoring a couple of alignment difficulties with 0.1 and 1.0), struggled to make a comparison between each of the cereals and their dietary information. Each of their separate graphs was drawn using a different scale. This student had to look specifically at the numbers on their y-axis to be able to make a comparison, they would have been able to make the comparison just as well using only the figures on the cereal boxes. A graphs purpose is to display information to the reader logically, quickly and effortlessly. These singular graphs do not do this.

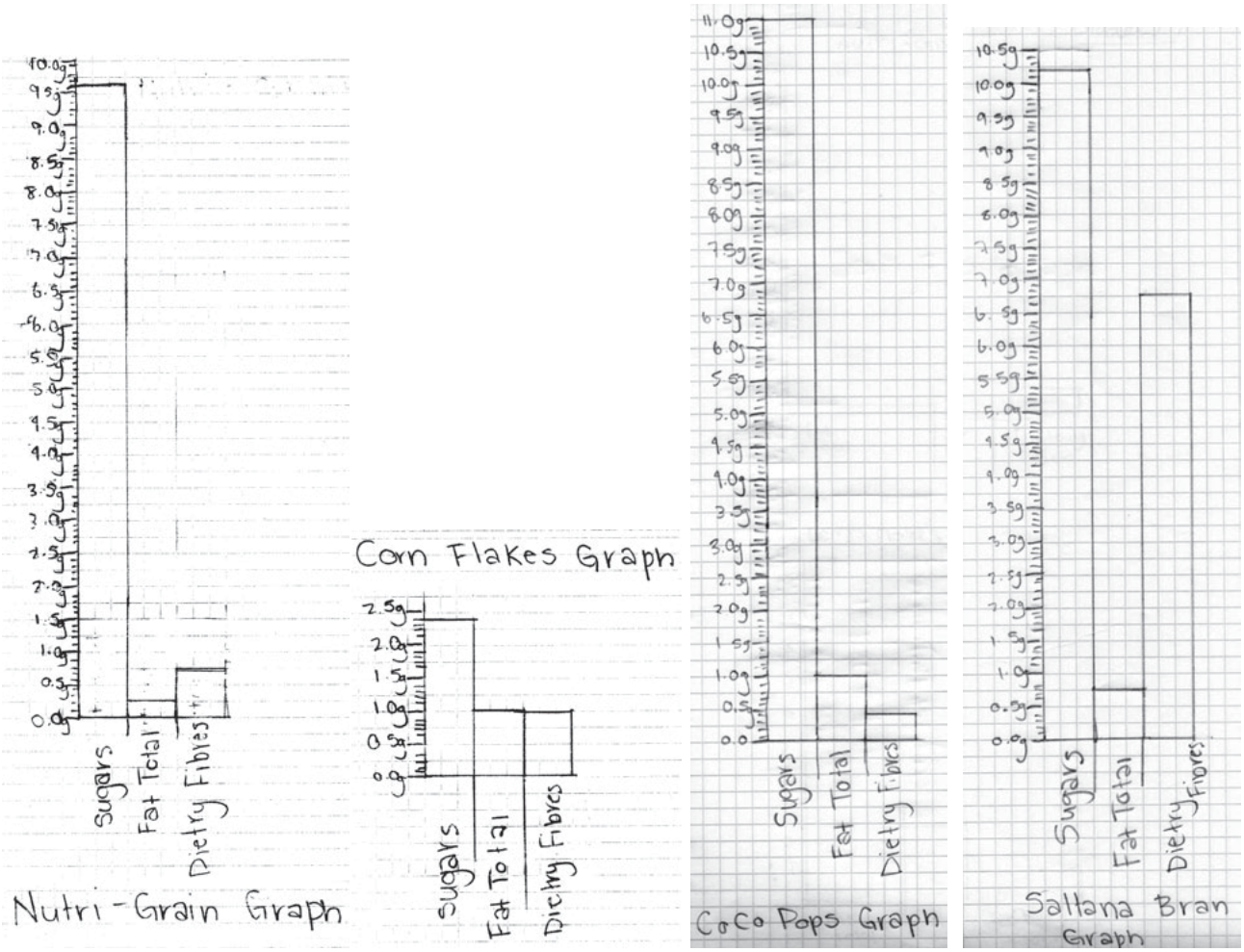

Figure 4. Individual graphs drawn by a student using different scales.

Finding 3: Students tend to launch into graphs without understanding the nature of the graph and the data they are graphing

Most students did not go through the phase that involves the organisation and tabulation of data (Phase 2) which requires them to organise the data into a table or in a form that makes sense to them. Because of this limitation a few students struggled with the construction of their graph(s) which in turn affected their ability to interpret the data.

Verbal responses to Figure 3

Researcher: Can you tell me what type of graphs you have drawn?
Student: Oh I forgot the name… um, a line graph, or something like that.
Researcher: Why have you chosen to draw this type of graph?
Student: Why? … Um… because I know how to draw them.

Looking at the responses to Figure 3, we can see that the student was not entirely sure about the type of graph that they had drawn and was unable to explain with any sort of conviction, why they had drawn this type of graph. They did not make any connection to the type of data that they were drawing on or the purpose of the relevance of the type of graph that they had decided to draw.

Finding 4: A number of students were able to tabulate and draw clustered graphs

A handful of students drew a table and or wrote down the contextualised information in a logical way. They then analysed this information and made a decision as to which graph was best suited for the information given. A few students drew clustered graphs and displayed all of the information given in a single representation. Figure 5, shows an example of a student that has firstly written the necessary information down in order to think about the type of graph that they could draw. They have then constructed a clustered column graph for each of the four cereals, with a scale and legend that make sense for the information. The labelling (axes and title) and one point of alignment (Sultana bran, Sugar 10.2) could be amended but overall the quality of this graph is satisfactory and is representative of the Year 7 standard and closest to our model solution (Figure 2).

Finding 5: Students, although able to draw graphs, are making idiosyncratic judgements about the graphs that they had drawn

The majority of students drew graphs without thinking about the value of the graph in helping them to make judgements and the need to make judgements with the data in context.

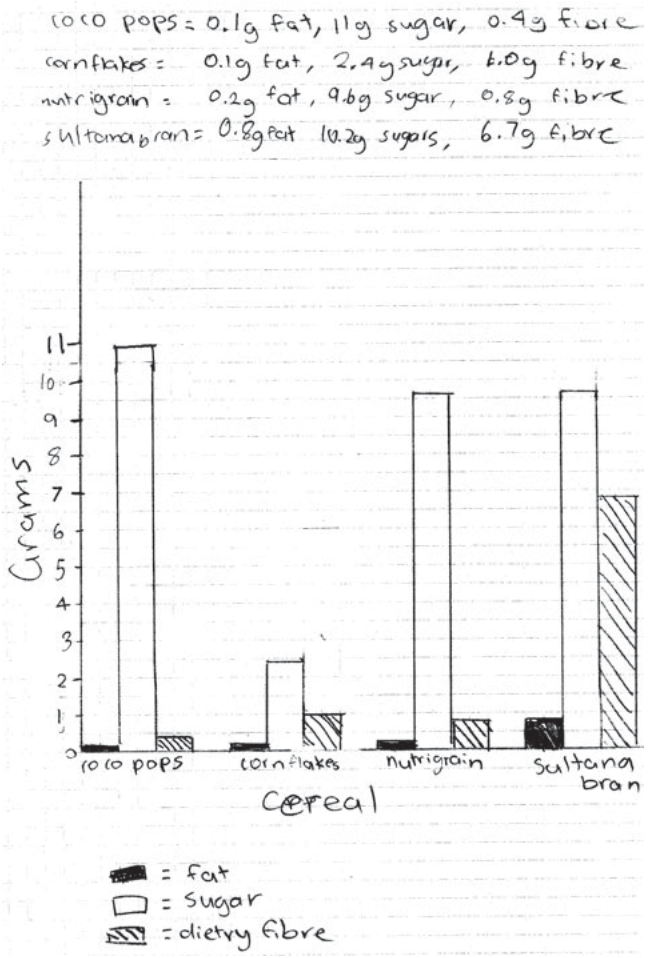

Figure 5. Clustered column graph drawn by a participating student.

Verbal responses to Figure 4

Researcher: What can you see is important in the graphs you have drawn? Why is this important?

Student: That the measurements you are using are accurate and that its name so that you know what the graph is for… and um that each bar has a name so that you know what it stands for.

Researcher: Using your graphs, if you had to recommend one of these breakfast cereals to your friends, which cereal would you recommend? Why?

Student: Um… one that is more healthy… um probably the Corn Flakes because it's got less sugars in it and it's got dietary fibres in it… and I like Corn Flakes.

This student was able to identify parts of the graph that they thought was important, yet made no connection of the graph being important for the data and the important data represented within the graph. The student could have made a comparison of cereals at this point in time, stating that it is important to note that they have different amounts of fat, etc. There are many things that were important about the graphs that this student had drawn and this student deserves to be exposed to this.

The student identified the fact that if they were going to recommend a cereal that it would be a healthy one, and with this statement they recommended cornflakes. They were able to make the deeper connection in stating that it had less sugar than other cereals which showed the student had integrated knowledge from other areas of learning to help them with their interpretation. The student made a comment that the cereal had dietary fibres in it, but this, although a good point. was not enough information as all of the cereals contained dietary fibre. The student then made the comment "…and I like corn flakes", although the student had a relevant reason for recommending it, their reason for liking Corn Flakes was not relevant to their graphs, or the information given. This was an idiosyncratic judgement that had no relation to their graphs.

Useful strategies for classroom practice

On the basis of the model for data interpretation and findings of how students responded to our breakfast task, we provide the following suggestions for classroom practice and student activity.

Students are in general, proficient in producing graphs from data that appears in a table because the data is already organised in the form of a table. There were two areas of difficulty when students are expected to graph data from a real-life context. Firstly, they are experiencing difficulty in extracting and organising the data appropriately, and secondly, drawing graphs in formats that would facilitate interpretation and extrapolation. The question is how can we help students who have such difficulties?

Students should be given time to understand the context so that they can grasp the different elements of the context and what these elements capture. The number of elements can be expected to vary depending on the complexity of the context. The understanding can be enhanced by having a group and/or classroom-based discussion about the context. The discussions can be facilitated by the teacher or a leader of the group about critical information embedded within this context and what this information tells the reader about the context. Such an open-ended discussion will increase

the participation levels of students, and students can feed off of each other's ideas. At the end of the discussion, an important outcome would be the identification of the variables and measures of these variables. Equally important is for students to raise questions about the context and how the information could be used to answer selected questions.

Following the above activities that support the understanding of the context, students should be encouraged to attend to the extraction and organisation of the data as well as the questions they have posed as part of their discussions. At this point leaders and or the classroom teacher could provide examples of tables and invite the students to enter data into these tables either individually or as a class. Students should also be required to critique their table for its usefulness in answering questions of interest.

Following the tabulation phase, students can be encouraged to draw more than one graph, and then select the graph that they feel is more appropriate or powerful to best represent data as a means to answering key questions. It is possible that a few students may have difficulties in constructing clustered graphs that show more than one variable. Or, the variables could be measured in different units and students have to choose an appropriate scale so that all of the variables fit into a single graph (Lake & Kemp, 2001). This part of graph construction is less problematic if students choose to draw separate graphs for each of the variables. Yet for a deeper processing of the information and interpretations that involve comparisons, students should be encouraged to draw clustered graphs, even though separate graphs may be easier for the students to draw.

Our finding showed that students find the interpretive phase most problematic because decisions that can be made are subjective in the sense that students have to use the graph as well as their knowledge of the wider world (Friel, Curcio & Bright 2001). For example, in our study, in order to make a recommendation about a breakfast cereal, students were required to look at their graphs and also access their prior knowledge about the brand of cereal, the dietary value of the contents, and possibly, the person it is being recommended to. This wider knowledge can be based on students' cross-curricula understandings. Graphing based on real-life contexts provides multiple points at which students can display or can connect to concepts from other key learning areas.

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