A short tour of bad graphs

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Contents

1 Introduction

There are three kinds of lies, “lies, damned lies, and statistics”. This is never more true than when poor statistical graphs are drawn.

A picture is worth a thousand words, and a graph worth a thousand numbers only if it is clear, concise, and correct.

Always graph your data - often a properly chosen graph will obviate the need for any further analysis. Don’t lose sight of the purpose of the graph when you are drawing it.

Thre are many good books on the proper construction of graphs. I particularly enjoyed the series by Tufte:

- The Visual Display of Quantitative Information, E. Tufte, Graphics Press
- Envisioning Information, E. Tufte, Graphics Press
- Visual Explanations, E. Tufte, Graphics Press

You will find these books a delight to read with many examples of well constructed graphs and figures.

2 Principles of good graphical design

Some basic principles to follow when constructing graphs are:

- There should be a high data to chart ratio. This means that the data points should be clearly visible , form the heart of the graph, and should not be overwhelmed by axes, titles, reference lines, and chart junk. Grid lines should not be too dark, missing, or not relevant to the graph. Grid lines, if present, are best presented in a light grey screen so that they are visible, but not obtrusive.
- Use the appropriate graph for the appropriate purpose. Most of the many graphs presented in Excel are POOR CHOICES! In particular, never use a pie chart!

  There are only a few basic types of graphs.

  - **Trend graphs**. If you wish to emphasize the trend in a time series, a line chart (i.e. use a line to connect the data points to show the trend) is better than a series of side-by-side bars.
  - **Relative size graphs**. Here side-by-side bar graphs are best, but all bars must be anchored at zero. All bars should be equal width, otherwise, readers of the graph will be confused by differences in area, rather than difference in lengths of the bars.
  - **Composition graphs**. This is where pie-charts are often (badly) used. The trouble with pie-charts is that people are not well programmed to compare angles of pies. A better graph is a segmented bar-chart where the bar (that streches from 0 to 100%) is segmented into pieces. Put the most important segments at the top or the bottom of the bar (so that they are anchored at 0% or 100%) – this enables most readers to accurately estimate the percentage of the bar used by the category.
- Make sure that the graph is complete. All axes must be labelled. There should be a title on the graph.
- Think about the overall presentation of the graph. The points on a plot should be spread over the area of the graph without being shoved into one corner. The axes scales should be appropriate. In some cases, a log-scale is a better representation of data that spans several orders of magnitude. Where is the 0 point on a graph. In particular, bar charts should always be anchored at zero. Use different plotting symbols or line-types to differentiate among groups on the graph. The independent variables is usually plotted on the X-axis; the dependent variable usually on the Y-axis.

The best graph is one that is self-explanatory!

There are many common errors that are made in poor graphs. Here are some of the most common errors:

- **Wrong graph type.** Think about what you want to present. Trends are best displayed using lines. Compositions best displayed using segmented-bar-charts.
- **Missing text.** All tick-marks and axes must be labelled. The graph needs a title.
- **Inconsistent scale.** The scale must be constant across the graph; don't change the increments between tick marks.. Most people read increasing scales from left to right and from bottom to top. Comparative graphs must be plotted on the same axes to facilitate comparisons.
- **Misplaced zero point.** Most people assume that the zero point is at the bottom of the graph. This can give a very misleading impression of the amount of change present in a data series.
- **Poor chart effects**. Shading, 3-D effects, or ducks are often added to liven up a graph. In most cases they are useless since they distort the graph and add little new information to the story. 3-D effects are particularly poor as no information is being added; it is difficult to read the chart values; and often the graph is also tilted to make it even harder to read the graph.
- **Confusing of area and length.** If you make a picture twice as large, it looks as if it has four times the area!.
- **No adjustment for inflation.** Dollar amounts must be adjusted for inflation. Otherwise, any comparison is misleading.
- **Too much precision.** We've all seen graphs reporting that the amount of money raised is $13,456,234.32. Most people can't distinguish objects at a resolution better than one part in a hundred. Consequently, giving 10 significant digits is just silly. It would be far better to present this number as simply $13 million (i.e. get rid of all the extra zeroes and use an appropriate scale).

3 A collection of links to more examples of bad graphs

Here is a collection of links to more examples of bad graphs.

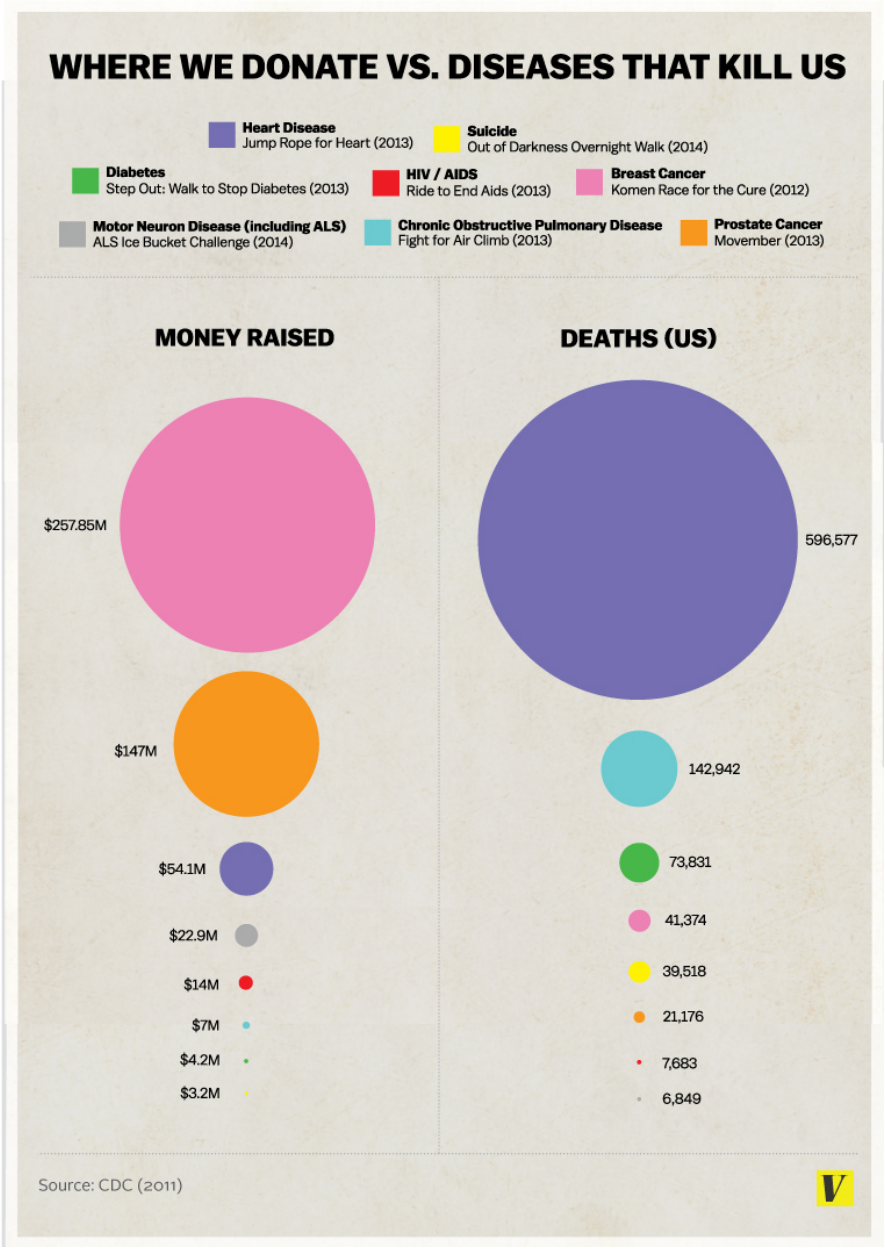
- `http://www.biostat.wisc.edu/~kbroman/topten_worstgraphs/`
- `http://lilt.ilstu.edu/gmklass/pos138/datadisplay/badchart.htm`
- `http://www.stat.auckland.ac.nz/~ihaka/120/Lectures/lecture03-8up.pdf`
- `http://pol.illinoisstate.edu/jpda/charts/bad_charts1.htm`

4 Examples of Bad Graphs

Here are some examples of bad graphs. Can you identify some of the problems with these graphs?

4.1 Where we donate vs. diseases that kill us

This graph was posted to Facebore (among other places) at `https://www.facebook.com/GuideStarUSA/posts/10152782668515984`.



The title of the graph is *Donating.vs.Death-Graph.0.jpg*. It is supposed to compare the relative amounts of funds raised for "disease research" vs. the relative number of deaths.

There are a number of flaws:

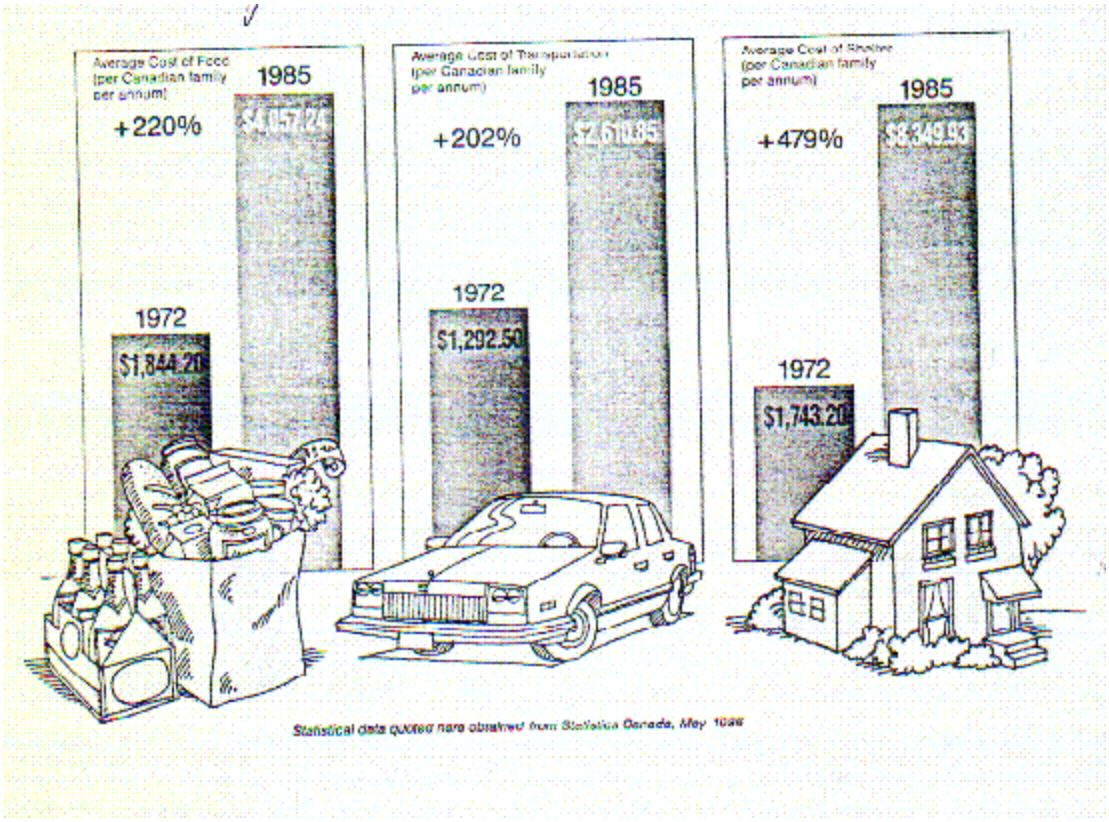
- The diameter of the circles is proportion to the values. For example, the diameter of the circle for Breast Cancer money raised ($257 million) is approximately twice as large as the diamger for Prostate Cancer raised ($147 million). However, people don't perceive the ratios using diameters, but rather ratios. The AREA of the circle for Breast Cancer raised is 4x larger than the area

for Prostrte Cancer raised, distorting the comparison. The same problem occurs in the circle representing the number of deaths.

- The circles are color coded to the legend above. Why not place the name of the disease directly on the circle to make it easier to interpret the graphs and to help color-blind readers.
- Presumably you want to compare the relative amount raised vs. the relative number of deaths caused by the disease. The money raised and deaths should be side-by-side, or some line should be drawn joining the two items to help the reader make the match.
- False sense of precision in the numbers. Do you really need 8 significant digits for the money raised for Breast Cancer and 6 significant digits for the deaths due to Heart Disease?
- Missing item for the last dollar raised item ($3.2 million)? This must belong to Diabetes? If the author of the graph had place the name of the disease directly on the graph, this mistake would have been detected.

Thanks to Emily Ross for forwarding the graph. Added 2014-09-02.

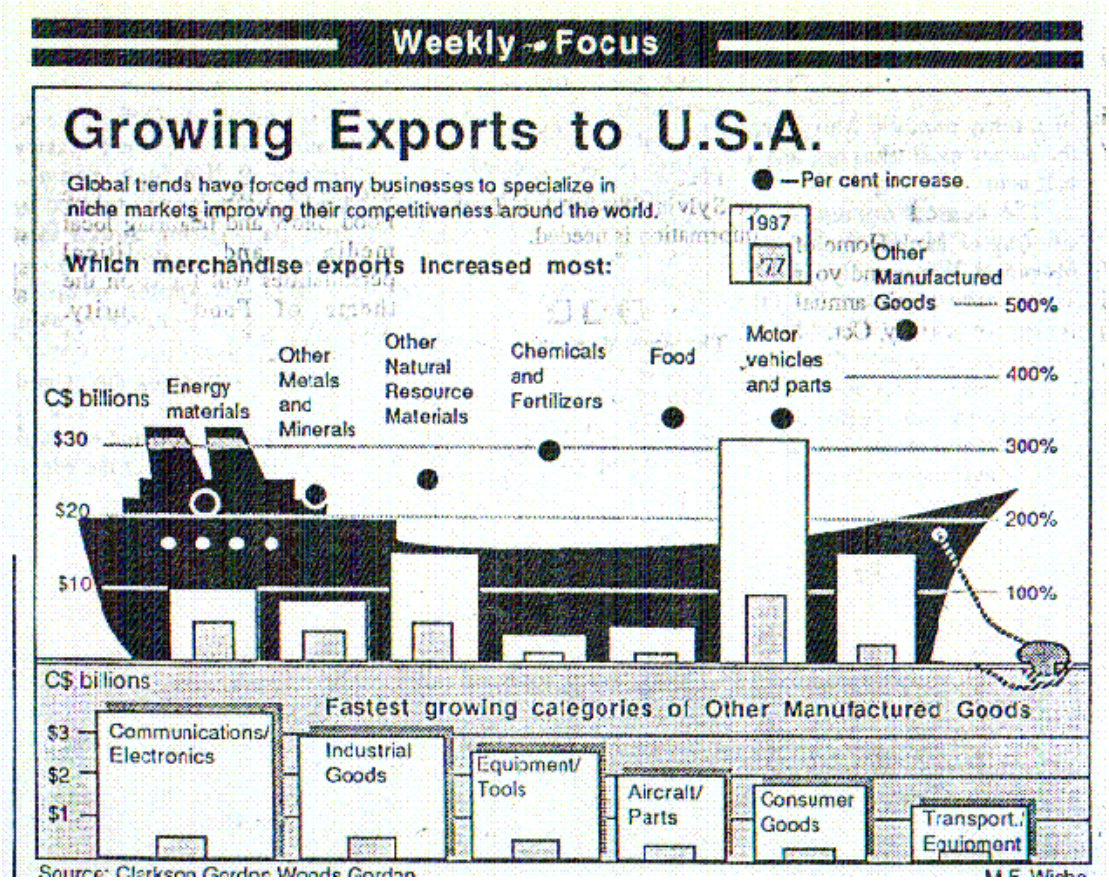
4.2 Cost of Living



In this graph, there are a number of flaws:

- The ratio of the heights of bars within each category does not reflect the actual ratio. For example, compare the ratio of the heights of bar in the housing category with those in food or transportation.
- There is an implied precision that is unrealistic. Do you think that the average can be estimated to the nearest penny!
- The percentages are computed incorrectly. A doubling of costs is only a 100% increase.
- Too many 'ducks'.

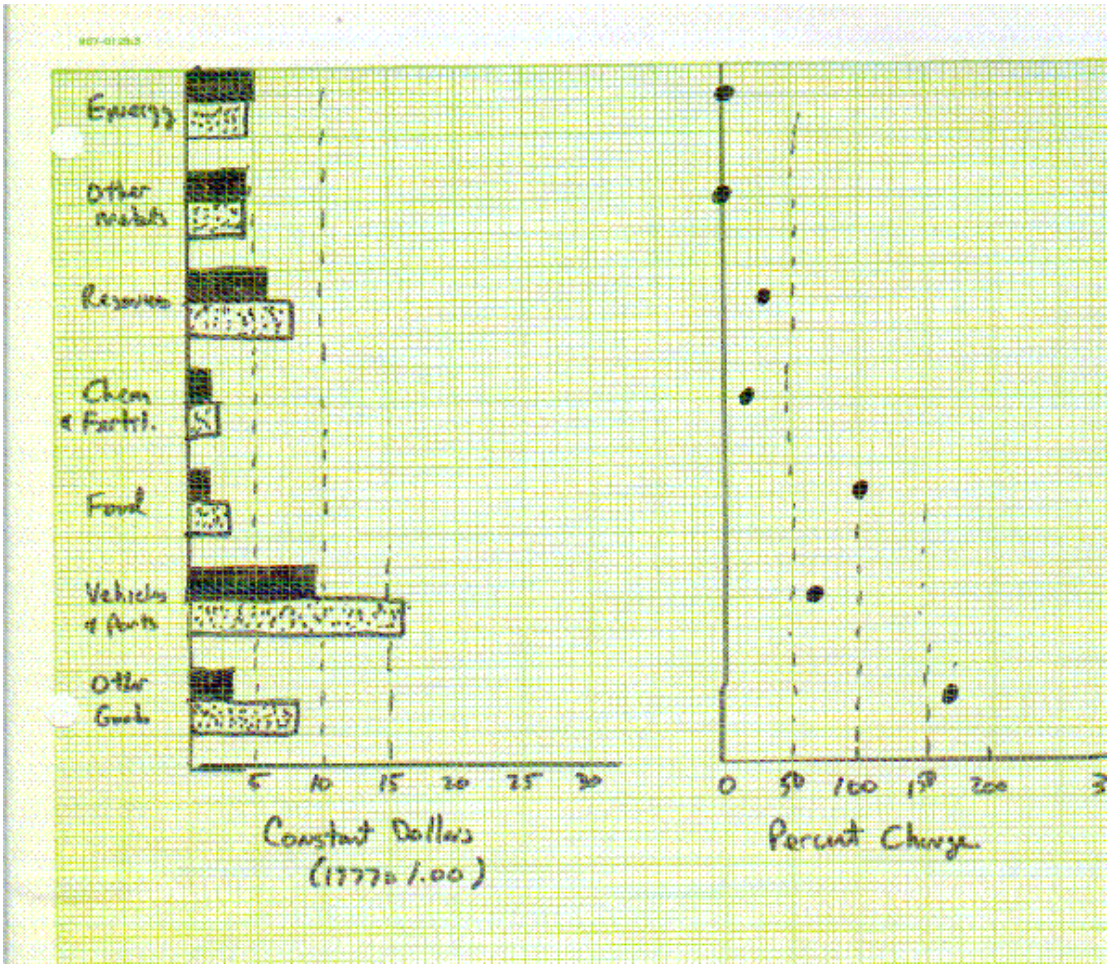
4.3 Exports to the US



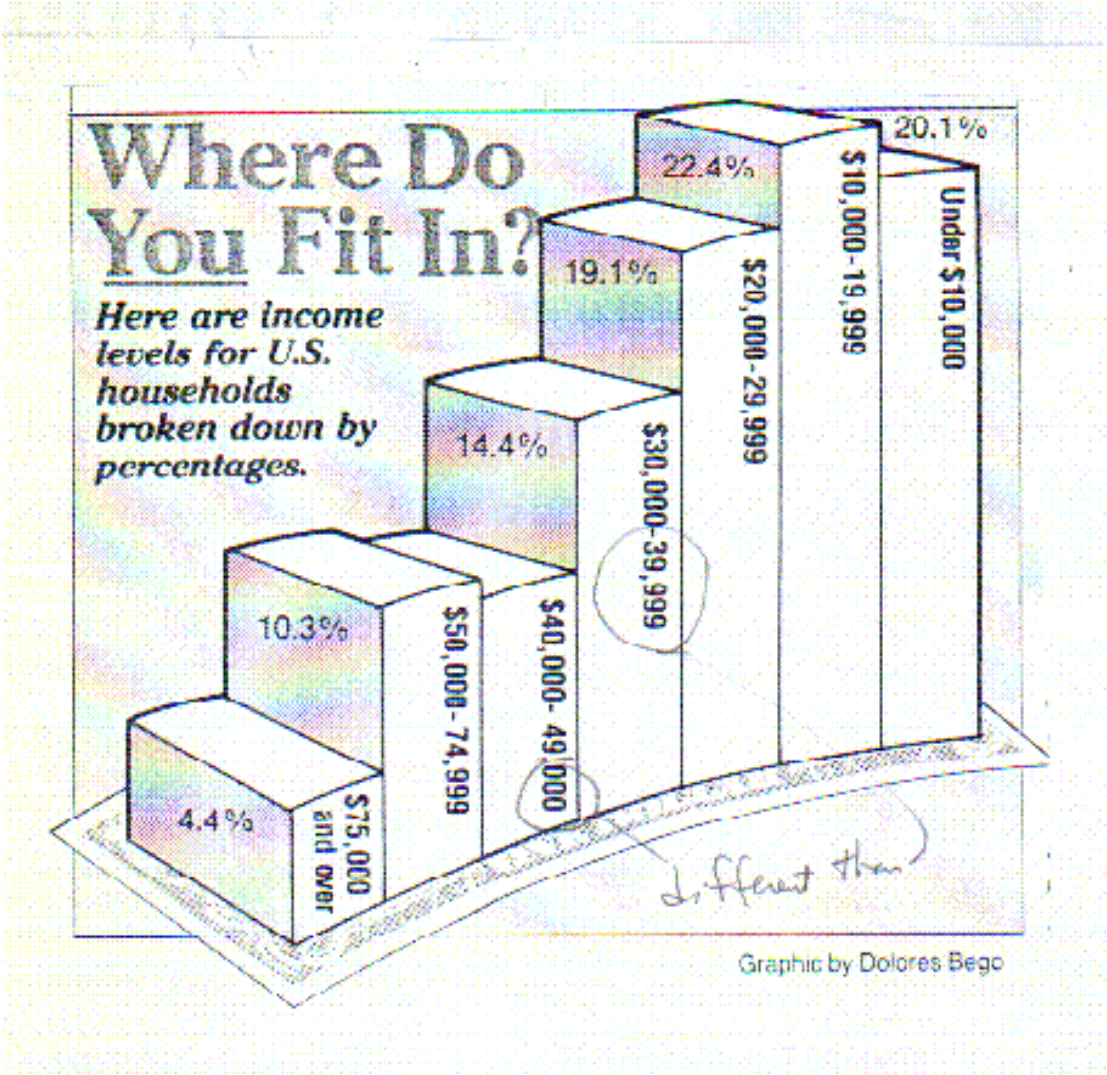
In this graph, there are a number of flaws:

- All $ amounts should be corrected for inflation.
- The little bars are within larger bars that are both higher and wider. Many people judge bar by their 'area' so this leads to and unfair comparison.
- The 'port holes' align with the per cent increases.
- Last time I looked, the border between the US and Canada was mainly land. Consequently, why is a ship used to designate exports?
- Too many 'ducks'.

Here is a revised graph correcting some of the errors:


Energy
Other Health
Research
Chem & Fertil.
Food
Vehicles & Parts
Other Goods
5
10
15
20
25
30
Constant Dollars
(1977 = 1.00)
0
50
100
150
200
Percent Change

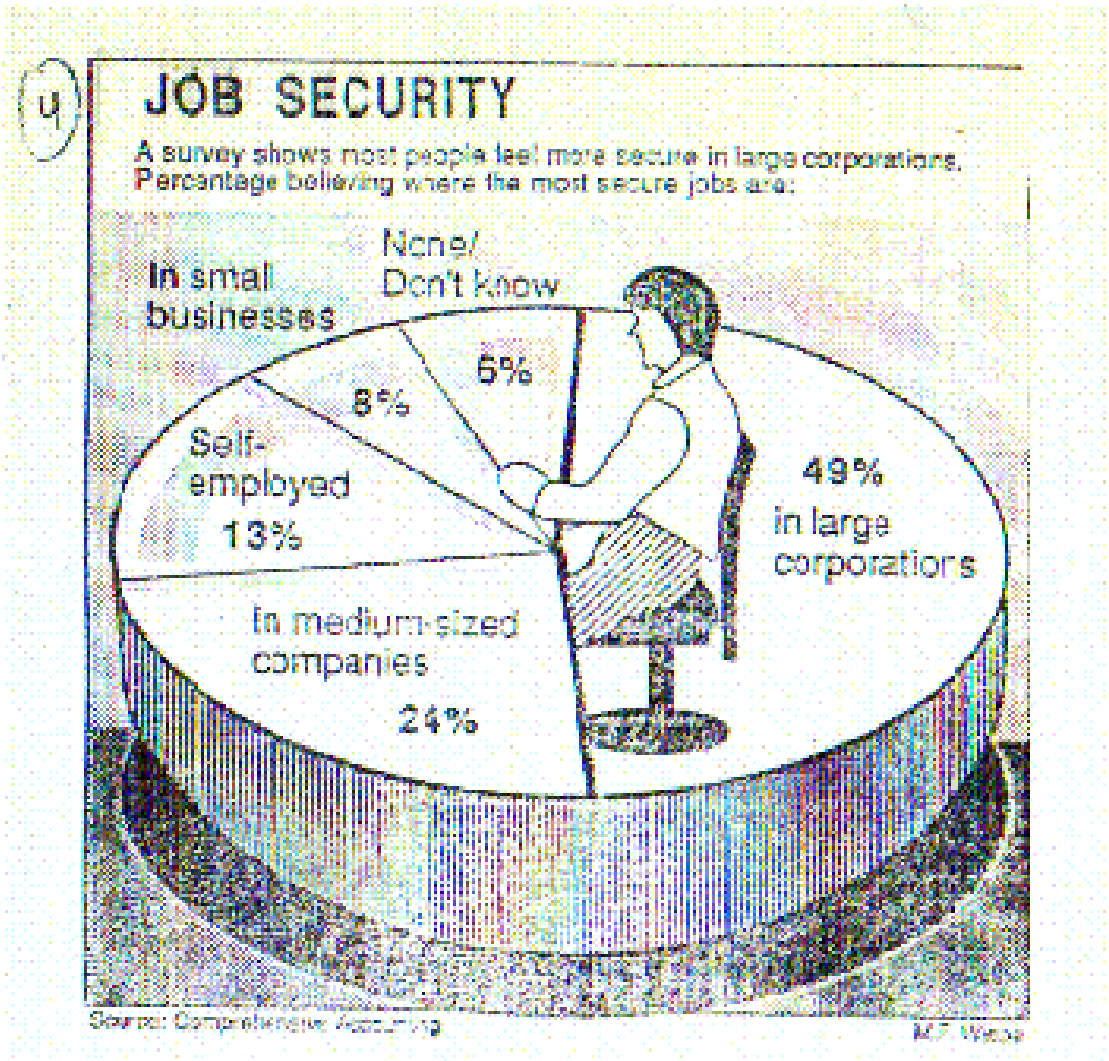
4.4 Income levels



In this graph, there are a number of flaws:

- The 3-D effects make it difficult to read the bars. Do you look at the front of each bar, the side of each bar, or the back of each bar?
- The non-horizontal scale artifically increases the lower-income bars compared to the upper-income bars.
- Some of the bars are missing the percentage figure?
- The interval sizes change. For example, it goes by by $10,000 than by $25,000 which artificially increases the 50-75,000 bar. As well why use 29,999 rather than 30,000?

4.5 Job security

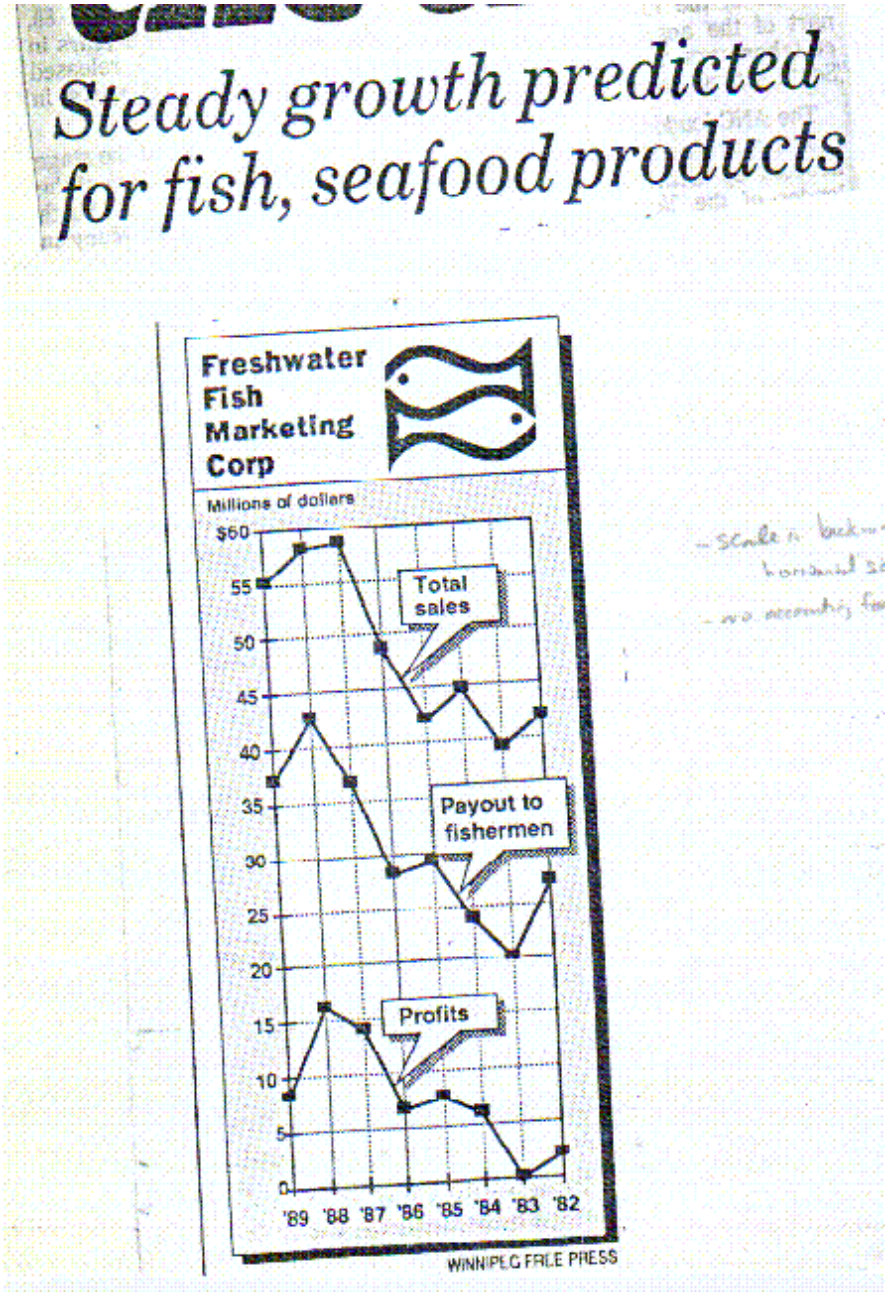


In this graph, there are a number of flaws:

- **A PIE CHART**. Pie charts should almost never be used. There are virtually no circumstances where a pie-chart is better than a simple table or a simple bar chart. The major problem with pie charts is that people have a difficult time comparing slices of the pie.
- Pie is distorted by tilting and 3-D effects.
- Slices are not properly made. Why is the 6% slice wider than the 8% slice?
- Ducks.

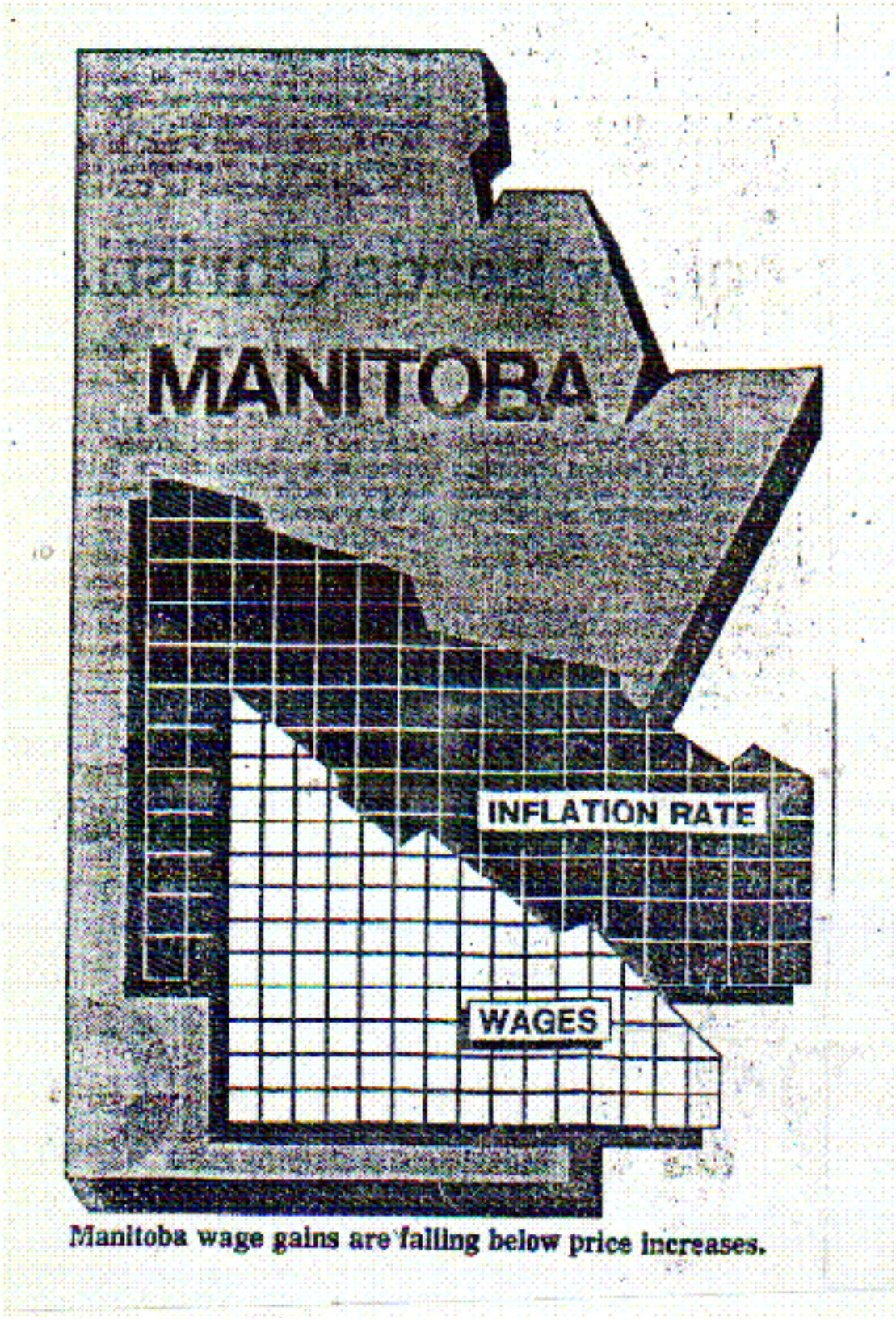
This pie chart used an enormous amount of space to display just 5 numbers!

4.6 Sales of seafood



If growth is predicted in fish and seafood products, why are all the lines pointing downward?

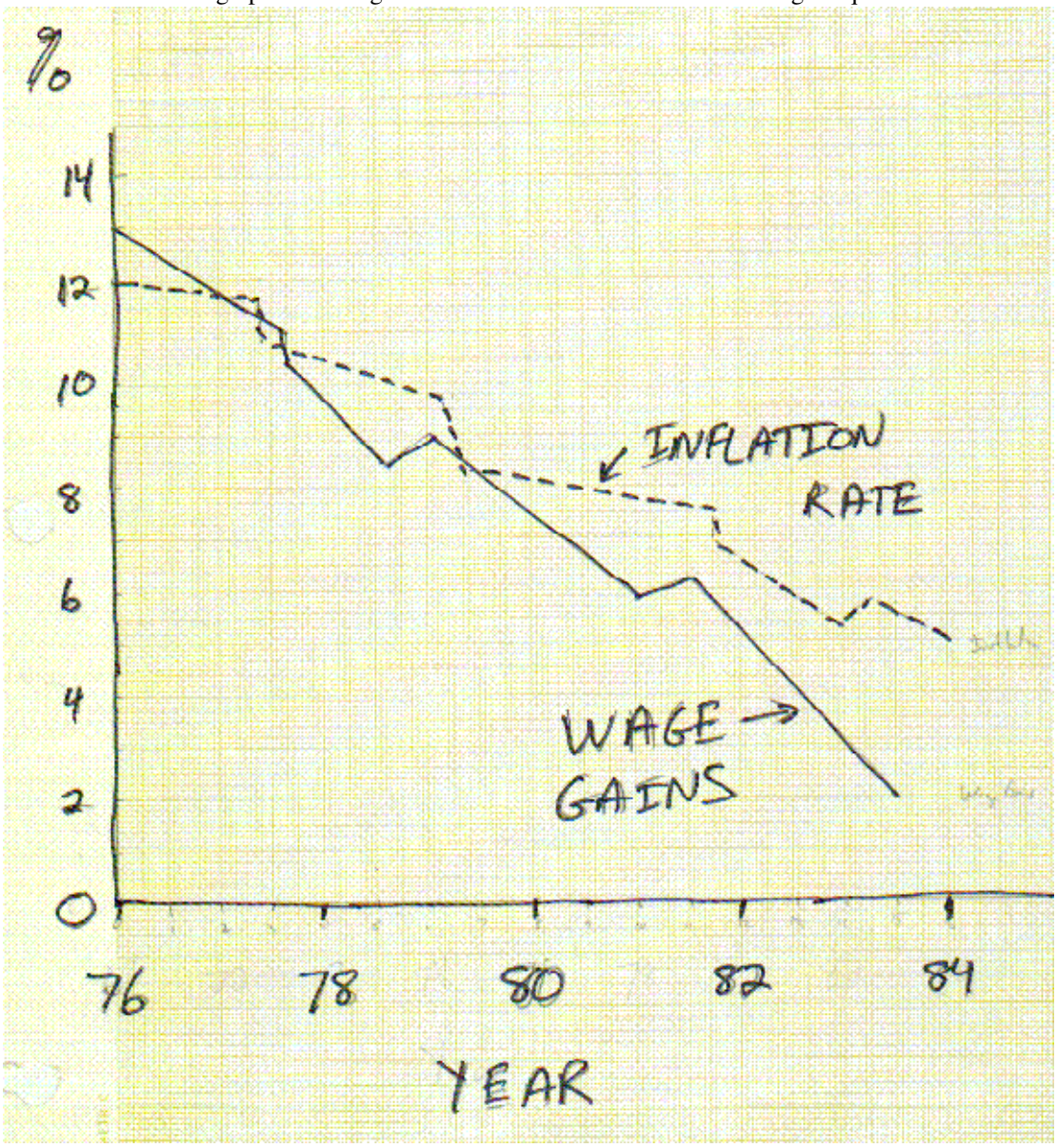
4.7 Wages and inflation



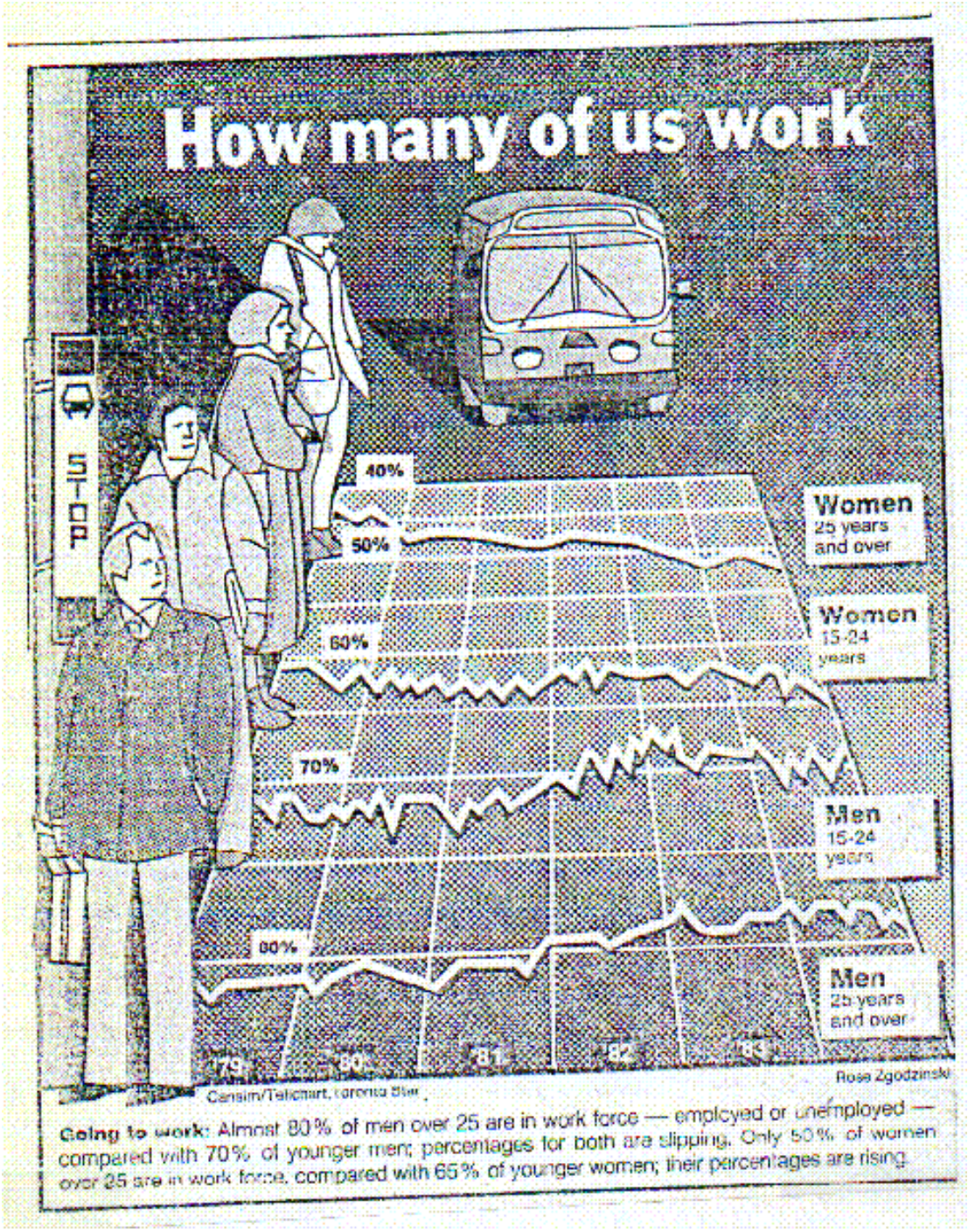
There are a number of flaws in this graph:

- The graphs are labelled incorrectly - it is wage gains that are falling not wages.
- Neither graph has any units on the axes.
- Because the wage gain graph is narrower than the inflation graph, the line will be steeper even if the two are falling at the same rate.
- The graphs are displaced from each other making it difficult to compare the slopes of the lines.
- This is a nice picture of the province of Manitoba, but does it need to take up the majority of the graph?

Here is a revised graph correcting some of the flaws. Notice how the messge is quite different.



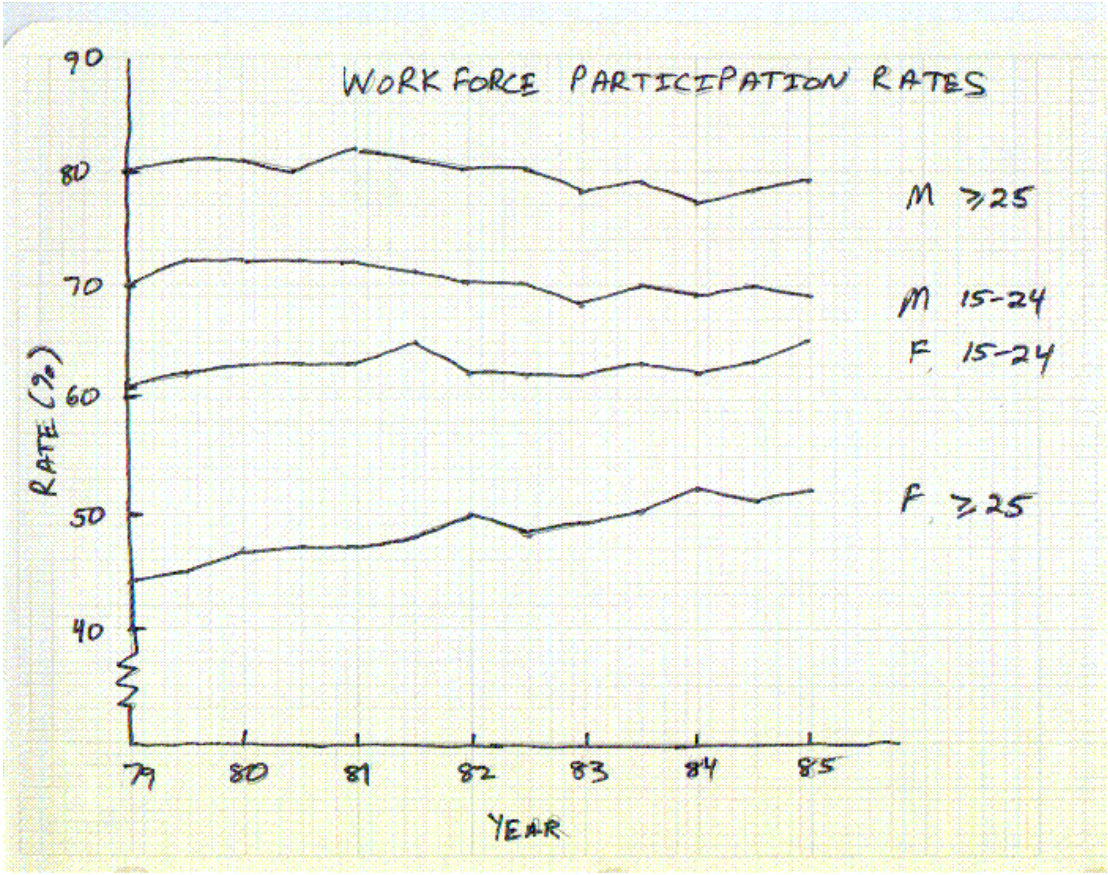
4.8 Workforce participation rates



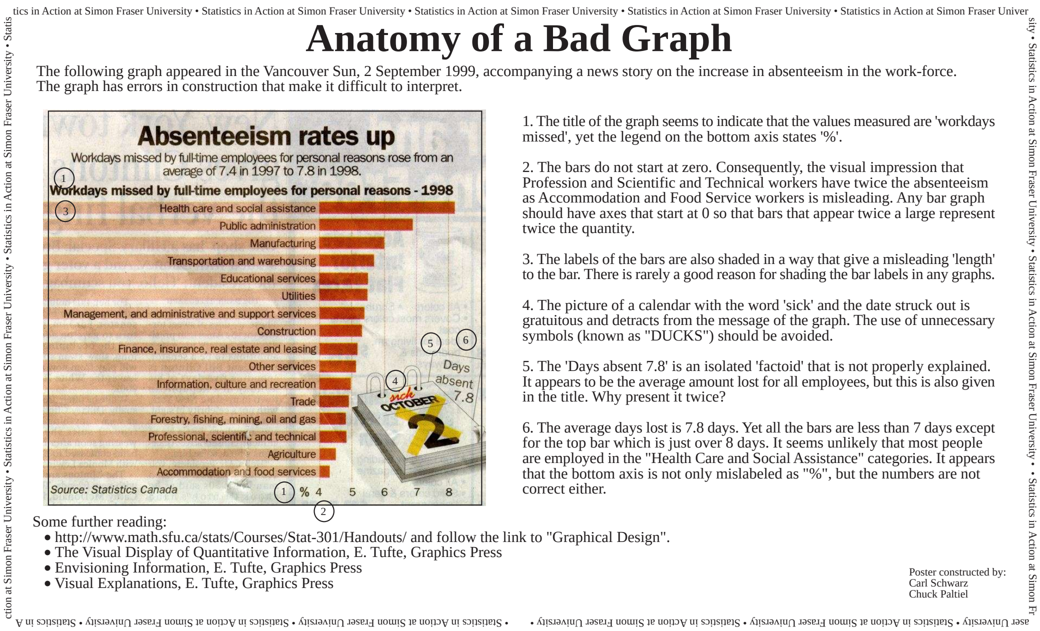
- It is not clear from the horizontal axis where 1980 starts and ends.
- The 3-D tilting makes the back lines look steeper even if they have the same slope.
- Do you think that workforce participation rates have been falling for women? [Hint - look at the scale.]

- It is nice picture of a bus and a bus-stop. Are they relevant?
- Too many ducks.

Here is a revised graph correcting some of the flaws:



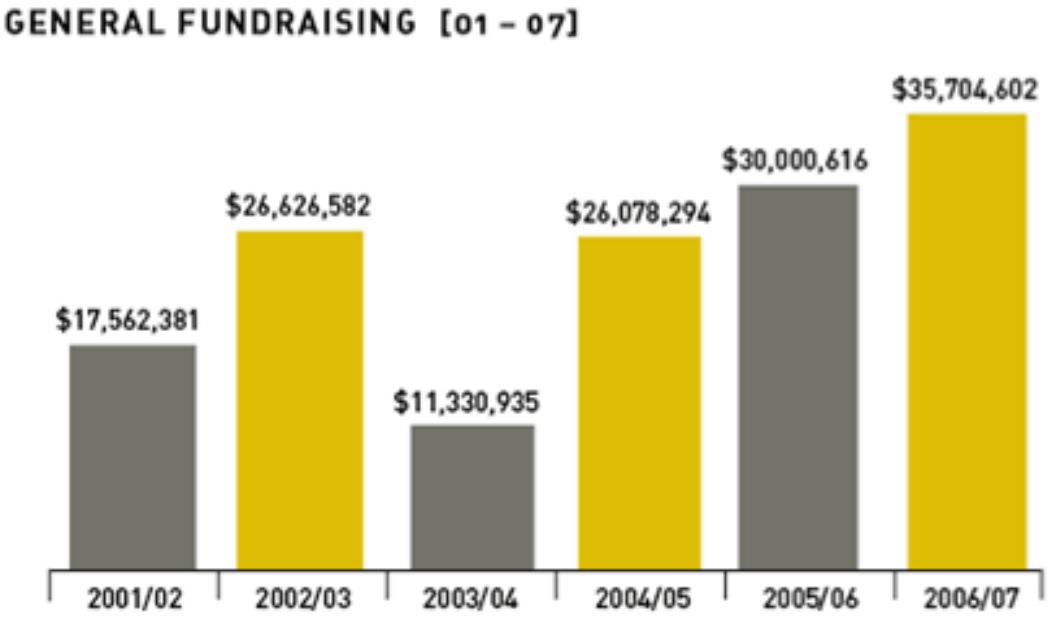
4.9 Absenteeism Rates



The fullposter is available at: `http://www.stat.sfu.ca/~cschwarz/posters/1999/absenteeism.pdf` appeared in the Vancouver Sun on 2 Sept 1999. Can you construct a proper graph that adhears to the principle of good graphical design?

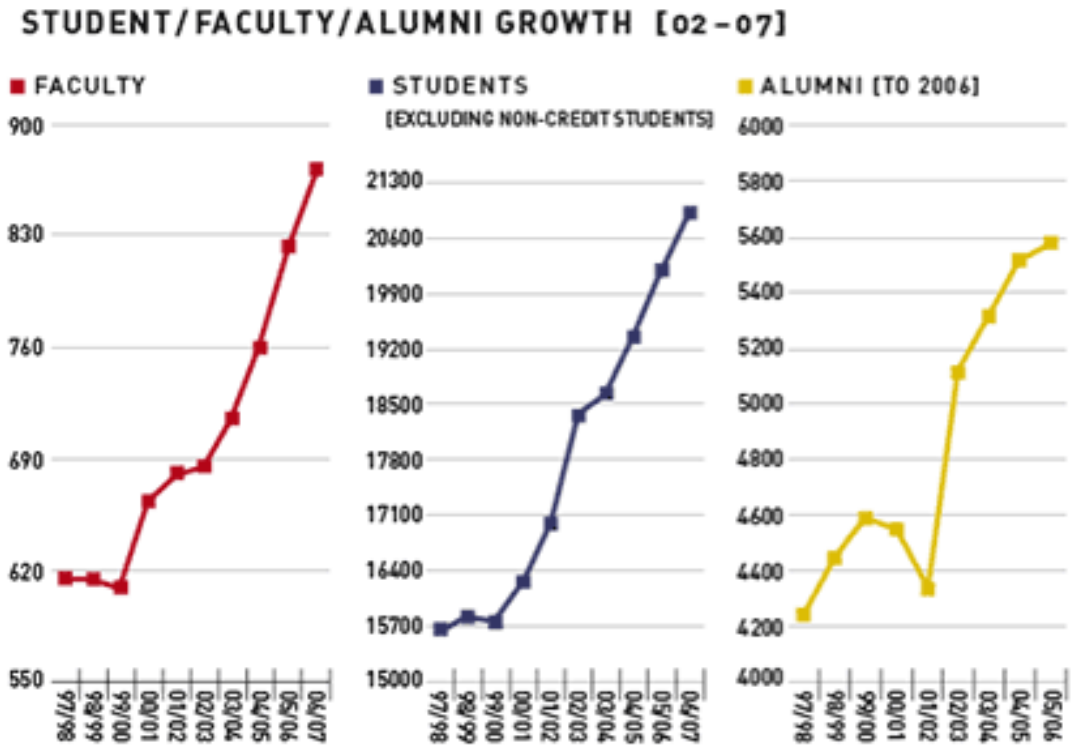
4.10 SFU 2006 Report from President - I

The following graphs were taken from my home institution's 2006 annual report to the public about Simon Fraser University and is available at: `http://www.sfu.ca/report2006/number.html`. It looks to me as if the designers need a refresher course in good graphical design (sigh ...)!



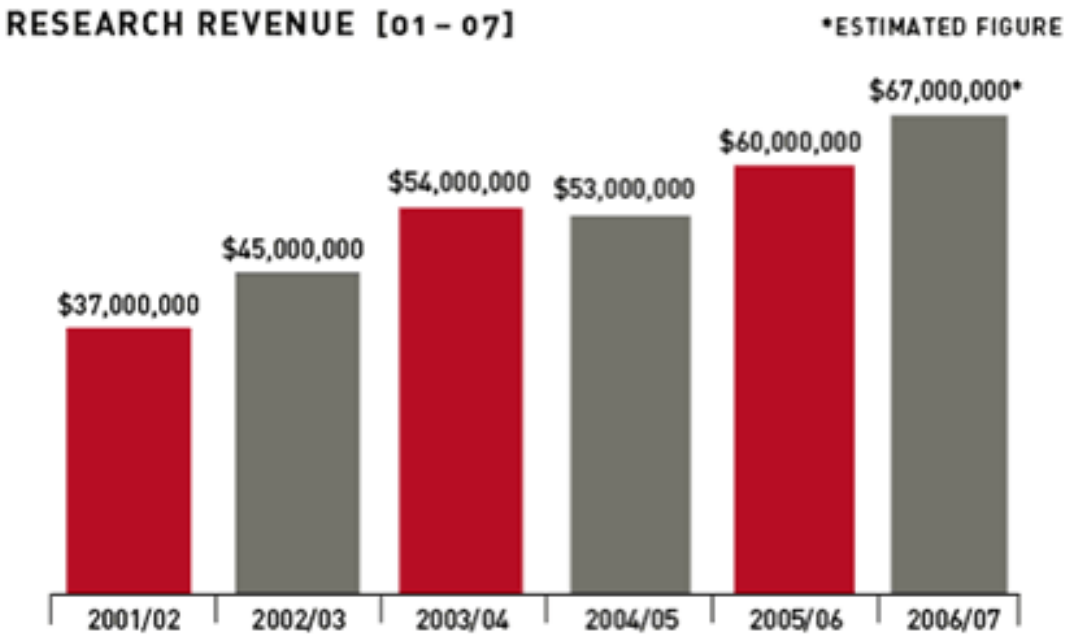
- Dollar amounts not adjusted for inflation.
- No vertical axis to measure heights of bars. Consequently, designers were forced to put actual dollar amounts on top of bars.
- Too many significant figures. Chart should be in millions of dollars and values reported to the nearest million dollars (after adjusting for inflation).
- Gratuitous use of color. What does the grey and yellow show?
- A line graphs showing the trend (of inflation adjusted values) may be a better choice.

4.11 SFU 2006 Report from President - II



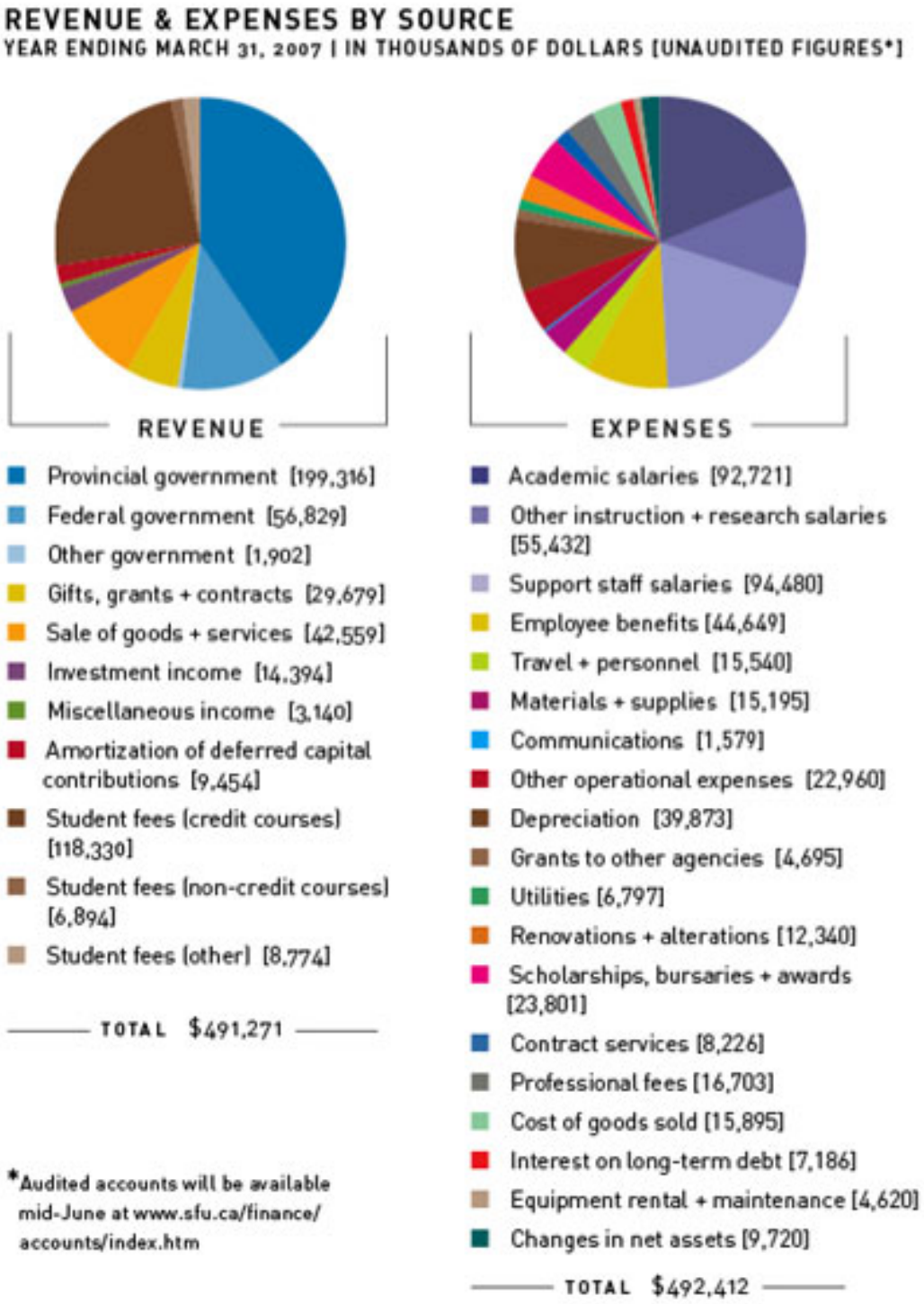
- Zero point on left axis hidden. The trend looks very steep, but only because the graphs starts very large.
- Bottom scales are different. The left two graphs show growth from 1997/98 to 2006/07 but the right most graphs goes from 1997/98 to 2005/06.
- Middle graph's vertical scale should be in thousands of students.
- Bad titling on the right graph. The graph shows the number of NEW alumni (i.e the number that graduate) rather than the total alumni of the university.
- It would be a more interesting graph to superimpose the three graphs to show relative growth in the three components.

4.12 SFU 2006 Report from President - III



- Dollar amounts not adjusted for inflation.
- No vertical axis to measure heights of bars. Consequently, designers were forced to put actual dollar amounts on top of bars.
- Too many significant figures. Values are properly rounded to the nearest million dollars, but all the extra zeroes are reported.
- Gratuitous use of color. What information is conveyed by the use of red and grey?
- A line graphs showing the trend (of inflation adjusted values) may be a better choice.

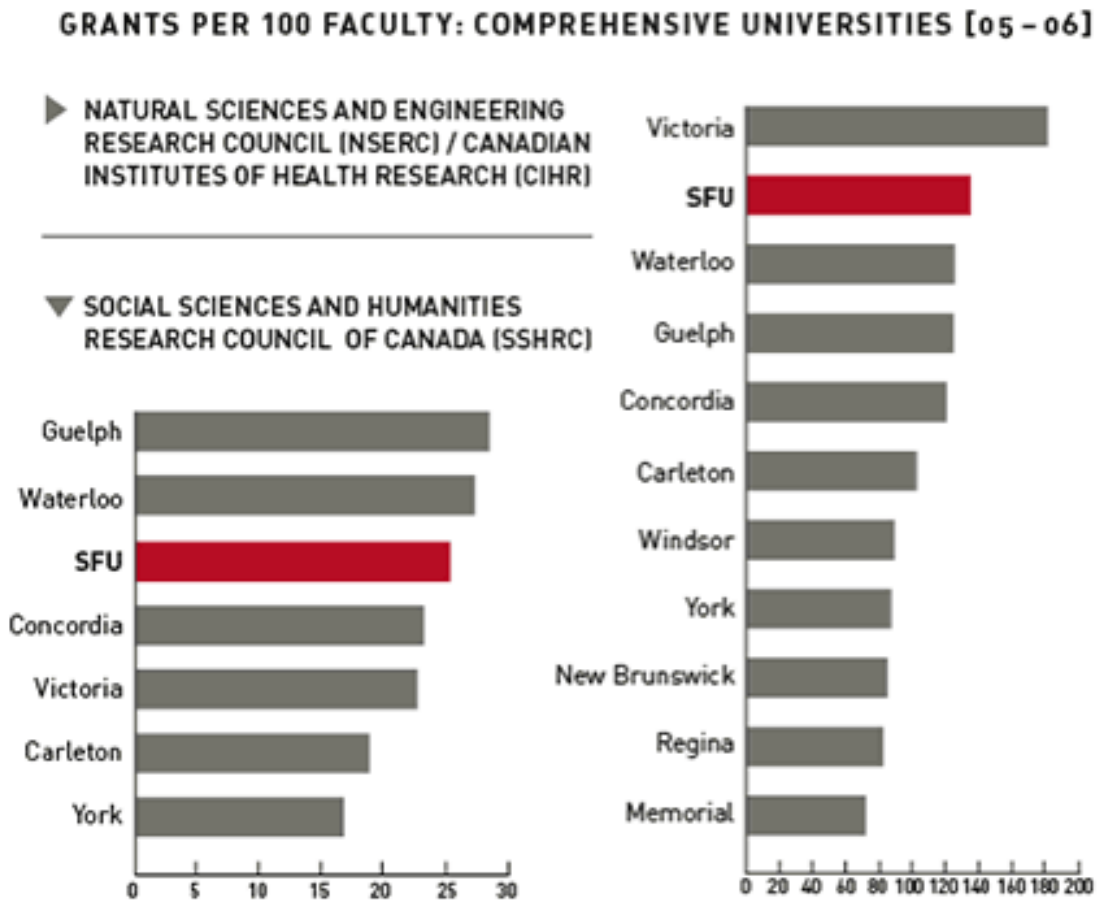
4.13 SFU 2006 Report from President - IV



- NO PIE CHARTS! Use a segmented bar chart instead.
- Too many pie segments. No one can read the smallest segment.

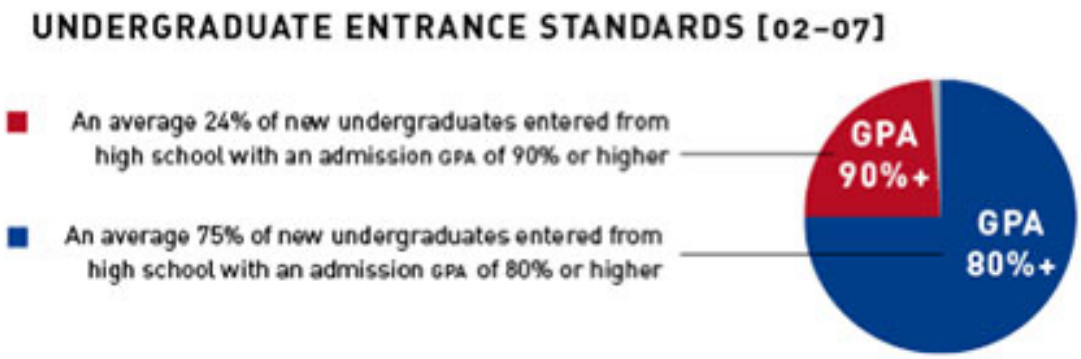
- Too many significant figures. The values are in thousands of dollars but still report 4+ significant figures. Values should be in millions of dollars.
- Think of what is being presented. For example, the right pie shows salaries broken by 3 groups, but doesn't break out benefits separately.

4.14 SFU 2006 Report from President - V



- Different scales on two graphs. The right graph is grants per 100 faculty members. The left graph is absolute numbers of grants. Presumably for the graph on the left, larger universities have larger numbers of grants?
- The graph could be improved by drawing vertical reference lines (in light grey screen) to make it easier to read the value on the bars.
- Reduce the white space between the bars.
- Here color to highlight SFU is appropriate.

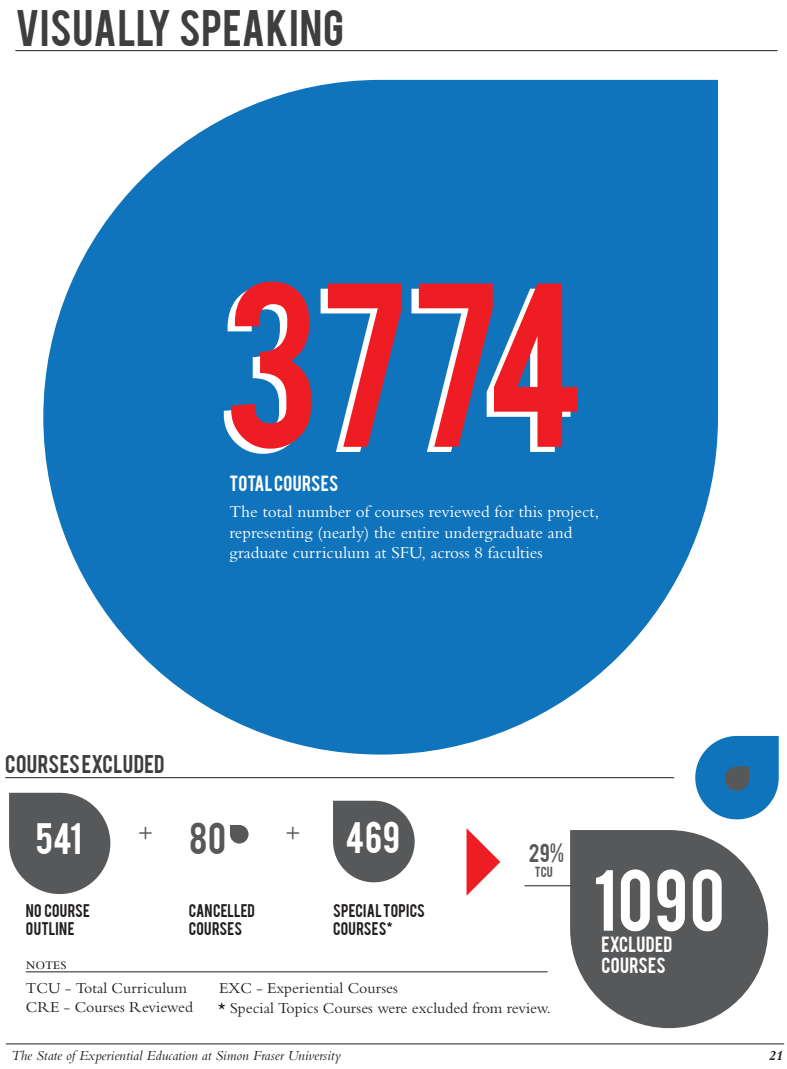
4.15 SFU 2006 Report from President - VI



- NO PIE CHARTS.
- The graph shows that 75% of students had averages of 80+. This figure presumably includes students who got 90% or higher which has a separate pie. This is double counting!
- What does it mean that "an average of 75% of new undergraduate...". Presumably, the designers totaled the number of students over the five years in the two categories and then simply found the percentage. There is no need to "average". For example, suppose that in year 1, 750 of 1000 new students had averages of 80+; and in year 2, 770 of 1100 new students had averages of 80+. Then over the two years, $750 + 770 = 1520$ students out of $1000 + 1100 = 2100$ had averages of 80+. This work out to $1520/2100 = 72\%$ of new students.

4.16 Report on Experiential Learning at SFU - I

This was taken from the *Report on course-based experiential education across all SFU Faculties* published in 2012 and available at: `https://www.sfu.ca/content/dam/sfu/vpacademic/files/vp_academic_docs/pdfs/ExpEduc_June2012.pdf`.



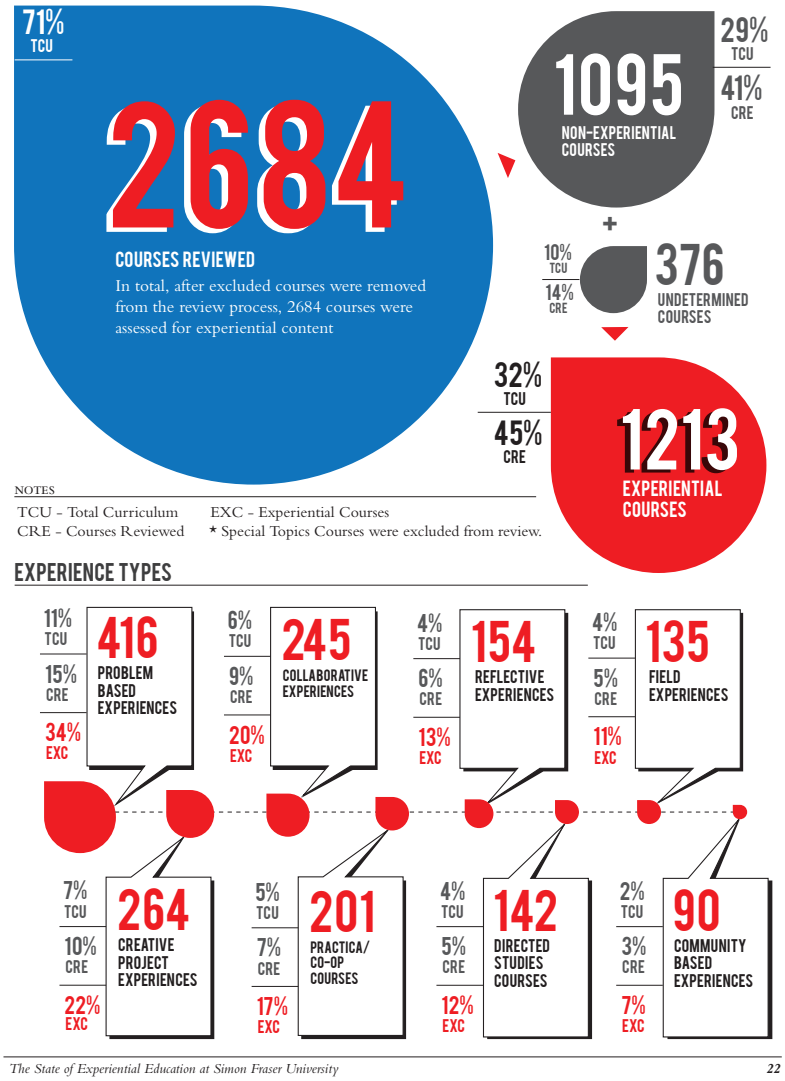
- Poor choice of graphic - a tear drop and the tear drop point in different directions on the top and bottom.
- Extraneous object - what does the tear drop on the line under Courses Excluded on the right side of the page mean?
- Extraneous use of color and three dimensions. Why is the 3774 looking three dimensional? Why is this number in red, but the other numbers in white.
- The scale of the teardrops is wrong. Compare the teardrops on the bottom line corresponding to 541 courses with no course outine to the 1090 excluded courses. The latter is about twice as large,

but the tear drop appears to be $4\times$ larger. People naturally compare areas rather than horizontal or vertical dimensions.

- Poor data to ink ratio. The authors took a whole page to present 5 numbers. Surely a table would be ore appropriate or a segmented bar chart?

4.17 Report on Experiential Learning at SFU - II

This was taken from the *Report on course-based experiential education across all SFU Faculties* published in 2012 and available at: `https://www.sfu.ca/content/dam/sfu/vpacademic/files/vp_academic_docs/pdfs/ExpEduc_June2012.pdf`.

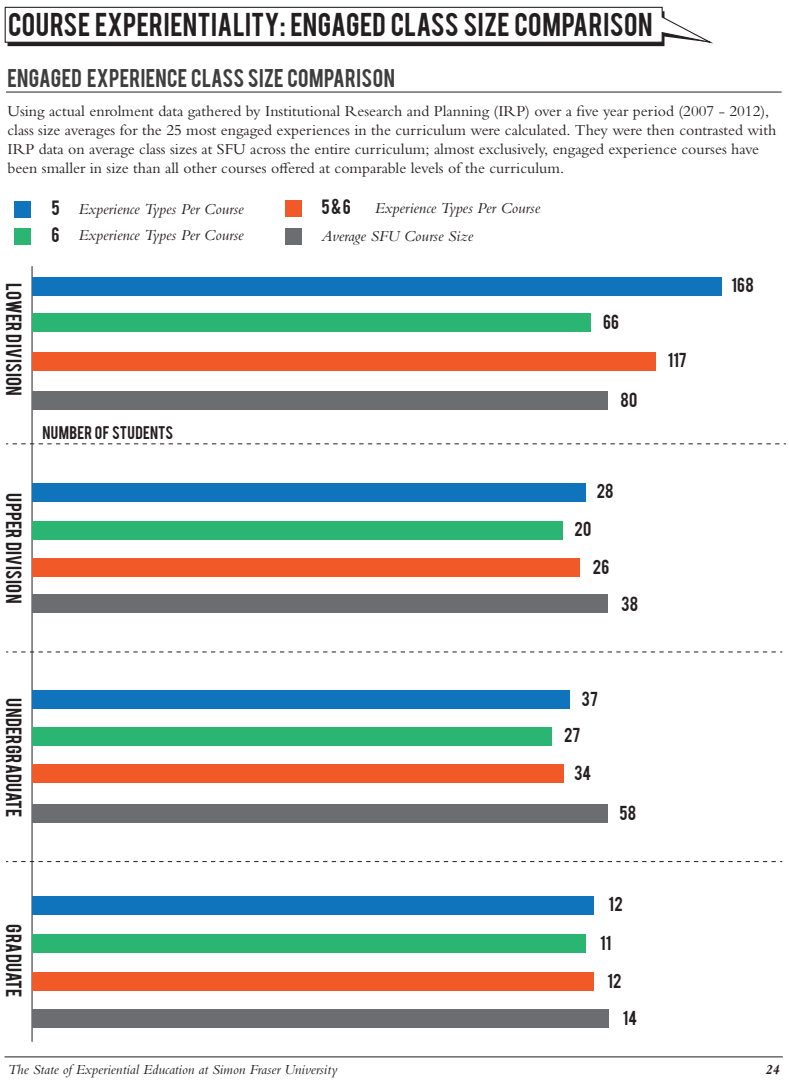


- Poor choice of graphic - a tear drop and the tear drop point in different directions on the top and bottom.
- Extraneous use of color and three dimensions. Why is the 2684 drawn three dimensional? Why is this number in red with a white drop shaddow, but other numbers or white with black drow shaddow or white with no shaddow.
- The scale of the teardrops is wrong. Compare the teardrops representing 1213 courses with that representing 2684 courses. It looks 1/4 of the size but represents 1/2 of the value. People naturally compare areas rather than horizontal or vertical dimensions.

- The number on the bottom half of the graph don't add to 1213. The is some double counting (as expected some courses can have more than one experiential type), but the grpahic implies that they should add to 1213.

4.18 Report on Experiential Learning at SFU - III

This was also taken from the *Report on course-based experiential education across all SFU Faculties* published in 2012 and available at: `https://www.sfu.ca/content/dam/sfu/vpacademic/files/vp_academic_docs/pdfs/ExpEduc_June2012.pdf`.



- Gratuitous use of colore. What information does the three colore represent?
- Bars are not proportion to class size. For example, in the first set of bars, the bar for 66 should be less than 1/2 of the length of bar for 168.
- Scale changes between set of bard. Notice that the first bar in the upper division set (representing 28 students) is about the same length as the bar in the lower division set representing 80 students.
- Poor data to ink ratio. A whole page is used to represent 16 numbers.