# A *FIVE STEP FRAMEWORK* FOR INTERPRETING TABLES AND GRAPHS IN THEIR CONTEXTS

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*High school, college, and university students as well as citizens encounter quantitative information in a wide variety of media and contexts, such as in books, journals, newspapers, magazines, advertising, the workplace and on the Internet. While it is often assumed that people are able interpret published data in context, this assumption is open to question. In this paper, a Five Step Framework to help both teachers and students to interpret data in the form of tables or graphs is described and exemplified. Development of the Framework by Kemp was based on the SOLO taxonomy devised by Biggs and Collis. The Framework offers a progression from simple numerical reading of a table, to more complex interpretations of tables and graphs needed for a better understanding of data in their context. The Framework has been used successfully in primary, secondary and tertiary mathematics education to support both students and their teachers.*

## INTRODUCTION

Advances in technology and communications have increased the extent to which people across the world are exposed to quantitative information in tables, graphs and text, highlighting a need for statistical literacy. Watson (2003, p.1) noted that, for citizens in the 21st century, 'decision making is likely to be made based on the critical skills from the realms of statistical literacy'. Earlier Wallman (1993, p.1) in her presidential address to the American Statistical Association described statistical literacy as:

> the ability to understand and critically evaluate statistical results that permeate our daily lives -coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions.

In this paper, we propose that the ability to interpret information presented in tables and graphs is a key element of statistical literacy, and that this needs explicit attention as part of all students' education. More than twenty years ago, the National Council of Mathematics (1989) in the USA claimed that a "knowledge of statistics is necessary if students are to become intelligent consumers who can make critical and informed decisions" (p.105). Similarly, the Australian National Statement on Mathematics (Australian Education Council, 1991, p.164) claimed "students should learn to question the assumptions underlying data collection, analysis and interpretation, and the reasonableness of inferences and conclusions". More recently, Gal (2002, pp. 2-3) proposed that these critical skills should be built up as a natural part of the chance and data curriculum that would lead to critical thinking across the school curriculum. Ideally this would be the case for all students. However discussion with teachers and lecturers in Australia indicates that although students might extract specific points of information they do not critically interpret material in tabular or graphical form unless explicitly directed to do so.

Many people seem not to engage adequately with quantitative information, rather choosing to rely on an author's interpretation. In this way they are vulnerable to intentional or unintentional misleading statements by an author (Dewdney, 1993). Indeed many people seem not to be aware that data may be chosen carefully to support an author's points of view. The authors may be politicians or others discussing key issues such as: policies on climate change, guidelines for water consumption, establishing rights of indigenous people versus mining rights, changes in traffic statistics or employment and unemployment data. As Best (2001, p.18) points out,

> Certainly we need to understand that people debating social problems choose statistics selectively and present them to support their point of view. Gun-control advocates will be more likely to report the number of children killed by guns, while opponents of gun-control will prefer to count citizens who use guns to defend themselves from attack.

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A range of media sources can be used (e.g., Gal, 2003; Kemp, 2009; Watson, 1994) to help students become familiar with quantitative information presented in the media where varying points of view are expressed and claims are made. Data sources might include printed material, news websites, official and unofficial statistical reports and survey data or opinion poll data. Interrogating such information should help students to understand that "[a]ll statistics are products of social activity-the process sociologists call social construction" (Best, 2002, p.1).

The *Five Step Framework* presented in this paper was developed in the context of helping university students to develop strategies to read tables and graphs, and to critically interpret the information presented in a range of contexts. The ability to do this is very important for all university students regardless of the discipline in which they are studying. The *Five Step Framework* is currently integrated into the authors' university's interdisciplinary first year Foundation units, in a first year primary education unit, in a first year statistics unit and the Enabling Program for pre-university students. It is also provided as part of the online resources for secondary mathematics teachers in Western Australia.

It is not the intention of the authors to offer advice as to precisely where the development of the use of the *Five Step Framework* should be located in a curriculum. However, for first year statistics units it does fit quite nicely into parts of the curriculum where students are learning to read tables and graphs. Commonly this is where they look for misleading graphs and tables but do not necessarily really interrogate the material. It could be revisited when students have learned more about sampling and data collection methods and pitfalls, to alert the students to the need to think more critically about the information presented. This paper presents a tool that can be used with a range of students with varying levels of complexity.

## LEARNING IN THE SOCIAL SCIENCES

In social science faculties, students enroll in a range of majors such as Sociology, Philosophy, History, Asian Studies, Education, Women's Studies and Politics. These span a wide range of topics and issues for which students are expected to consider social, economic and environmental factors from international and global perspectives. Students might be required, for example, to consider gender issues, community development, health risks (such as H1N1 and HIV), indigenous issues, poverty, employment, crime and traffic statistics, war and the expenses of the military. Thus, in every topic covered in their studies and in many examples in their lives outside of college or university, students encounter quantitative information in one form or another. In Australia it is not always the case that students are required to undertake a statistics course unless they are studying in one of the physical or life science disciplines.

If students studying non-quantitative majors are to participate in a statistics course then naturally the materials chosen for their learning experiences would be selected explicitly to interest and motivate the students while aiding the development of their statistical concepts. In combination with this careful attention should be paid to the use of appropriate materials to develop critical reading skills. The ability to read critically and interpret quantitative information is vital and the realization that people manipulate data to support their own point of view is essential. Indeed, the media provides a wide range of topical and relevant contexts for students to question what they read, as well as think about the appropriateness of the statistical parameters used.

The *Five Step Framework*, (Kemp, 2005) which is summarized in Table 1, was based on the SOLO taxonomy (Biggs & Collis, 1982). This taxonomy provides a framework within which teaching can be planned to help students develop their levels of thinking from simple point extraction through to making comparisons, looking for trends and meaning. The *Five Step Framework* provides a generic template for teachers to help their students develop strategies for interpreting data in tabular or graphical form, and can be applied to both simple and complex tables and graphs.

The level of complexity and the content of the table or graph need to be selected according to the types of materials being studied by the students as well as the statistical concepts being learned at the time. For example, opinion polls can be used as a vehicle to learn about random sampling, the size of the sample and basic probability alongside other learning experiences provided in the classroom to develop them. Poll websites usually give information about the sampling procedures and size and the sampling errors involved where students can access essential information that is not necessarily provided in the media or an article.

Table 1. *Five Step Framework* for Interpreting Tables and Graphs

**Step 1: Getting Started**
Look at the title, axes, headings, legends, footnotes and source to find out the context and expected quality of the data. Take into account information on the questions asked in surveys and polls, sample size, sampling procedures and sampling error.
**Step 2: WHAT do the numbers mean?**
Make sure you know what all the numbers (percentages, '000s, etc.) represent. Look for the largest and smallest values in one or more categories or years to get an impression of the data.
**Step 3: HOW do they differ?**
Look at the differences in the values of the data in a single data set, a row or column or part of a graph. This may involve changes over time, or comparison within a category, such as male and female at any time.
**Step 4: WHERE are the differences?**
What are the relationships in the table that connect the variables? Use information from Step 3 to help you make comparisons across two or more categories or time frames.
**Step 5: WHY do they change?**
Why are there differences? Look for reasons for the relationships in the data that you have found by considering social, environmental and economic factors. Think about sudden or unexpected changes in terms of state, national and international policies.

There is not space here to describe in detail the development and validation of this *Five Step Framework*. (See Kemp (2005) for details.) Rather, we provide two examples of its recent use to scaffold interpretative thinking, one each for a table and a graph.

## INTERPRETING TABLES

Data are presented in a variety of contexts in tabular form. Koschat (2005) identified three main advantages in using tables for providing information. Firstly, a table presents data, or a summary of that data, in numerical form. Secondly, people can easily use the data and convert to other forms such as a graph or a model if they wish to do so, but this is not easy in reverse. Thirdly, it can quite often be the case that the reader wants to see and interpret the actual numbers. It is expected that teachers would provide learning experiences and discussion concerning ways in which data may be collected and summarised and help develop students' awareness of the potential pitfalls and distortions. They can then bring this awareness of the process of data collection to their interpretations of tables and graphs.

Table 2 concerns employment in the Philippines by gender and was selected to highlight issues of gender difference and to illustrate that questions should always be asked about the way in which data were collected and why categories were devised. It is based on data from the National Statistics Office of the Philippines (2009).

Table 2. Number & Percentage Distribution of Employed Persons by Sex & Major Industry Group

| Major Industry Group | Employed Persons | | | | | |
|---|---|---|---|---|---|---|
| | Both Sexes | | Male | | Female | |
| Philippines | ('000) | % | ('000) | % | ('000) | % |
| | 34,533 | 100 | 21,276 | 100 | 13,257 | 100 |
| Agriculture, hunting and forestry | 10,861 | 31.5 | 7,814 | 36.7 | 3,047 | 23 |
| Fishing | 1,461 | 4.2 | 1,342 | 6.3 | 118 | 0.9 |
| Mining and quarrying | 176 | 0.5 | 160 | 0.8 | 16 | 0.1 |
| Manufacturing | 2,896 | 8.4 | 1,605 | 7.5 | 1,291 | 9.7 |
| Electricity, gas and water | 124 | 0.4 | 103 | 0.5 | 21 | 0.2 |
| Construction | 1,880 | 5.4 | 1,840 | 8.6 | 40 | 0.3 |
| Wholesale and retail trade; repair of motor vehicles, motorcycles, personal & household goods | 6,528 | 18.9 | 2,638 | 12.4 | 3,890 | 29.3 |
| Hotels and restaurants | 940 | 2.7 | 423 | 2.0 | 517 | 3.9 |
| Transport, storage and communication | 2,587 | 7.5 | 2,441 | 11.5 | 147 | 1.1 |
| Financial intermediation | 373 | 1.1 | 155 | 0.7 | 218 | 1.6 |
| Real estate, renting and business activities | 984 | 2.8 | 648 | 3.0 | 336 | 2.5 |
| Public administration and defence; compulsory social security | 1,691 | 4.9 | 1,037 | 4.9 | 654 | 4.9 |
| Education | 1,094 | 3.2 | 264 | 1.2 | 831 | 6.3 |
| Health and social work | 405 | 1.2 | 122 | 0.6 | 283 | 2.1 |
| Other community, social, and personal service activities | 798 | 2.3 | 413 | 1.9 | 385 | 2.9 |
| Private households with employed persons | 1,733 | 5.0 | 271 | 1.3 | 1,463 | 11 |
| Extra-territorial organizations and bodies | * | 0 | * | 0 | | |

* Less than 500 Source: NSO, October 2008 Labour Force Survey

The questions in Table 3 illustrate the kinds of questions that may be asked to help students to develop strategies in table reading, following use of the *Five Step Framework*. It should be noted that in Step 3 comparisons are made within one row or column while in Step 4 comparisons between those categories are made. Step 5 asks students to think about *why* things are the way they are.

Table 3. Using the *Five Step Framework* to Interpret Employment by Gender and Industry

**Step 1: Getting started**
**Scope**
Q: From the title, what is the general topic being examined?
Q: From the column labels what is being compared?
Q: From the row labels how are they being compared?
**Data Quality**
Q: From the footer, what is the source and credibility of the data?
**Definitions**
Q: What does the * represent?
**Step 2: WHAT do the numbers mean?**
Q: In the table heading there are several sections, consider the numerical row. What is the precise meaning of 34,533?
Q: How many workers are male? How many female?
Q: What is the total of numerical column four? Why is this so?
Q: What is the meaning of the 31.5 in the second numerical column? How was it calculated?
Q: What is the meaning of the 36.7 in the fourth column? How was it calculated?
Q: Why don't the three percentages for *Agriculture, hunting and forestry* add up to 100?
Q: What percentage of workers in the *Education* industry are women?
Q: What is the percentage of women workers who are employed in the *Education* industry?
**Step 3: HOW do they differ?**
Q: List in descending order the five Major Industries by numbers of employees (Include the numbers)
Q: Which of these industry has the most males? Least males?
Q: For how many industries is the number of males higher than the number of females?
Q: Where is the biggest difference in the actual numbers of males and female employees?
Q: Where is the biggest difference in the percentages of males and female employees?
**Step 4: WHERE are the differences?**
Consider the *Agriculture, hunting and forestry* workers:
Q: If you are an *Agriculture, hunting and forestry* worker what is the probability that you are male?
Q: If you are male what is the probability that you are an *Agriculture, hunting and forestry* worker?
Q: For *Agriculture, hunting and forestry* workers the number of males is more than the number of females and the corresponding percentages of males and females are in the same order of size. Compare this with the numbers and percentages for males and females for the *Manufacturing* industry. What do you notice?
**Step 5: WHY do they change?**
Q: When data are collected and collated into groups someone makes decisions about those groups. How might you subdivide the *Wholesale and retail trade; repair of motor vehicles, motorcycles, personal & household goods*? Consider the groupings of other industries. Suggest some other groupings that would make sense to you.
Q: Look at the industries where there are more females. What do you notice?
Q: Suggest reasons for the differences in the numbers of people who work in the industries and the gender break down.

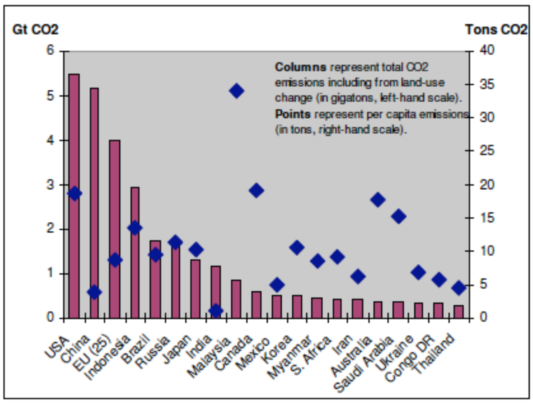
In 2009, the responses of secondary school teachers and undergraduate students in the Philippines made it clear that, while it is quite unusual for scaffolding of this kind to be provided, questions such as those in Table 3 supported a careful interpretation of the data, while also highlighting the previously unrecognized need to interrogate tabular data carefully to extract meanings.

## INTERPRETING GRAPHS

Graphs are often seen in all forms of media, printed and electronic. Students need to learn about the appropriate use of graphs for specific purposes such as showing trends or proportions, for discrete and continuous data and to have some knowledge of what the shape of a graph can convey. Students also need to be diligent about observing misleading and distorted graphs, and as Watson (2006, p.55) points out, "conscious effort needs to be expended to achieve the lie detectors … [in reading graphs] required by statistically literate adults". In addition, they need to have strategies for interpreting the graphs they encounter.

The graph in Figure 1 has been chosen for two reasons. Firstly, it depicts a topical issue that can be considered from a number of perspectives, and secondly, it illustrates that even complex-looking graphs like this can be interpreted using a structured series of steps.

Table 4 includes the kinds of questions that can be constructed to assist students to develop the necessary strategies to interpret graphs. Once the students have completed some examples prepared by their teachers they are able to construct appropriate questions for themselves.




*Data source: World Resources Institute*
Note: Total emissions combine fossil fuel emissions for 2004 and land-use change emissions for 2000. Per capita emissions divide this total by 2004 population.
Note that estimates of land-use change (deforestation) are subject to large uncertainties in many of the main emitting countries.

Figure 1. $CO_2$ Emissions Including Land-Use Change, 20 Largest Emitters, and Per Capita Emissions

Table 4. Using the *Five Step Framework* to Interpret the Graph on $CO_2$ Emissions

**Step 1: Getting started**
**Scope**
Q: What is the general topic being examined?
Q: From the vertical axis what are being measured?
Q: What do the columns represent?
Q: What do the points represent?
Q: How have total emissions been calculated?
**Data Quality**
Q: From the note, what is the source and credibility of the data?
**Definitions**
Q: What does per capita mean?
**Step 2: WHAT do the numbers mean?**
Q: What is the value of the total $CO_2$ emissions for Australia?
Q: What is the value of the per capita emissions for Australia?
**Step 3: HOW do they differ?**
Q: What is the highest total $CO_2$ emission value (left axis) and for which country?
Q: For this top 20 set what is the lowest total $CO_2$ emission value (left axis) and for which country?
Q: What is the highest/lowest per capita emission (right axis) and for which countries?
**Step 4: WHERE are the differences?**
Q: Look at the graphs of India and China, which have similarly large populations (India 1.1 billion and China 1.3 billion) but quite different total $CO_2$ emissions. Why might these total values be different?
Q: Look at the graphs for Malaysia and Japan. Why do you think the per capita emissions are so different?
Q: Compare the per capita emissions of Australia, Canada and USA.
Q: Compare the per capita emissions of Brazil and Korea.
**Step 5: WHY do they change?**
Q: Make some observations about what you see in the graphs and give some reasons for the differences, taking into account what you know about industrialization and developmental levels of countries.

This graph, and the associated questions, was used in an interdisciplinary unit for undergraduate students in 2007-2009. Tutors from a range of disciplines reported that, as well as finding the context and the task interesting, students found the scaffolding provided by the framework helpful. Both tutors and students reported that they had not learned how to interrogate graphs productively in this sort of way at school.

## USING THE *FIVE STEP FRAMEWORK*

It is relatively easy to teach students how to extract point information from the data in tables and graphs but it is more difficult to help them develop strategies to question how and why the data were collected, to make comparisons within and across categories and to think about the meaning of the data within its context. This is what the *Five Step Framework* aims to do in conjunction with sound pedagogical teaching and learning of statistical concepts. Some research (Kemp 2005, Kemp

& Bradley, 2006) showed that students did engage more with data in tables and graphs after using the *Framework* ($p < .01$). The *Five Step Framework* has also been used over several years in workshops with primary, secondary and tertiary mathematics teachers in Australia, Thailand, Singapore, the Philippines, the Czech Republic, Germany and Mexico. Informal feedback has consistently suggested that there is a need for work of this kind in classrooms, and that the *Framework* acts as a useful scaffold.

## CONCLUSION

The *Five Step Framework* provides a means for teachers to scaffold their students' thinking through the development of materials such as those illustrated in this paper. The *Five Step Framework* can be used by teachers to examine contemporary materials, of direct interest to students, addressing issues of significance to them personally as well as to their studies. Experience suggests that, while such scaffolding is necessary, it is not necessary to continue using it over an extended period of time. Rather, well-chosen examples of interest to students can be used to help them develop the kinds of expertise and strategies, needed to read and interpret data in tables and graphs, that they can then apply in new contexts.

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