Visual Representations of Data:
Review and Recommendations

Alison Preston, Laura Stapleton, & Dan McNeish
University of Maryland, College Park

Outline

- Single graphic design
  - Views from stakeholders
  - Types of graphs
  - Table or graph?
  - Using attributes
- Dashboard design
- Recommendations for the Center
- References

MLDS Center
Maryland Longitudinal Data System
Better Data • Informed Choices • Improved Results

Single Graphic Design

Views from Stakeholders

Views from Stakeholders

- Alverson & Yamamoto (2013)
  - "What do stakeholders want to see?"
  - Teacher, administrator, and parent focus groups (29 participants)
  - Four stimulus graphs

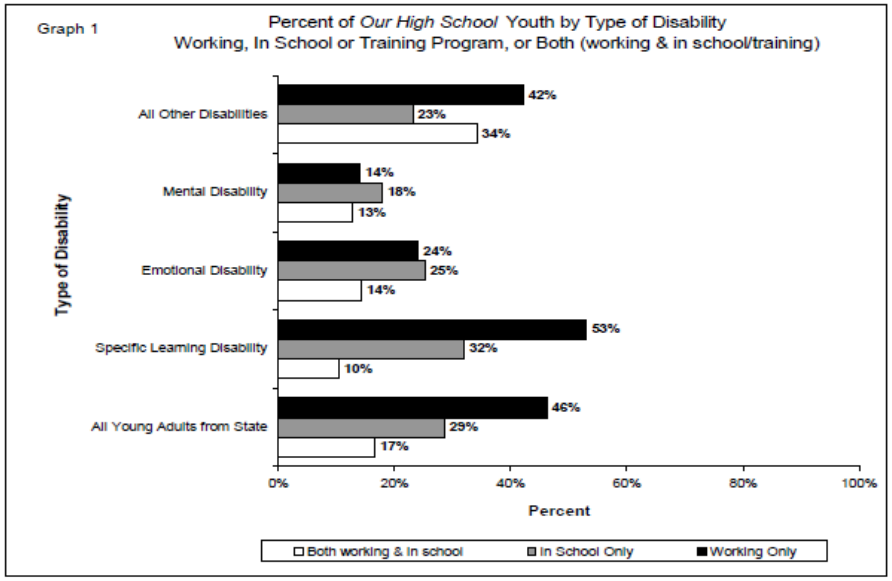


Figure 1. Horizontal Grouped Bars

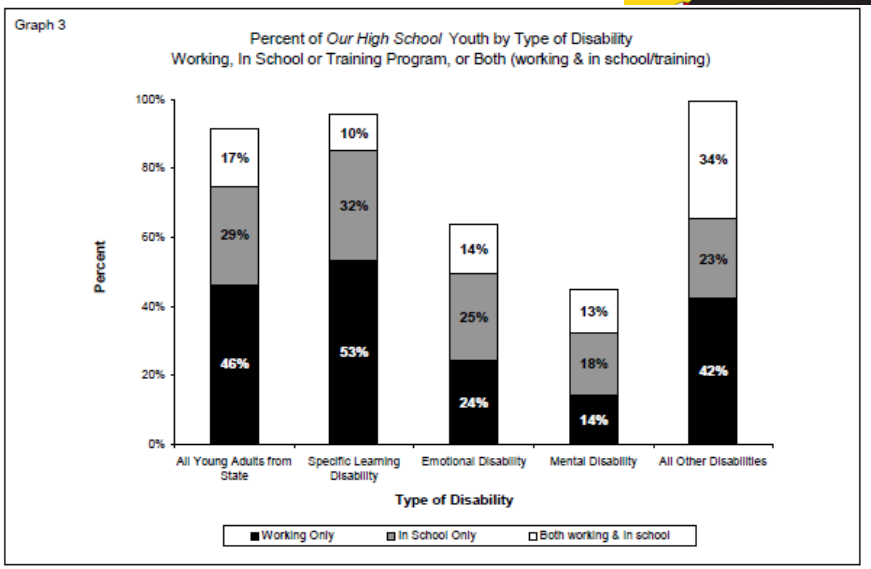


Figure 3. Vertical Stacked Columns

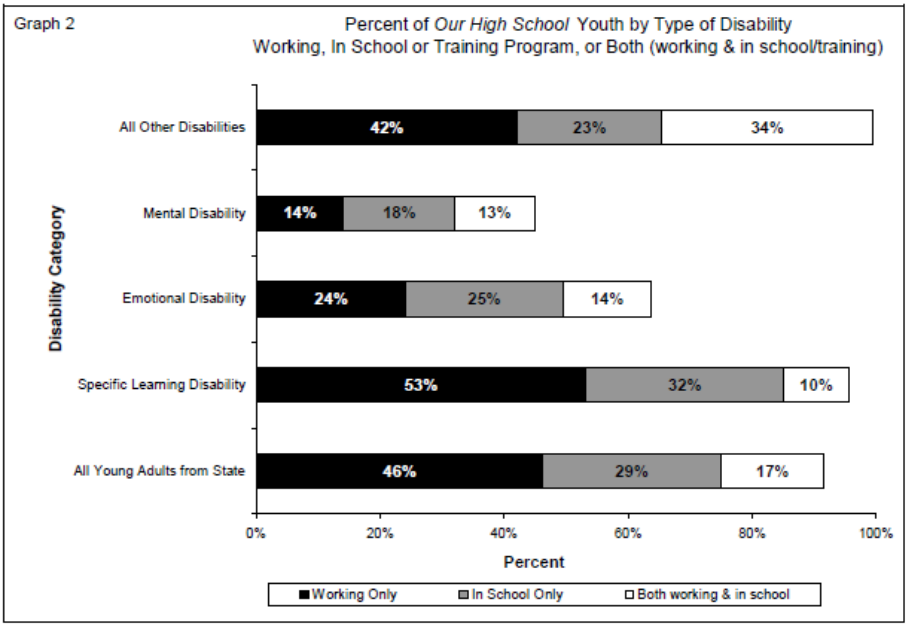


Figure 2. Horizontal Stacked Bars

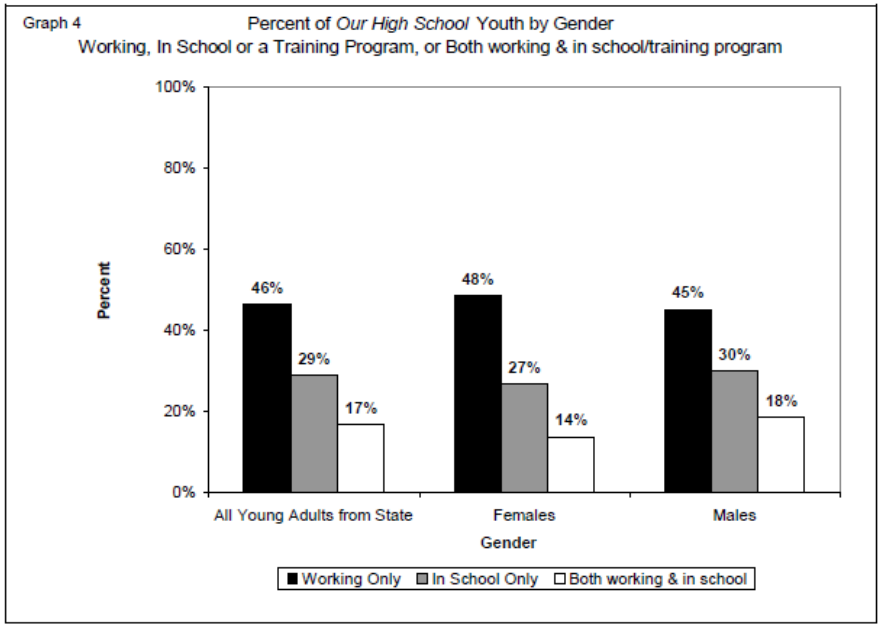


Figure 4. Vertical Grouped Columns

Favorite- Teachers, Administrators, and Parents

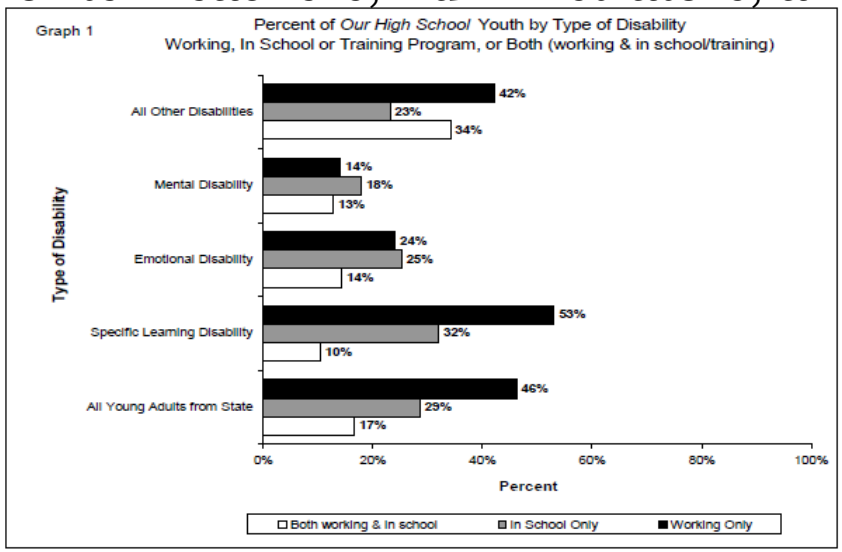


Figure 1. Horizontal Grouped Bars

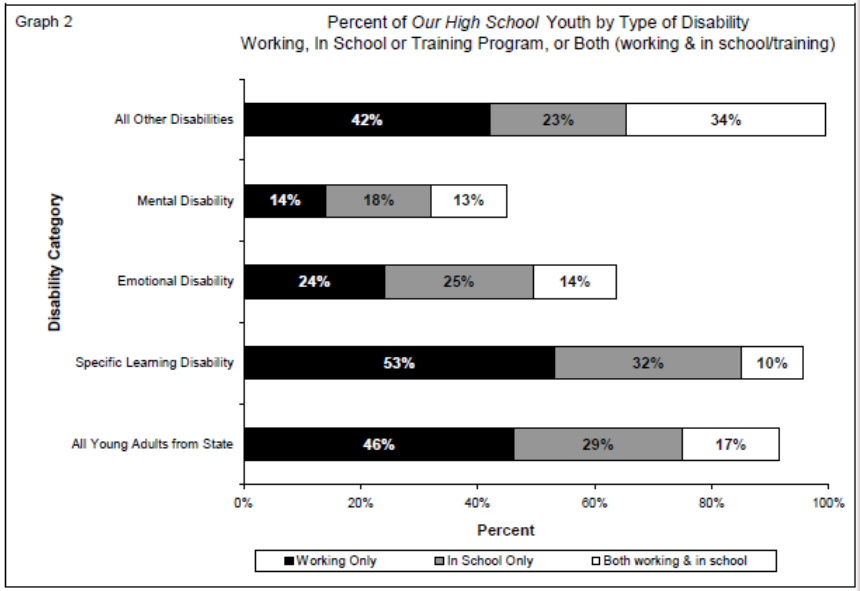


Figure 2. Horizontal Stacked Bars

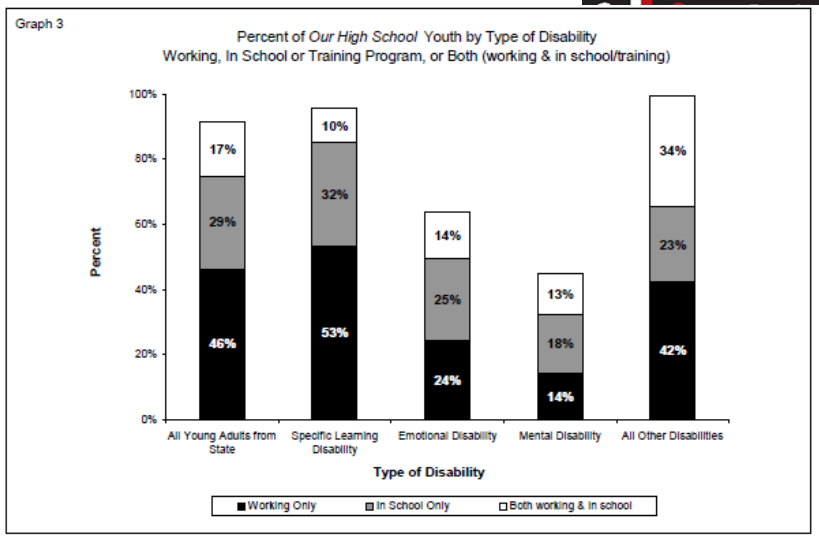


Figure 3. Vertical Stacked Columns

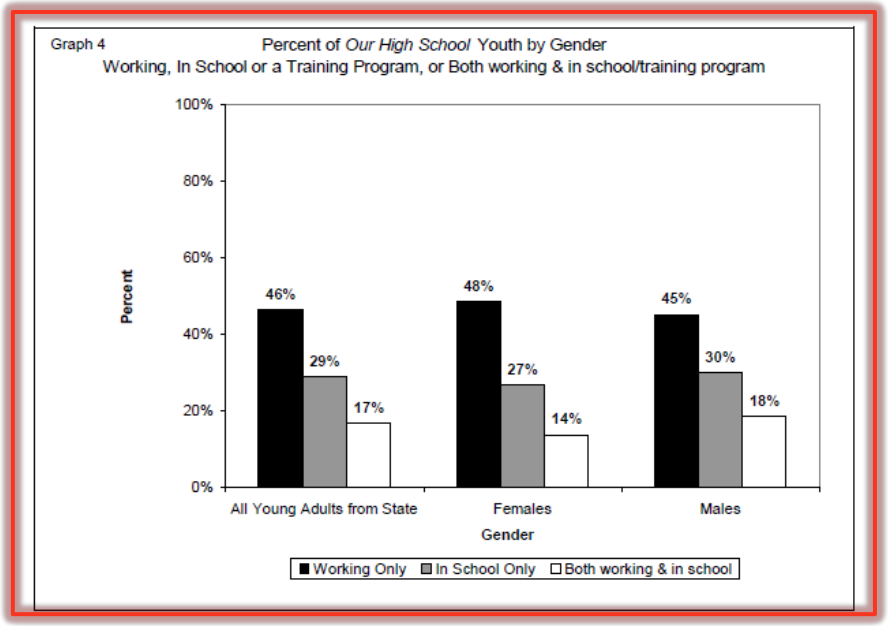


Figure 4. Vertical Grouped Columns

Why Vertical Grouped Columns?

- Each group supported their decision with similar reasons
- Teachers:
  - Ease of comparisons
  - Comfort and familiarity
- Administrators
  - Ease, comfort, familiarity
  - Speed- quick to interpret
  - Habit
- Parents
  - Ease, comfort, familiarity
  - Speed- wouldn't bother if it couldn't be understood quickly

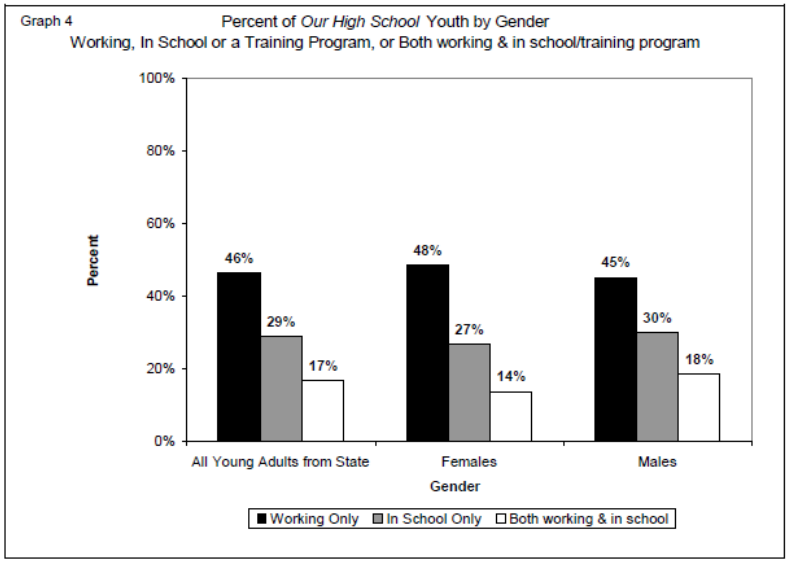


Figure 4. Vertical Grouped Columns

Least Favorites- Teachers, Administrators, and Parents

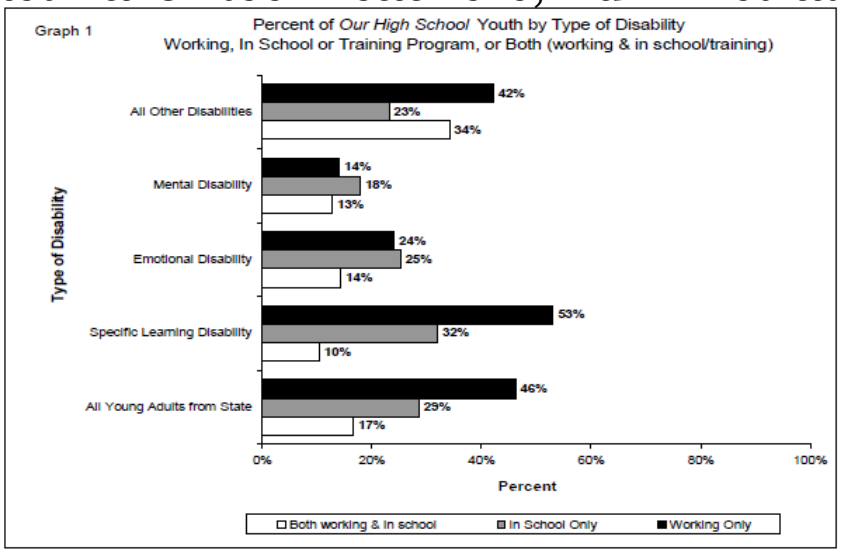


Figure 1. Horizontal Grouped Bars

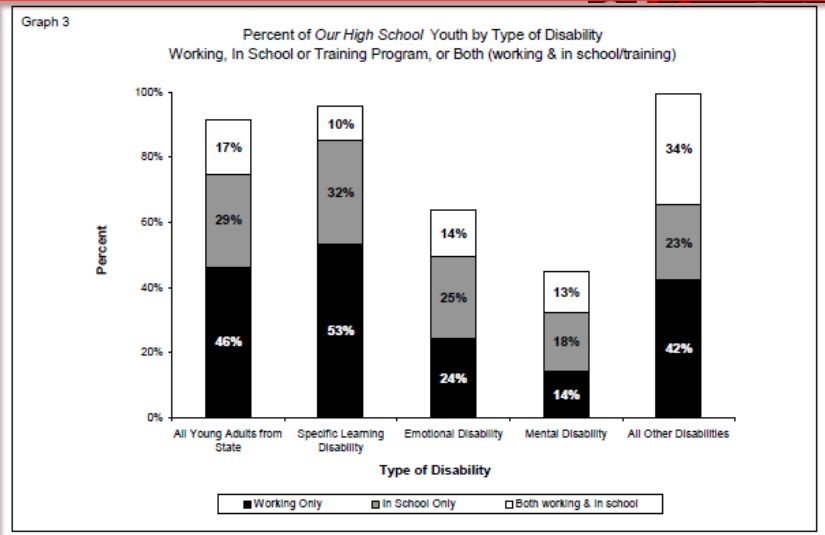


Figure 3. Vertical Stacked Columns

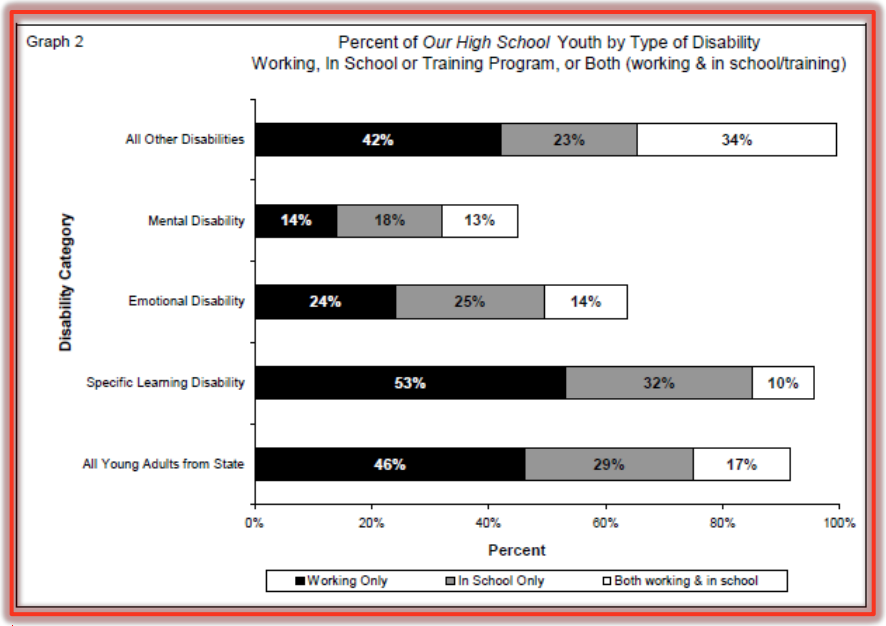


Figure 2. Horizontal Stacked Bars

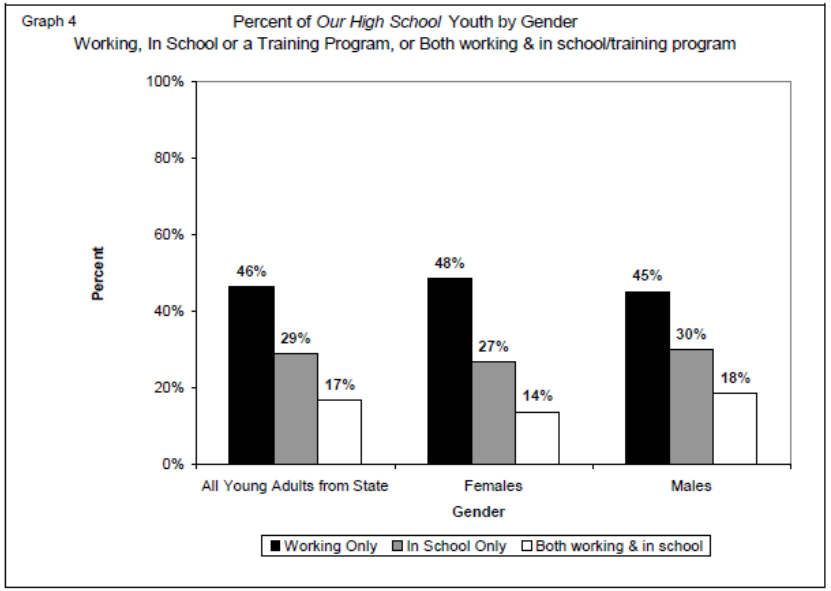


Figure 4. Vertical Grouped Columns

Why Dislike Stacked Graphs?

- Teachers:
  - Difficult to understand/make comparisons
  - What is the point? Total or segments?
- Administrators:
  - Only prefer stacked if the alternative is multiple grouped graphs over many pages
  - Lack of comfort/familiarity
  - Too much time to interpret
- Parents:
  - Lack of comfort/familiarity
  - Too much time to interpret
  - Difficult to understand

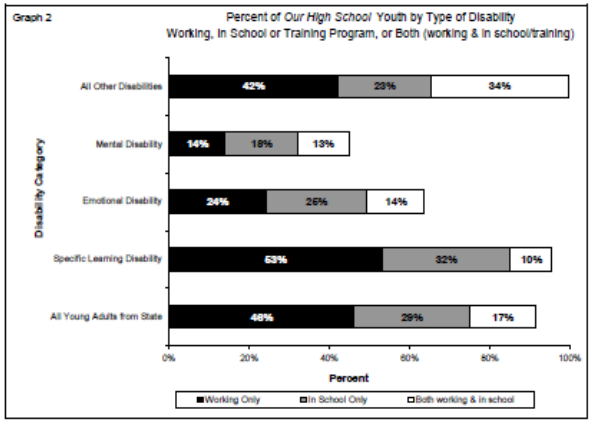


Figure 2. Horizontal Stacked Bars

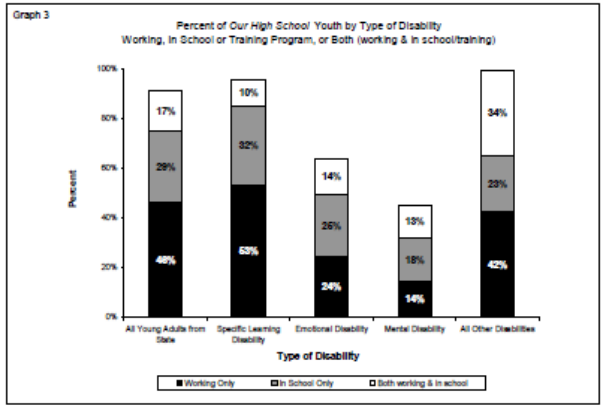


Figure 3. Vertical Stacked Columns

Views from Stakeholders

- Key point: The design of individual graphics contributes to the understanding/perception of the information by the consumer
- Keep in mind:
  - Accurate and efficient display of content
  - Ease of interpretation
  - Familiarity

Single Graphic Design

Types of Graphs

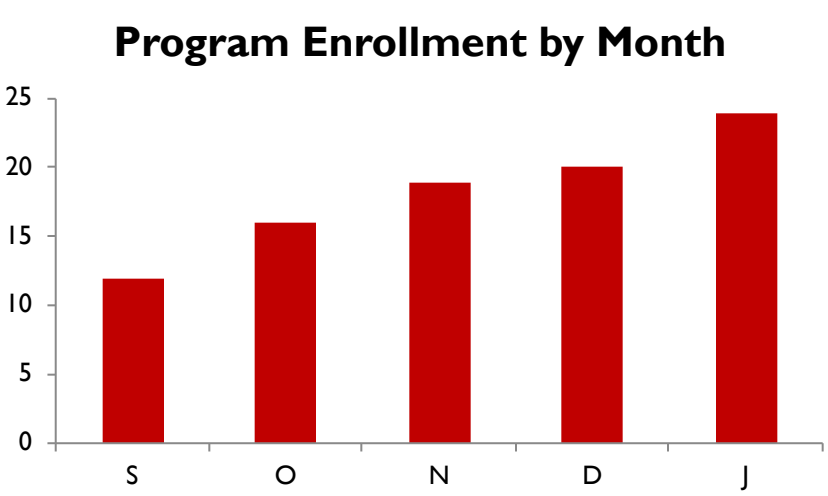
Types of graphs

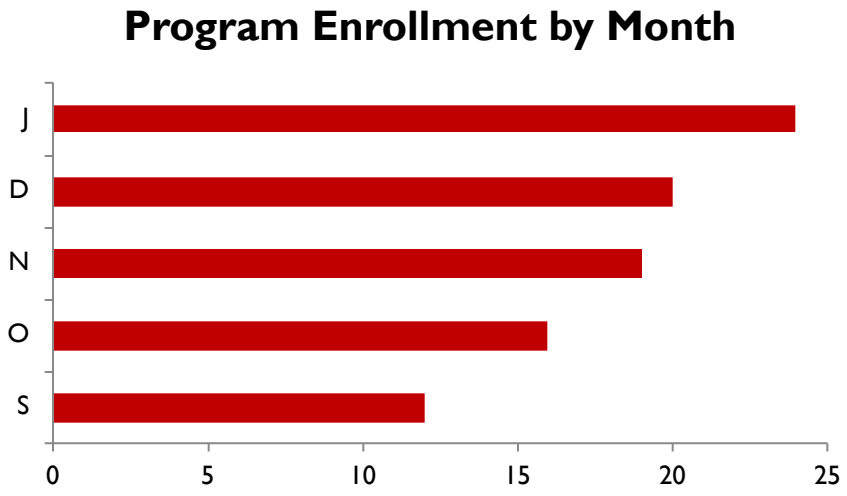
- Bar graph
- Grouped bars
- Stacked bars
- Histogram
- Scatterplot
- Line graph
- Pie Chart

- This list is not all inclusive, but contains the common formats most comfortable for many consumers

Bar graph

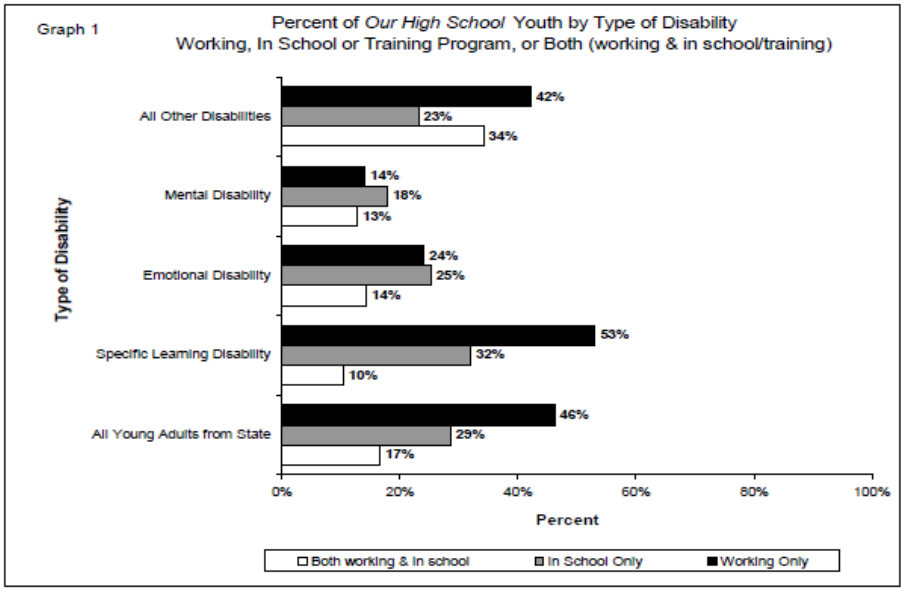
- Categorical data
- Horizontal or vertical
- Relatively easy to compare different groups

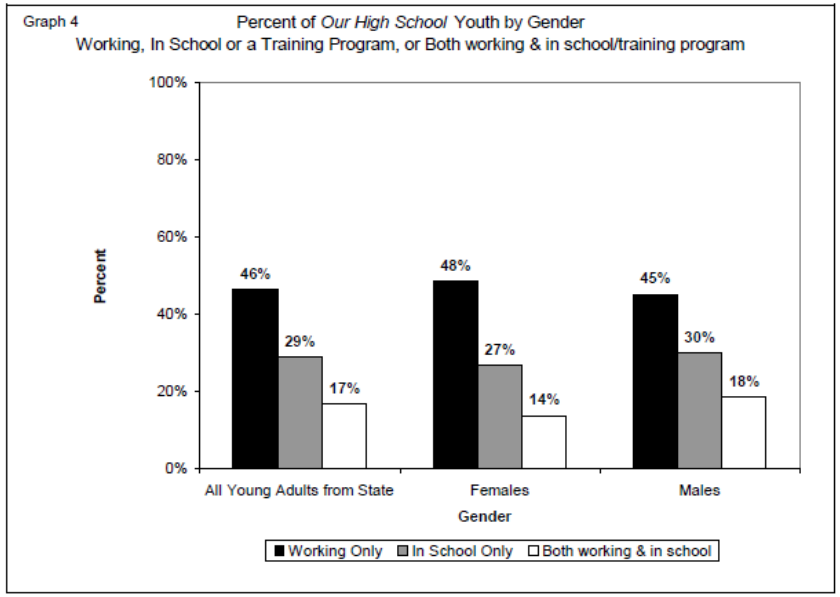




Grouped bar graph

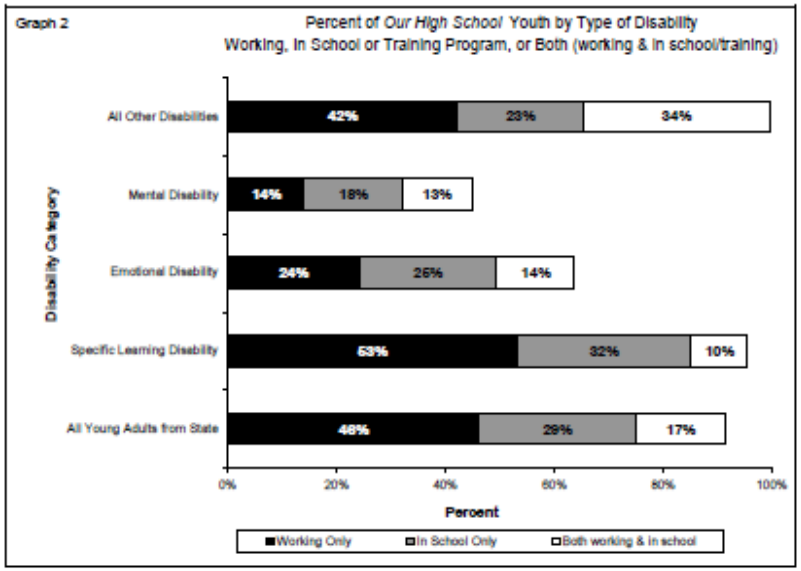
- Categorical data with main categories and sub-categories
- Can aid in comparisons within categories
- Comparisons across categories can be more difficult

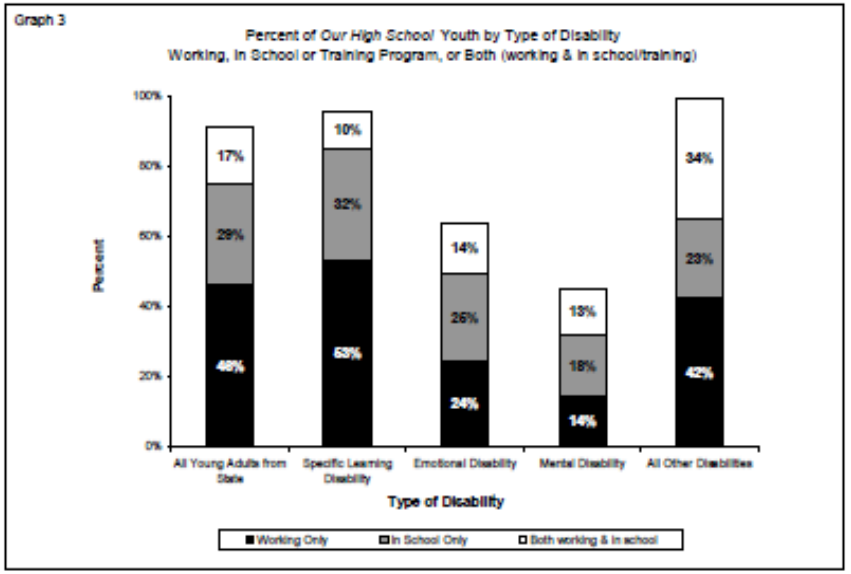




Stacked bar graph

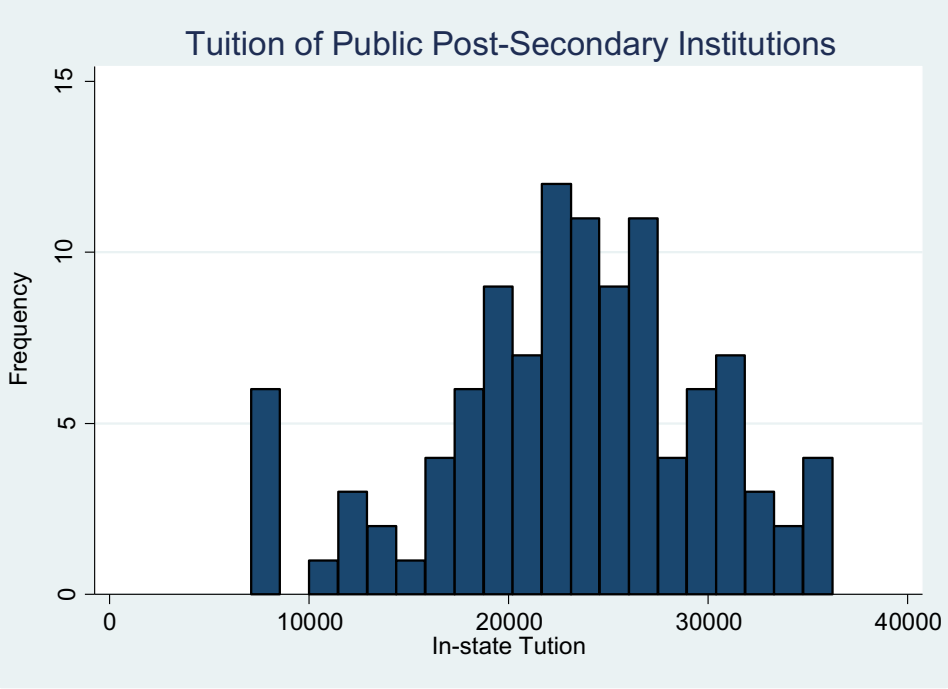
- Categorical data with main categories that contain stacked sub-groups
- Stacks show relative contribution with percentages or counts
- Can be difficult to compare sub-groups





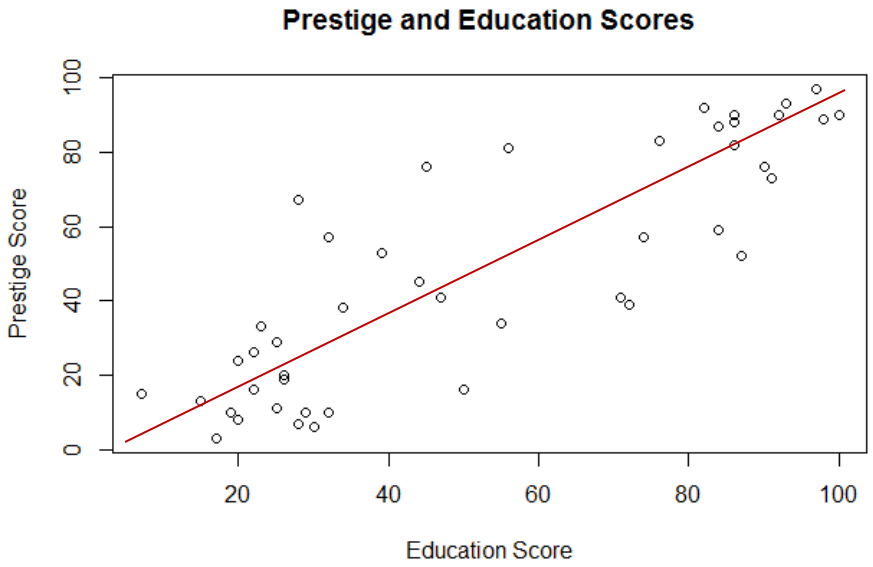
Histogram

- Continuous data
- Frequency or proportion of observations in "bins"
- Provides information about shape of data



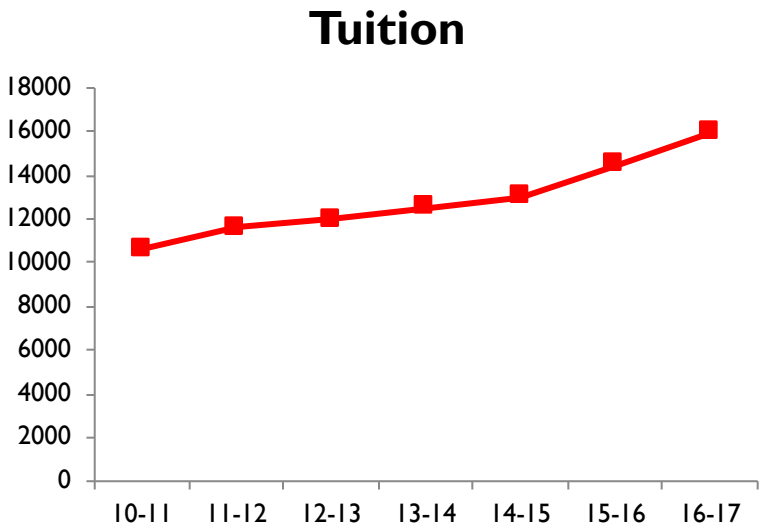
Scatterplot

- Displays relationship between two continuous variables
- May have points that share x- or y-values
- Trend line can be added to help visualize relationship
- Displays all observations (advantage or disadvantage?)



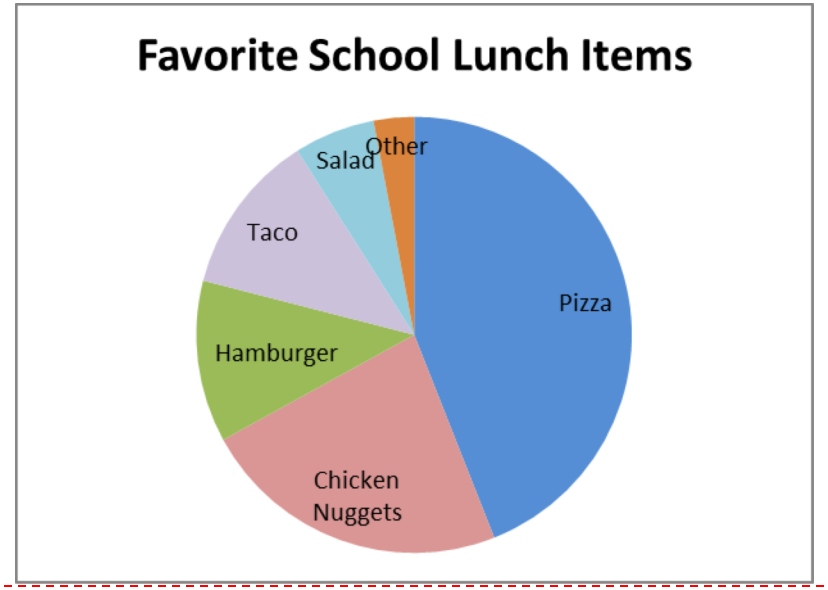
Line graph

- Points plotted to show a relationship between the variables and connected with line segments
- Only one y-value per x-value
- Often demonstrates trend over time



Pie chart

- Used to display proportion/percentages when all elements together add to 1 (100%)
- Clear perception of the whole picture (these are *all* the options and their relative proportion)
- Difficult to compare sections or across charts



Summary-Types of graphs

- Again, there are many more types, but these were some of the basic and most common types
- Consider type and purpose of data as well as ease and familiarity for interpretation when selecting a graph

Single Graphic Design

Table or Graph?

Do I Use a Table or a Graph?

- Use a table when…
  - Display will be used to look up individual values
  - Comparison of individual values
  - Precise values are required
  - Multiple units of measure
  - Detail and summary values included
- Use a graph when…
  - Message contained in the shape of the values (patterns, trends, exceptions…)
  - Display will be used to reveal relationships among whole sets of values

Do I Use a Table or a Graph?

- The traditional assumption is to use tables for small data sets and graphs for large ones
- More modern view is that patterns may be better seen with graphs.

Do I Use a Table or a Graph?

- Research question: What are the trends in physical fitness scores of middle school students by grade, gender, and sport team membership?

Student Performance on Physical Fitness Tests By Gender, Grade, and Team Membership				
	Grade 7		Grade 8	
Gender	Male	Female	Male	Female
No Team	79	64	60	72
Team	92	74	86	66

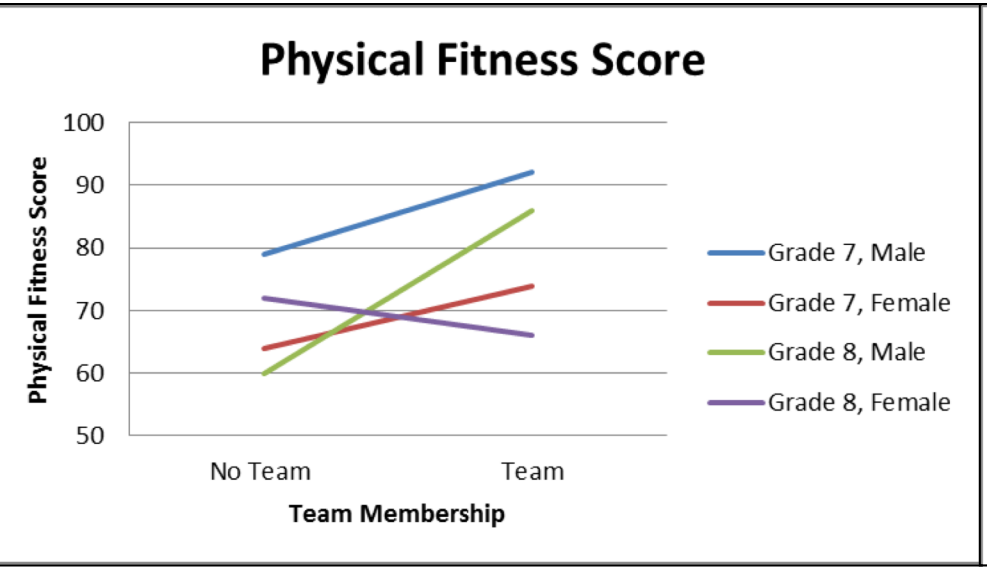
- Patterns can be tricky to spot even with a small set of numbers.

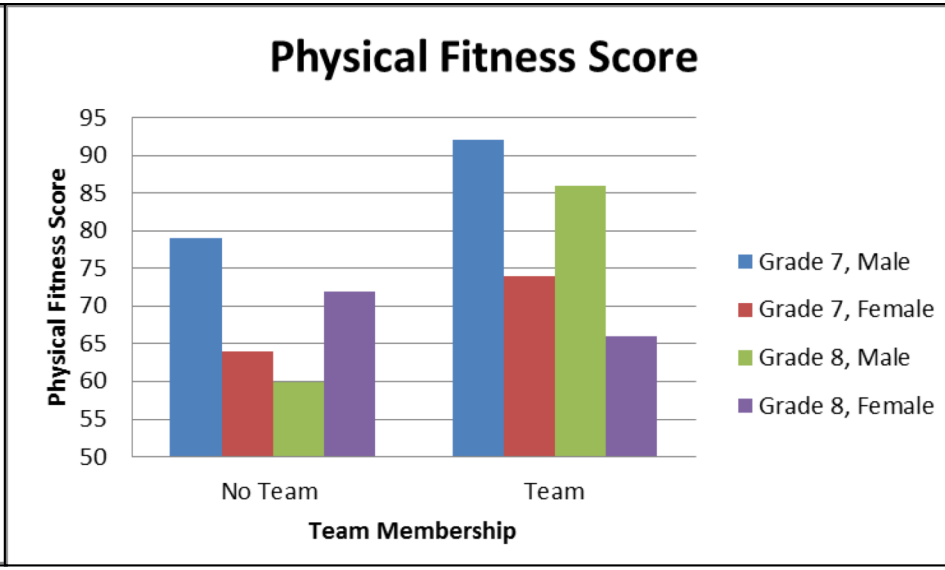
Do I Use a Table or a Graph?

- Which graphic best displays an inconsistent pattern?

Student Performance on Physical Fitness Tests By Gender, Grade, and Team Membership

	Grade 7		Grade 8	
Gender	Male	Female	Male	Female
No Team	79	64	60	72
Team	92	74	86	66





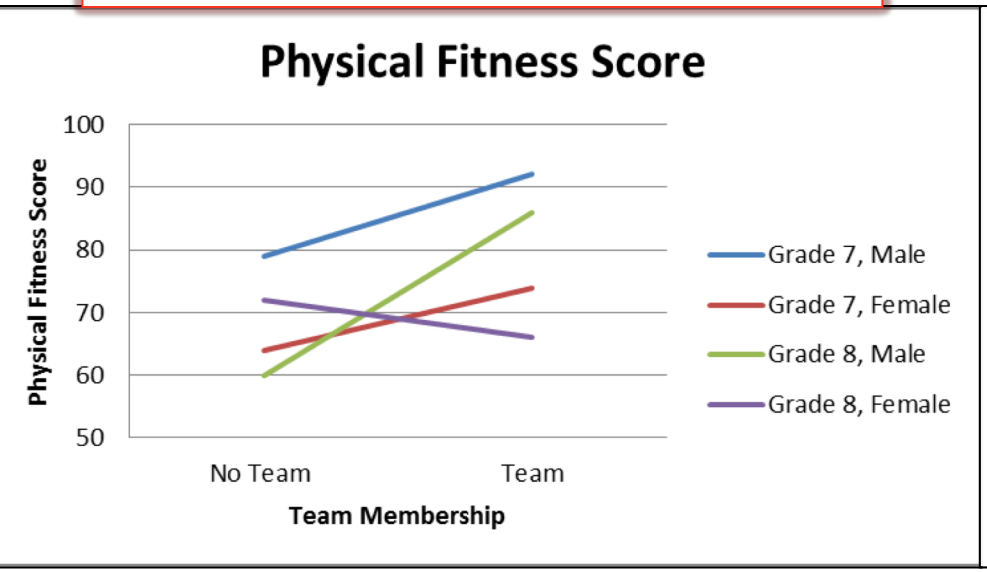
Do I Use a Table or a Graph?

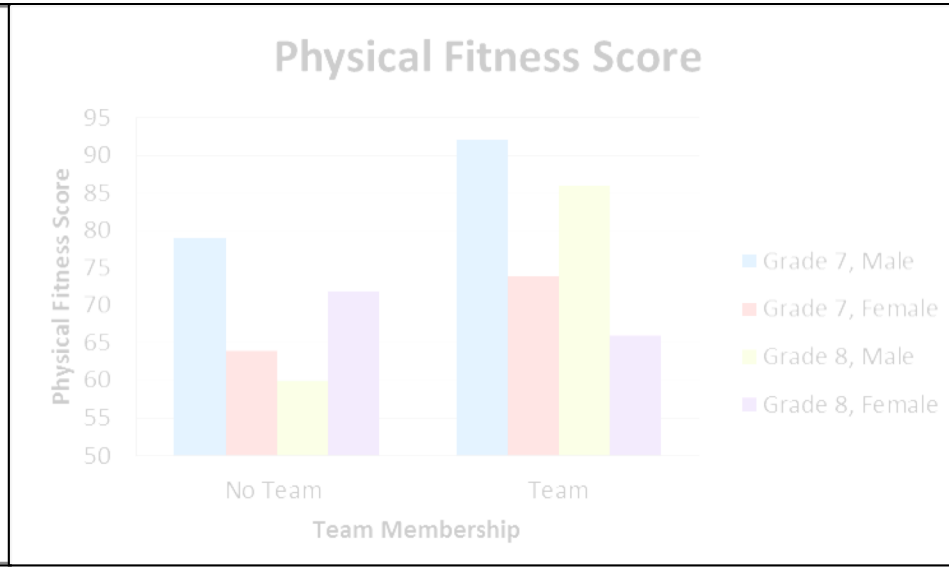
- Which visual best displays an inconsistent pattern?

Student Performance on Physical Fitness Tests By Gender, Grade, and Team Membership

	Grade 7		Grade 8	
Gender	Male	Female	Male	Female
	64	60	72	
	74	86	66	

Here I can quickly spot the one line with a negative slope. It is the best graphic for finding this trend.





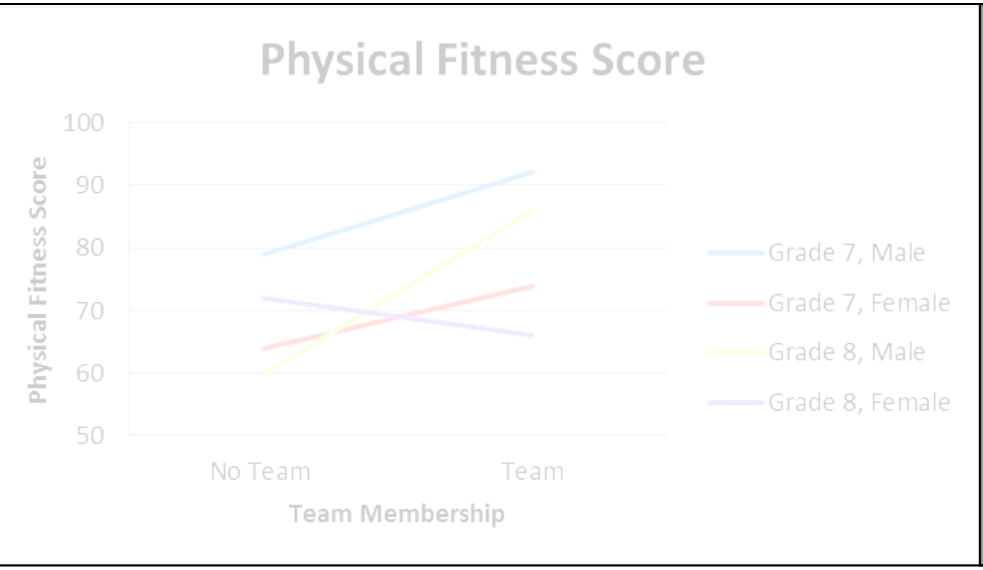
Do I Use a Table or a Graph?

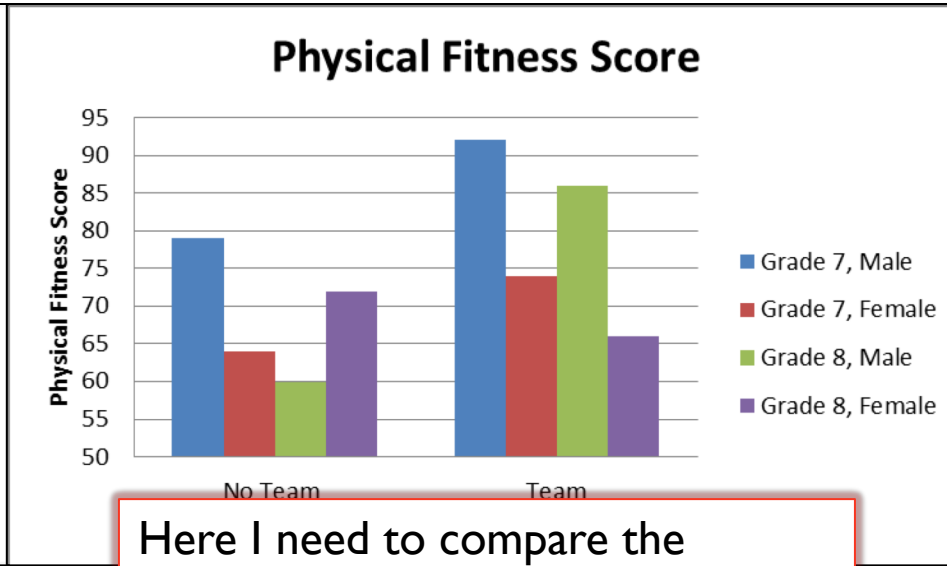
- Which visual best displays an inconsistent pattern?

Student Performance on Physical Fitness Tests By Gender, Grade, and Team Membership

	Grade 7		Gra	
Gender	Male	Female	Male	
No Team	79	64	60	72
Team	92	74	86	66

Here I need to locate and compare pairs of numbers to find the same trend





Here I need to compare the relative heights of each color bar to find the same trend

Single Graphic Design

Using Attributes

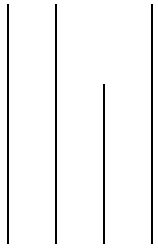
Using Attributes

- Various attributes of a graph or table can be manipulated to aid interpretation or highlight certain details, trends, or patterns

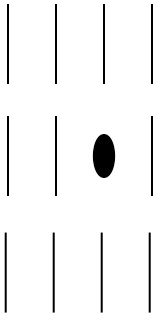
Category	Attribute
Form	Length
	Width
	Orientation
	Shape
	Size
	Enclosure
Color	Hue
	Intensity
Spatial Position	2-D position
	Scale

Form

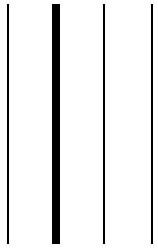
- Length



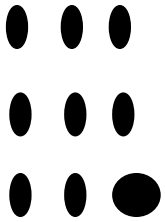
- Shape



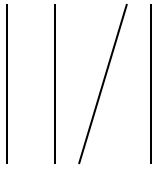
- Width



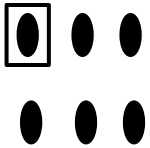
- Size



- Orientation



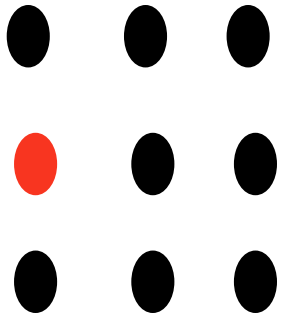
- Enclosure



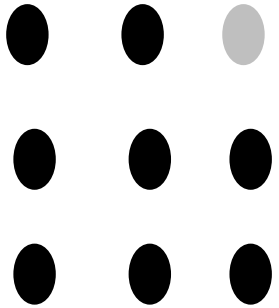
In all of these examples, one object stands out because of its form.

Color

- Hue



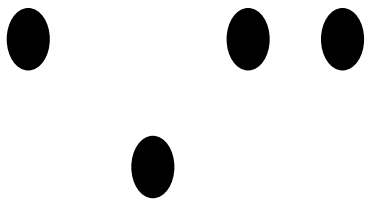
- Intensity



In these examples, one object stands out because of an aspect of its color.

Spatial Position

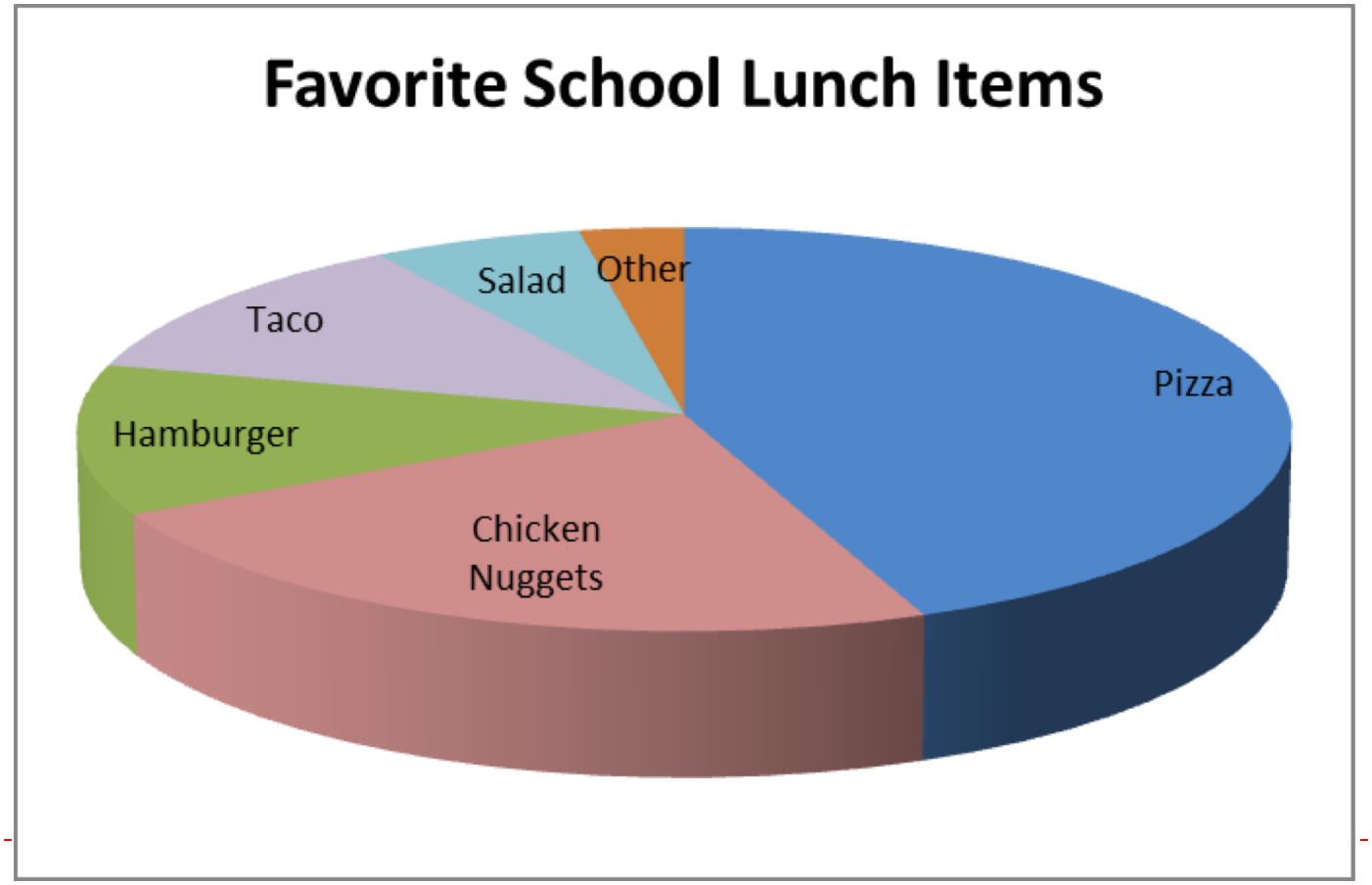
- 2-D position



In this example, one object stands out because of its position.

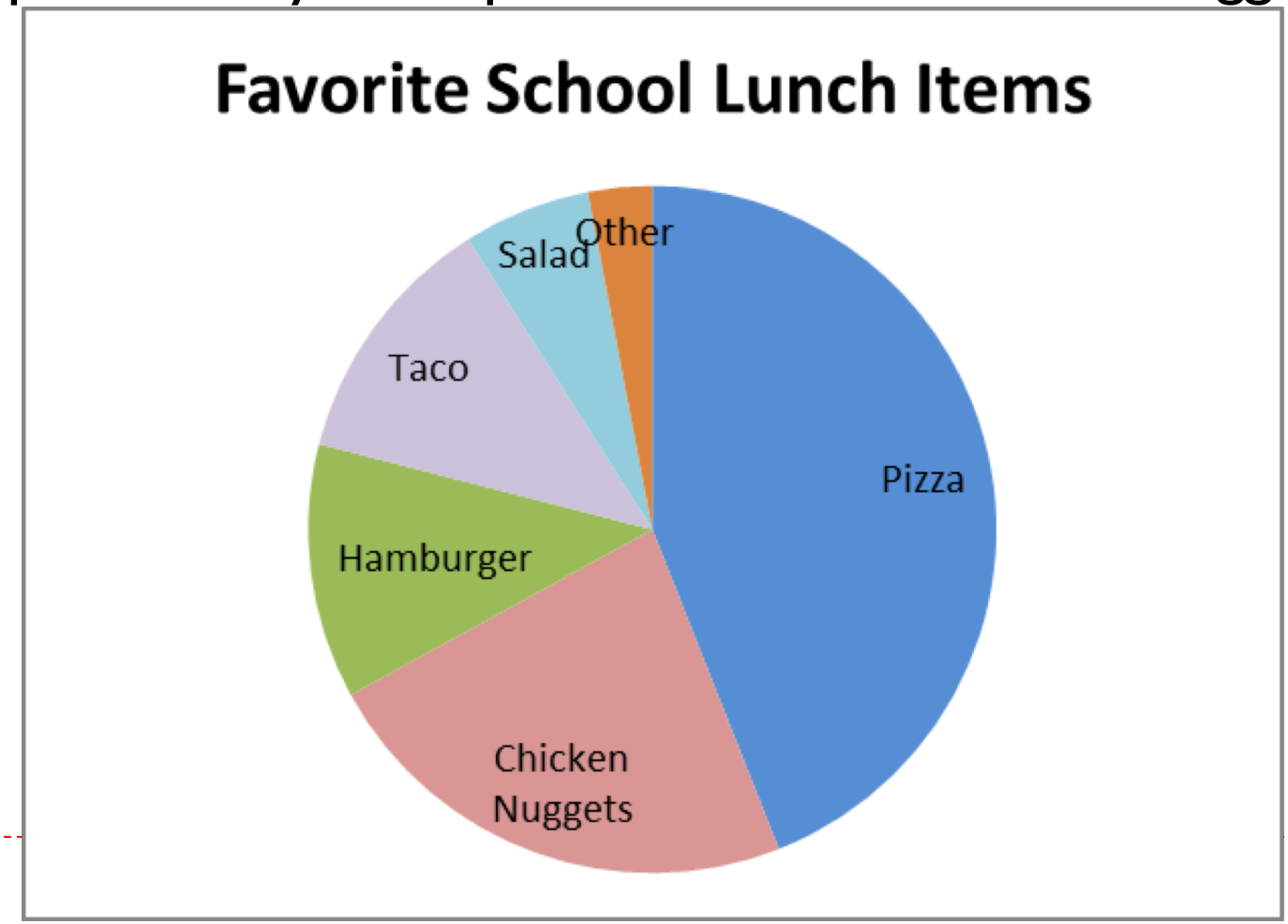
What about 3D?

- Which is more popular- taco or hamburger?
- Approximately what percent selected chicken nuggets?



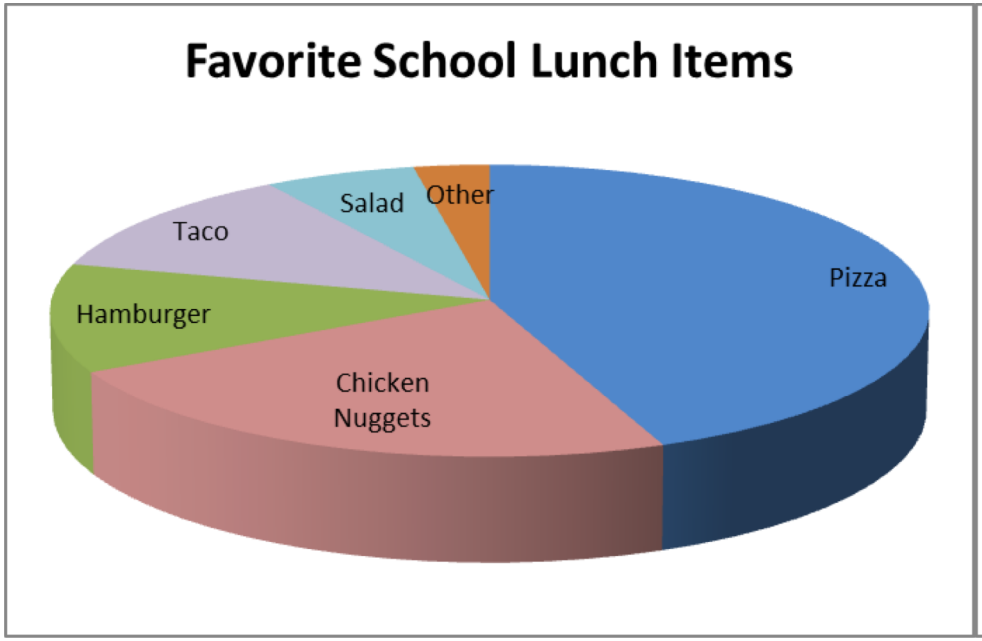
What about 3D?

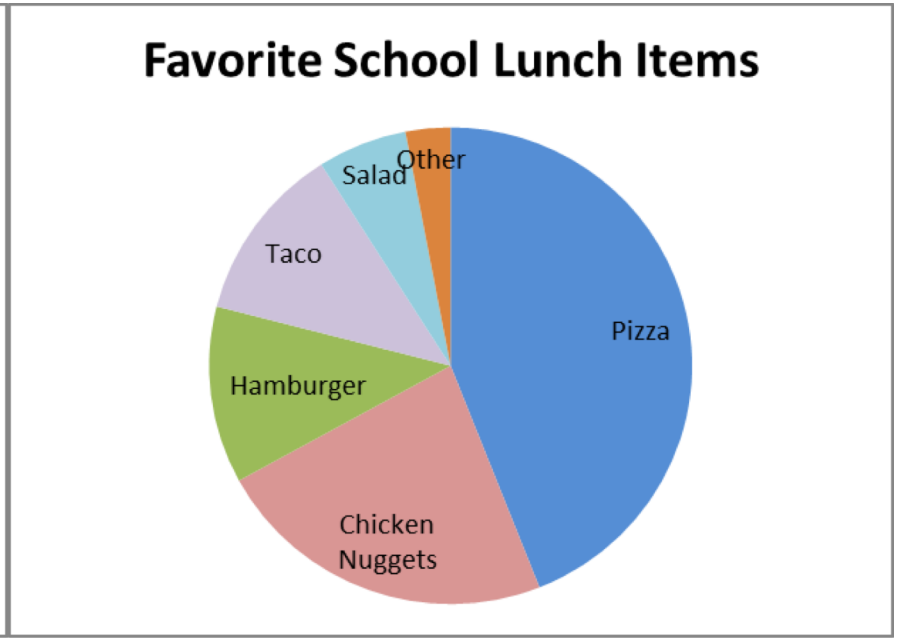
- Which is more popular- taco or hamburger?
- Approximately what percent selected chicken nuggets?



Answers…

- Which is more popular- taco or hamburger?
- Approximately what percent selected chicken nuggets?



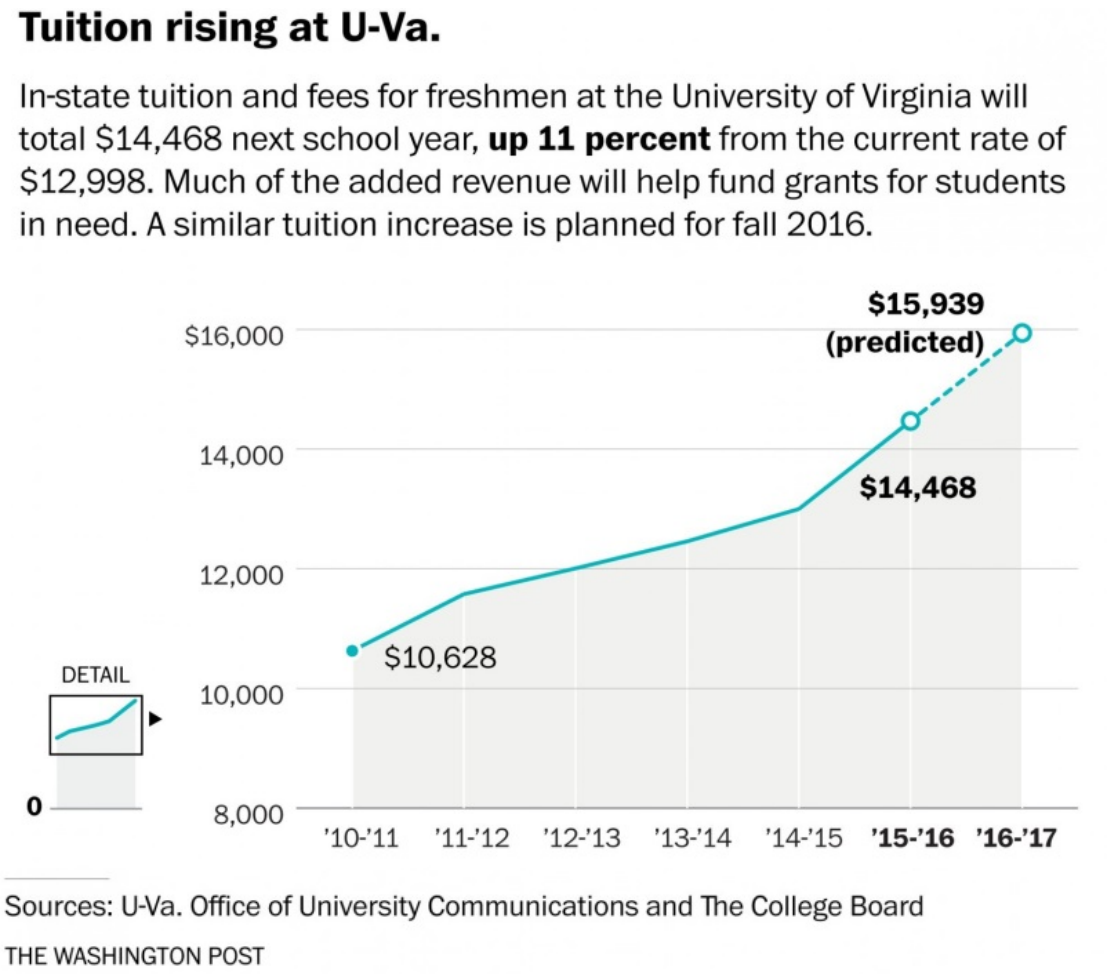


What about 3D?

- It may look cool, but is not as effective for communication of data relationships.
- Humans are unable to interpret depth as well as length and width on a flat surface.
- This typically leads to a skewed perception of the data.
- 3D graphics are not recommended in any graph type intended for consumer/stakeholder interpretation.

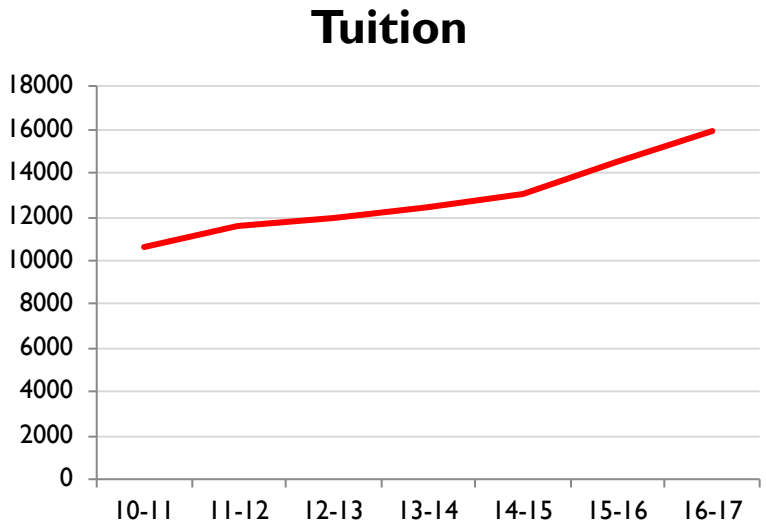
The Importance of Scale

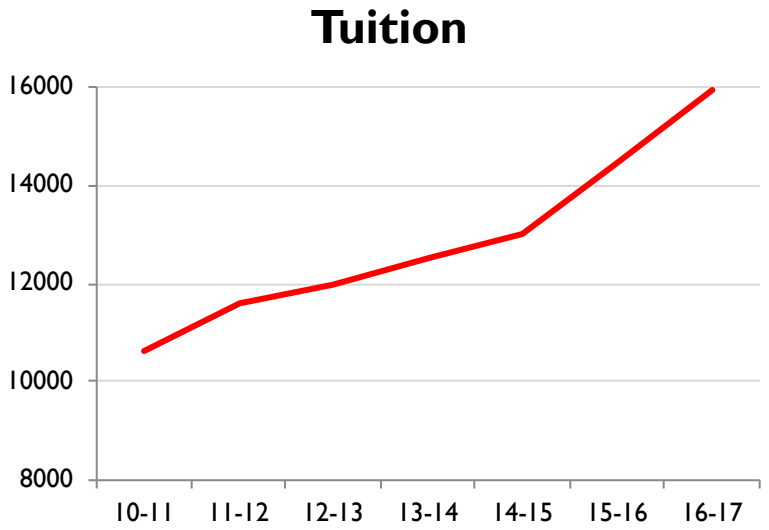
- This graph was seen recently in a Washington Post article:



The Importance of Scale

- Let's look again…





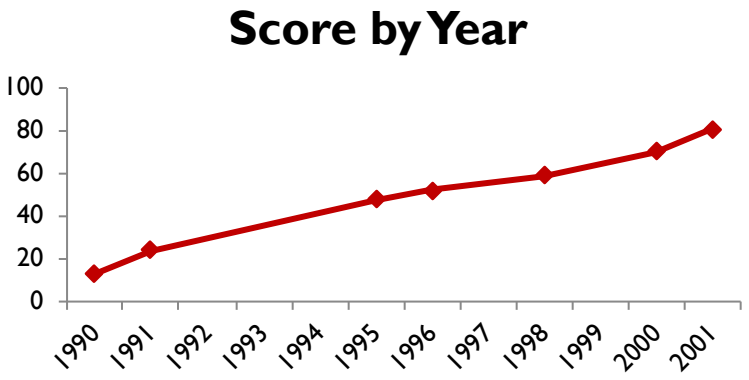
- The impact of these graphs may be different- the one on the right seems much more dramatic.

Guidelines for Scaling

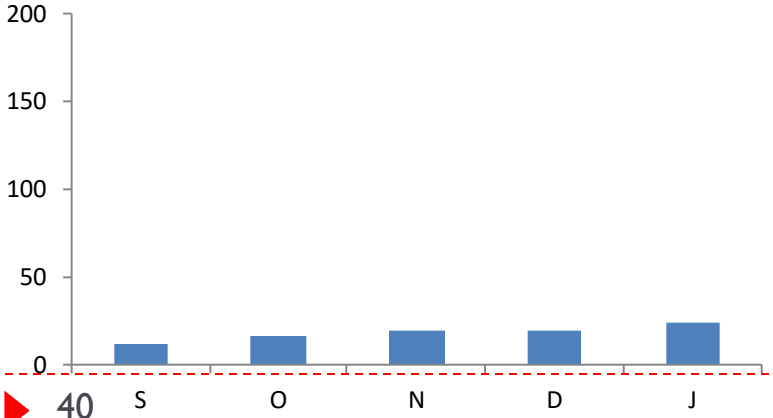
- Is there a "Golden Rule"?
  - Not really. Several statisticians have agreed that it is a complex issue but decisions need to be made by the graph designer.
  - However, there are some guidelines

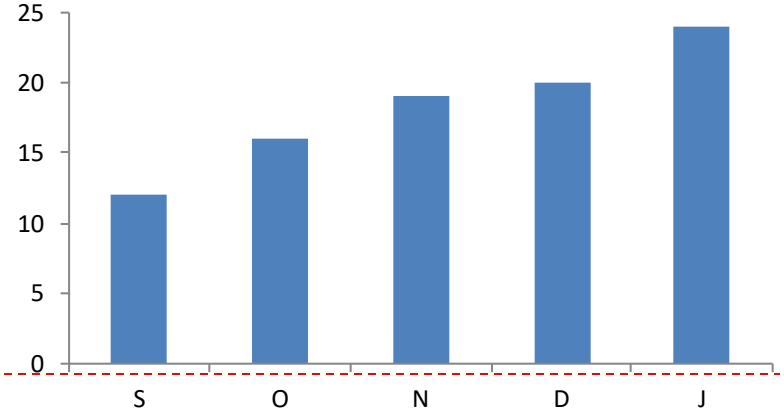
Guidelines for Scaling

- Consistency of axes



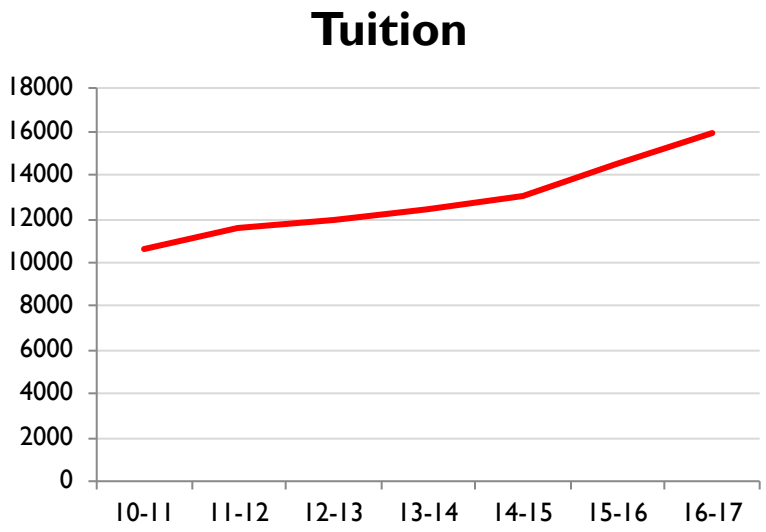
- Appropriate to scale of data (large enough to show detail, small enough not to exaggerate variations)

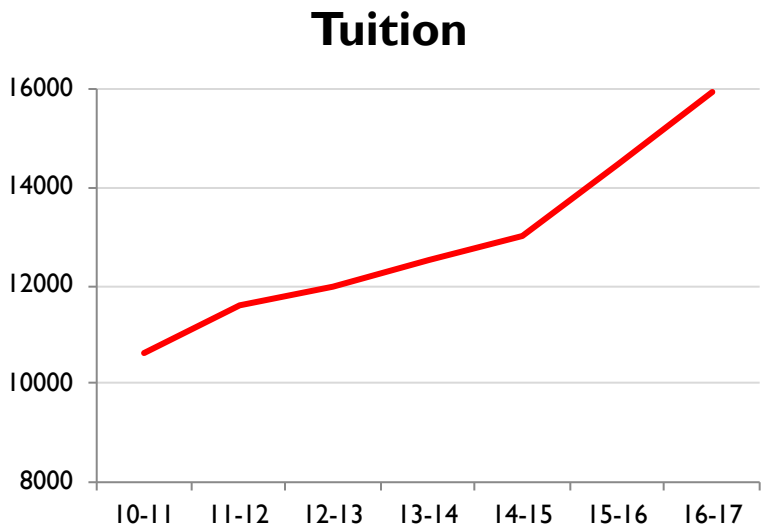




Guidelines for Scaling

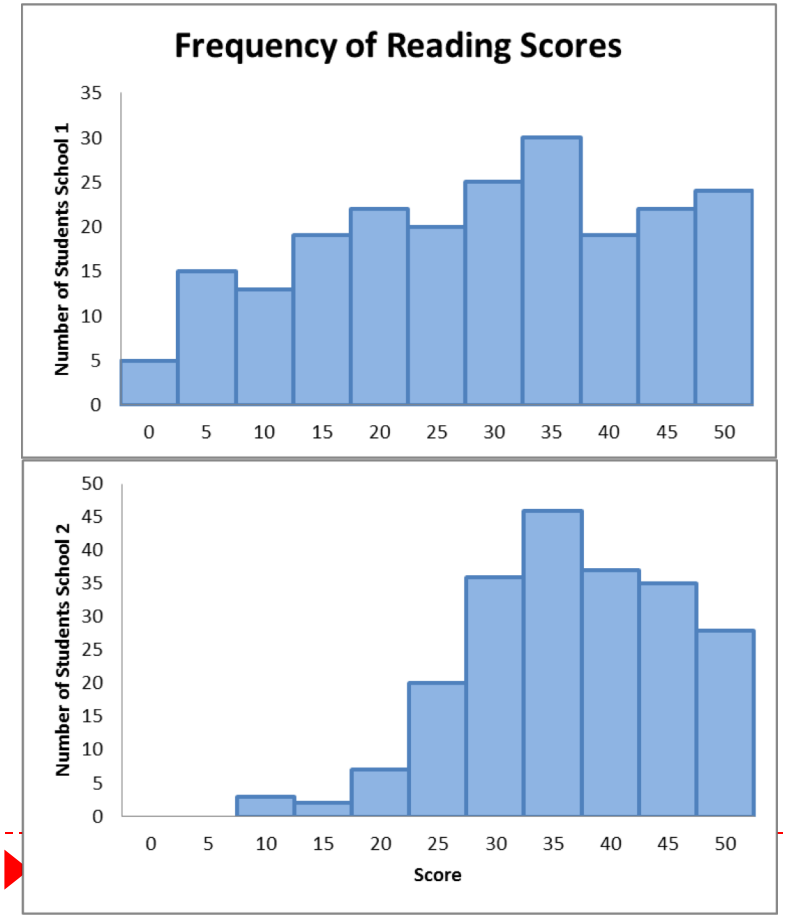
- Not always necessary to include zero

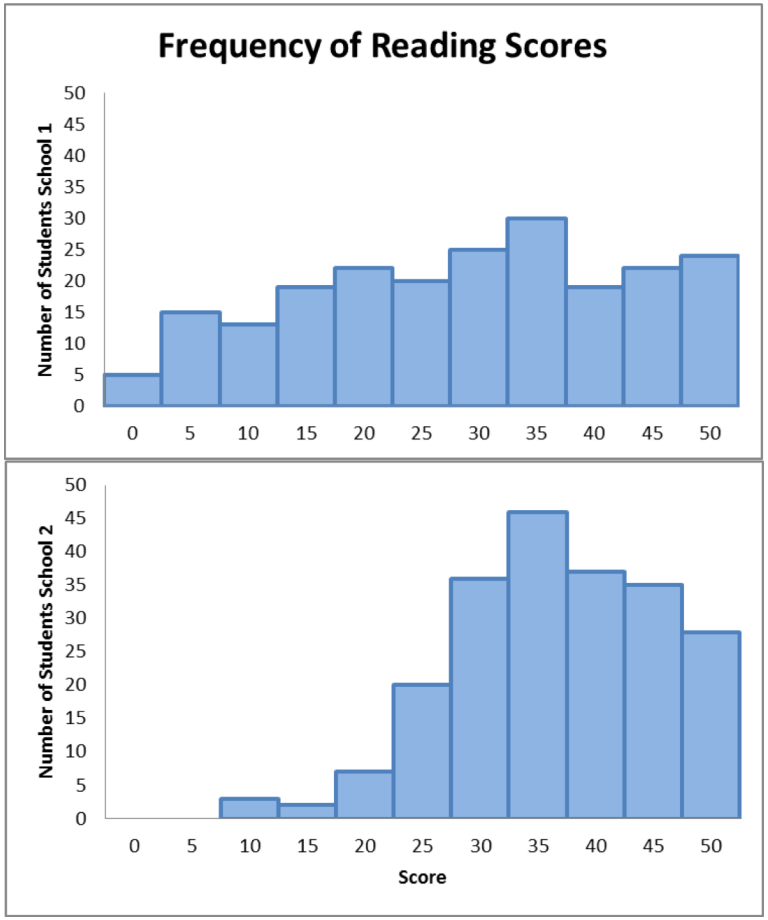




Guidelines for Scaling

- Attempt consistency with multiple panels to aid comparisons
  - It is easier to compare the panels on the right because the scales are the same.





Dashboard Design

What is a Dashboard?

*"A dashboard is a visual display of the **most important information** needed to achieve one or more objectives, **consolidated and arranged** on a single screen so the information can be monitored **at a glance**."*

–Stephan Few, 2013

Beginning Steps

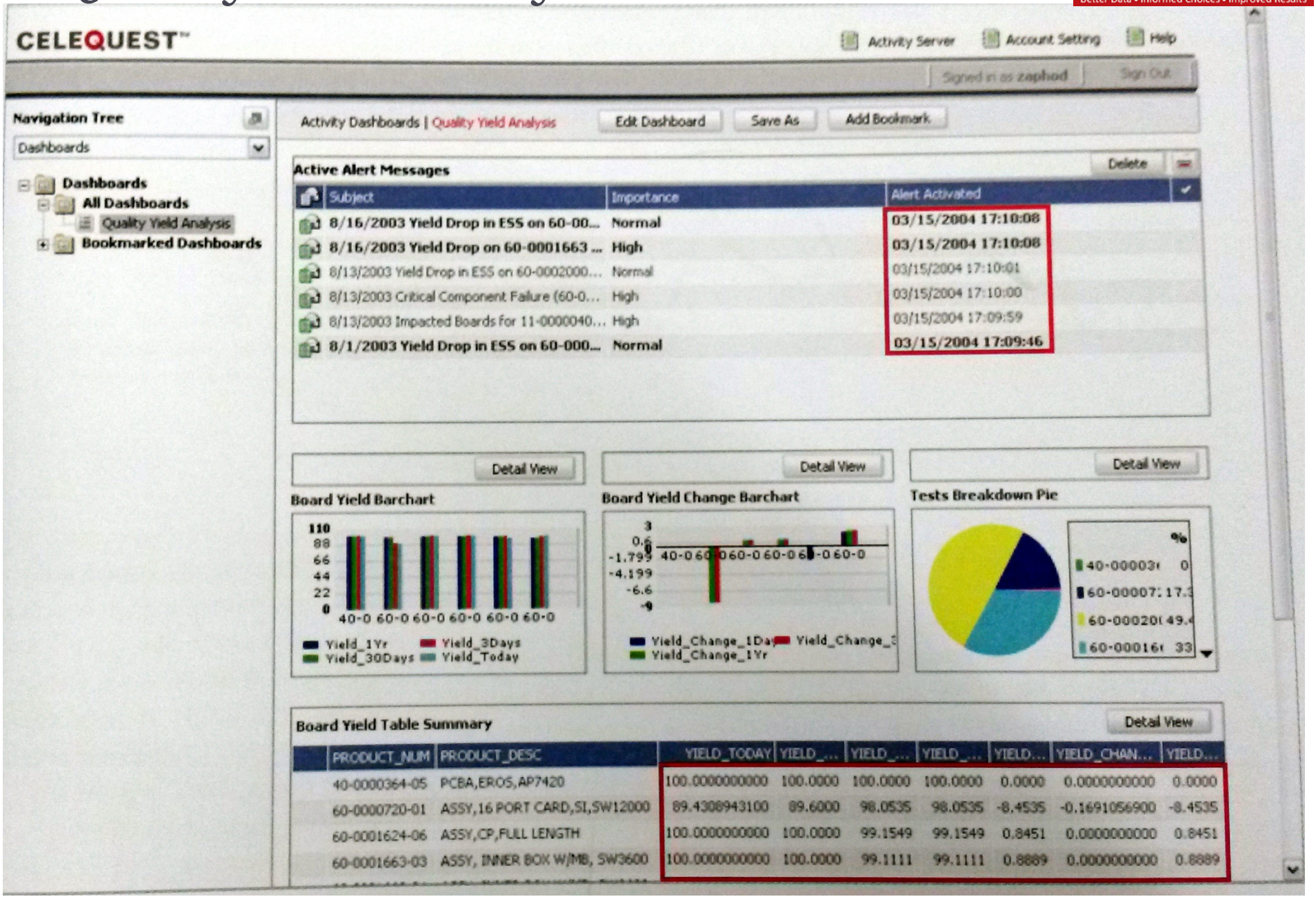
- Begin by defining the purpose of the dashboard
- Identify necessary information and context
- Identify individual graphics necessary to convey only needed information
- Assemble individual graphics and contextual information into a balanced dashboard

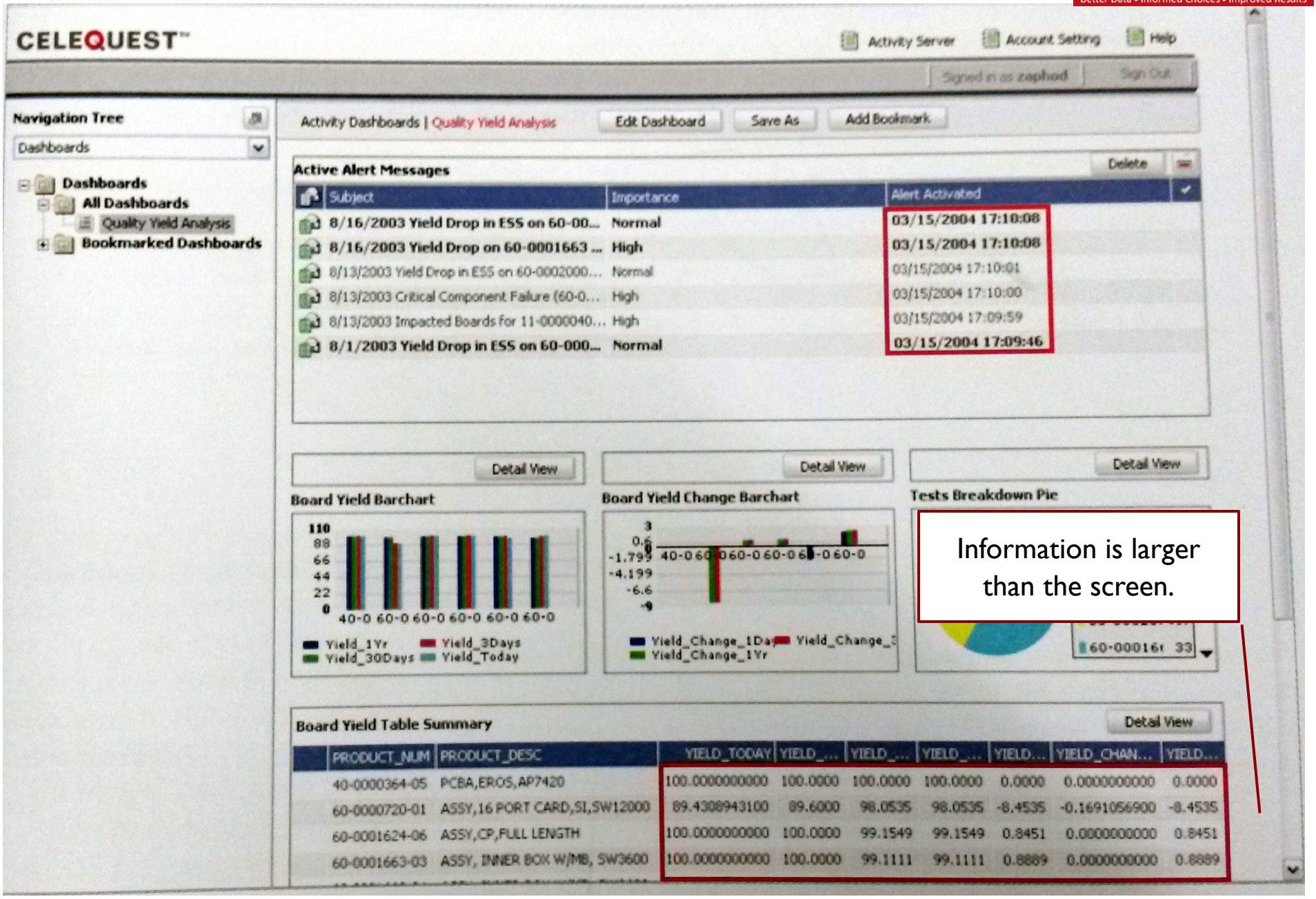
Dashboard Design Balancing Act

- Simplicity vs. Achieving Objective
  - Single Screen
    - Scrolling can make it difficult to compare or cause some information to be overlooked
  - Adequate Context
    - Should be clear what the viewer is looking at, but no extra information
  - Only enough detail to achieve objective
    - Graphics can have detail that relates to the objective, but avoid unnecessary distractors

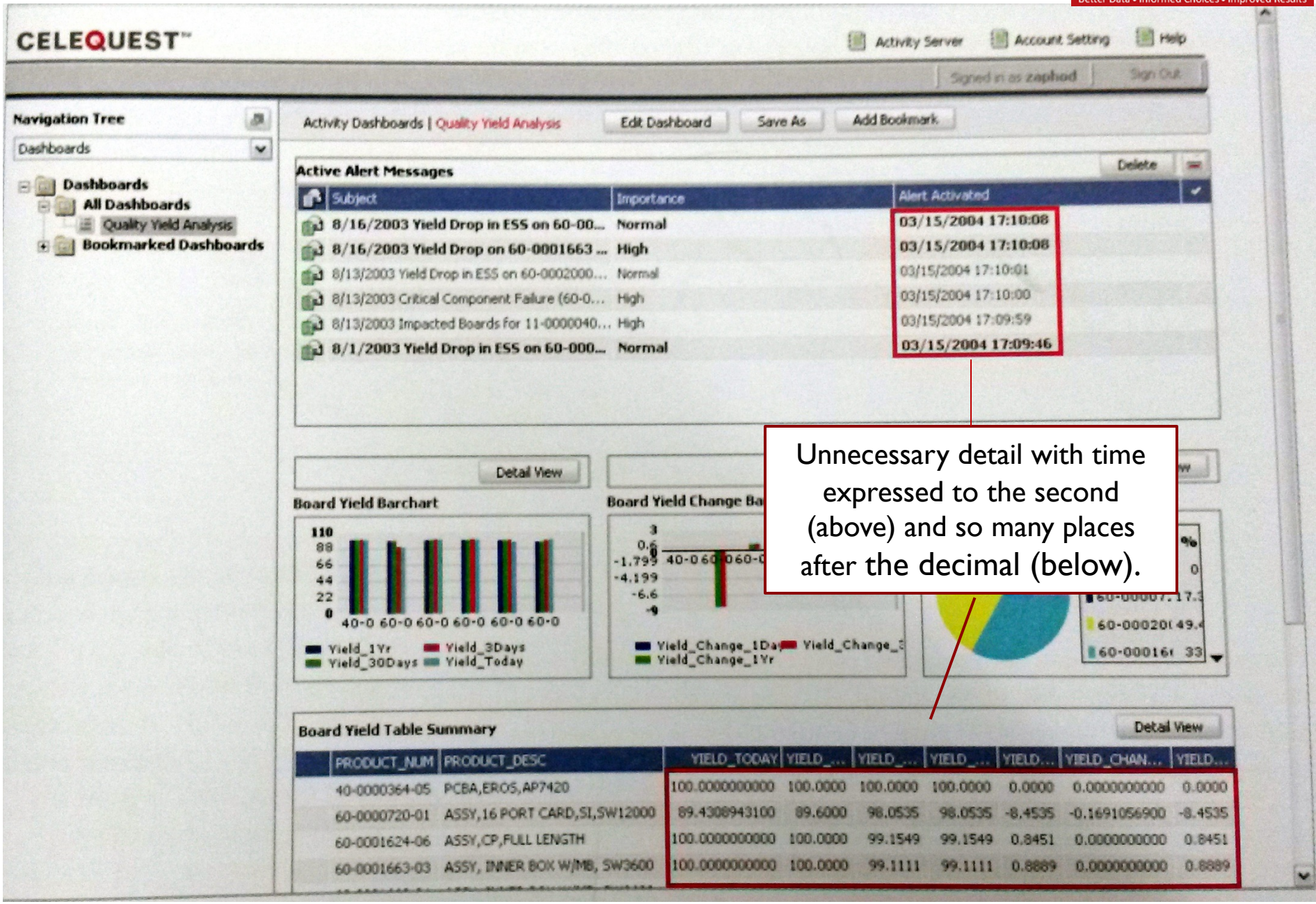
- The following dashboard has some design issues. Can you find them?

Quality Yield Analysis





Information is larger than the screen.



Unnecessary detail with time expressed to the second (above) and so many places after the decimal (below).

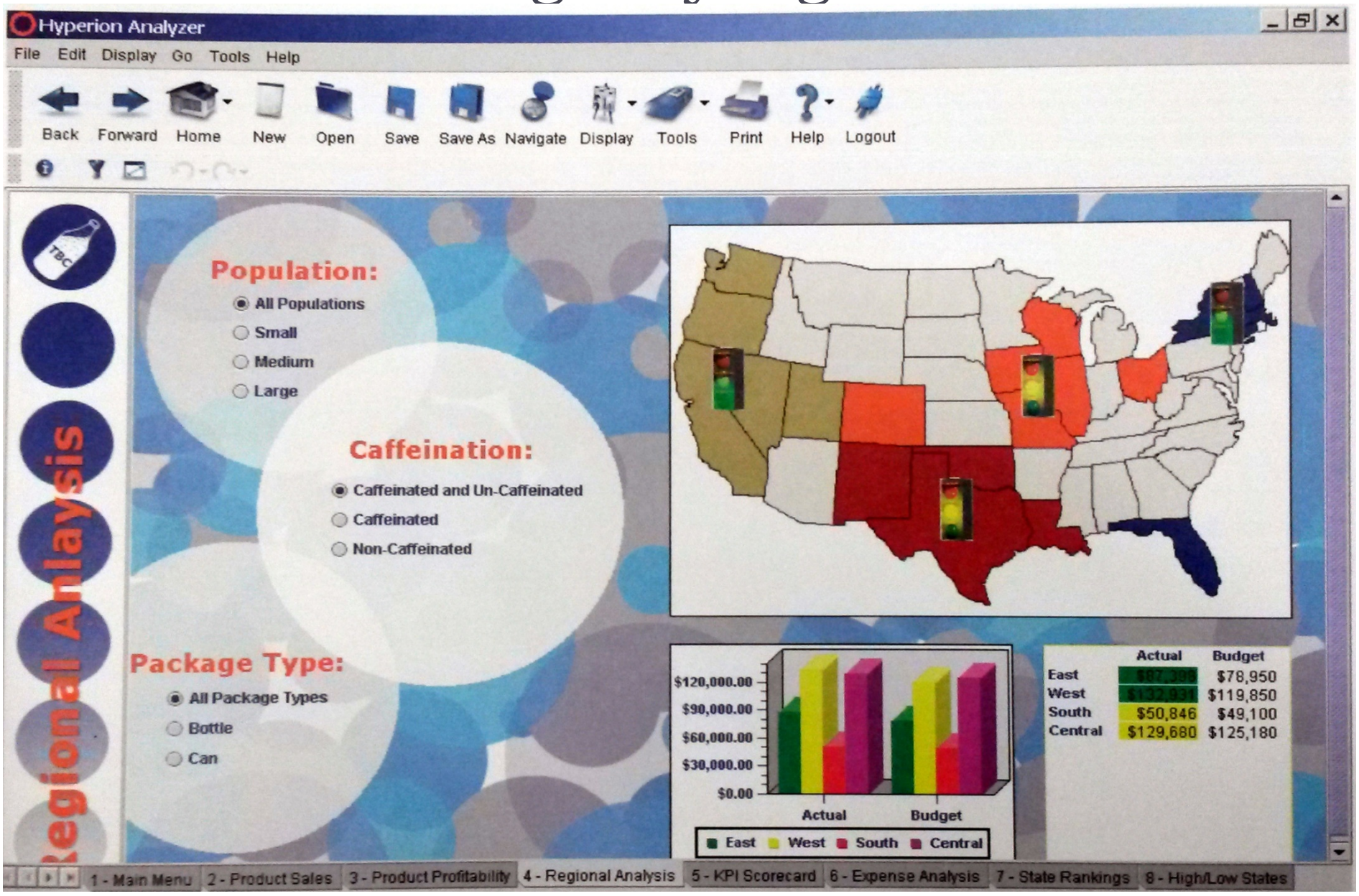
The Dashboard Design Balancing Act

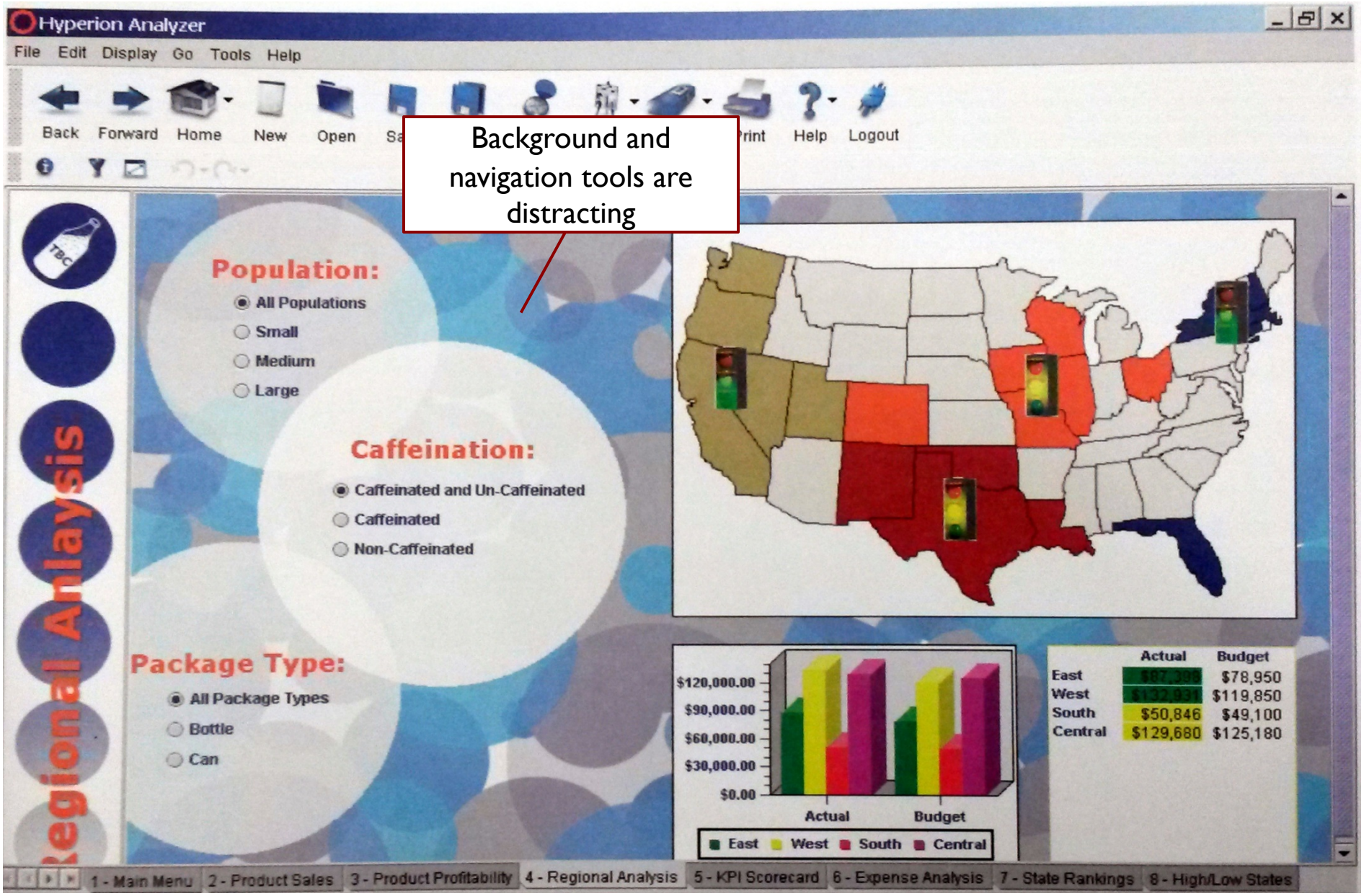
- Visual Appeal vs. Meaningless Variety and Poor Design
  - Varying graph types for the sake of variety can make interpretation more difficult
  - All elements should be concise and organized
  - Color should be simple and not overwhelming
    - Semi-saturated colors work best- bright colors can be overwhelming

  - Avoid backgrounds/unnecessary gridlines

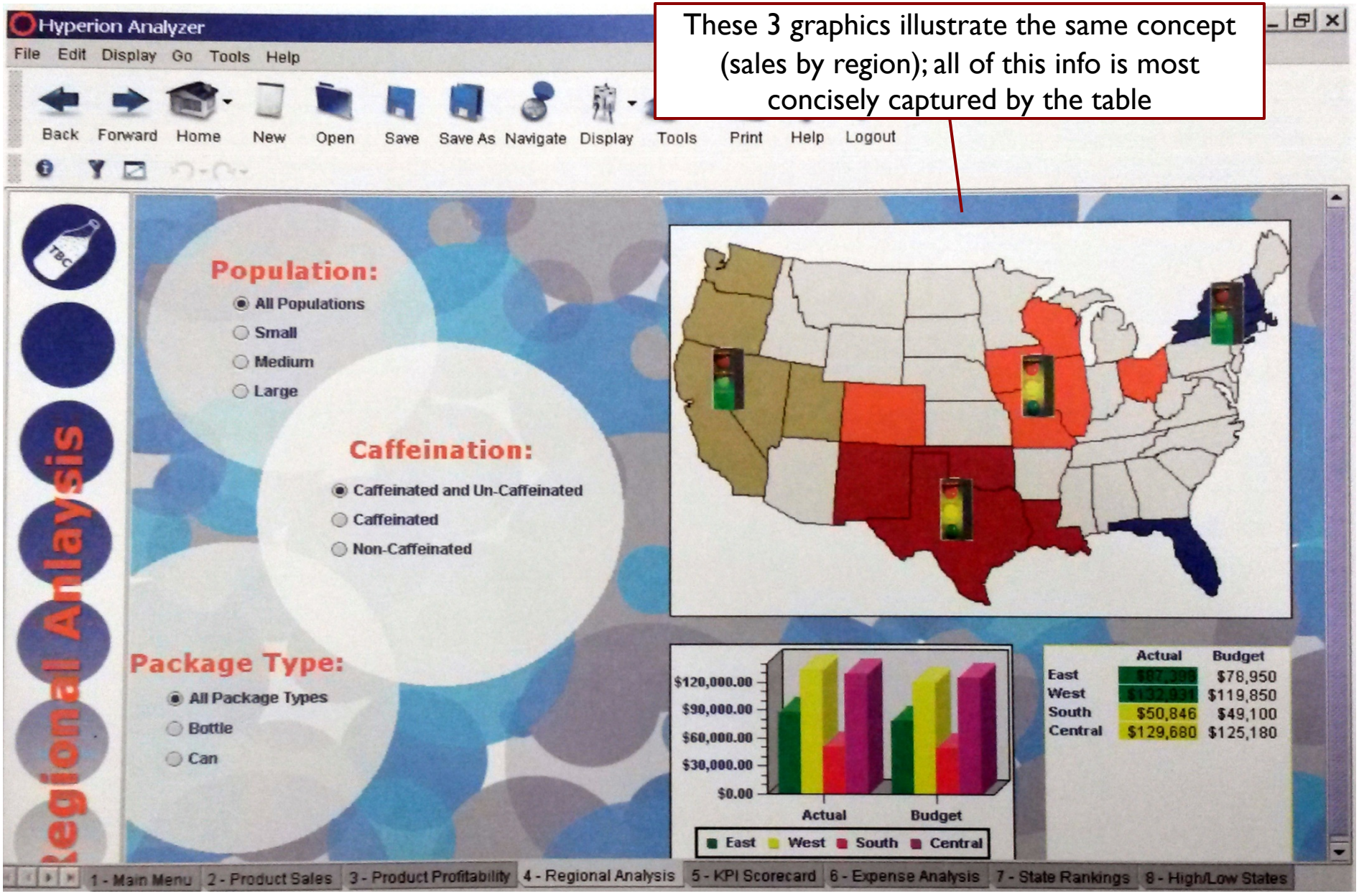
- The following dashboards have some design issues. Can you find them?

Sales of beverages by region



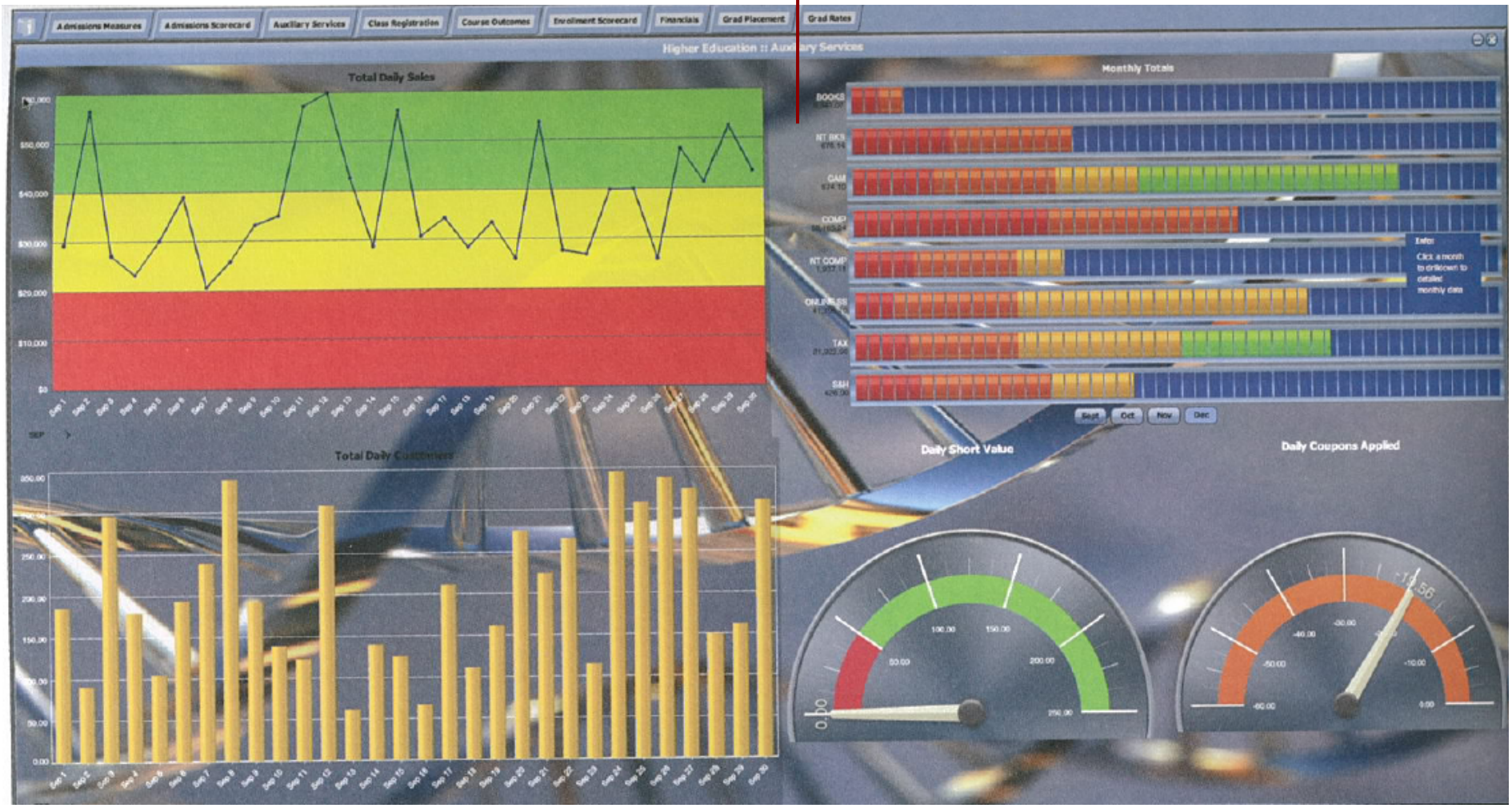

Hyperion Analyzer
File Edit Display Go Tools Help
Back Forward Home New Open Print Help Logout
Background and navigation tools are distracting
Regional Anlaysis
Population:
All Populations
Small
Medium
Large
Caffeination:
Caffeinated and Un-Caffeinated
Caffeinated
Non-Caffeinated
Package Type:
All Package Types
Bottle
Can
$120,000.00
$90,000.00
$60,000.00
$30,000.00
$0.00
Actual
Budget
East West South Central
Actual Budget
East $78,950
West $119,850
South $50,846 $49,100
Central $129,680 $125,180
1 - Main Menu
2 - Product Sales
3 - Product Profitability
4 - Regional Analysis
5 - KPI Scorecard
6 - Expense Analysis
7 - State Rankings
8 - High/Low States

These 3 graphics illustrate the same concept (sales by region); all of this info is most concisely captured by the table



Daily Sales Analysis

Distracting background and competing graphics



These dials show "Daily Short Value" and "Daily Coupons Applied"- not a logical format for this information

No descriptors for the stacked bars

They aren't all bad…

- The following dashboard is an example of an effective combination of tables and graphs to convey information.

Personal Finance

Personal Finance Dashboard: August 2011

Current Position	
Savings	25,020
Equity	142,720
Mortgage Principal	213,580

Current Month

!	Activity	Actual	Budget	Actual Variance	Actual:Budget	Actual:Budget %
	House Expense	1,927	1,924	3		
	Savings	1,000	1,000	0		
	Grocery	590	500	90		
	Car Expense	421	403	17		
	Dine Out	393	400	-7		
	Entertainment	221	200	21		
	Misc	100	-	100		
	Travel	98	400	-302		
	Interest	87	-	87		
	Bank Fees	11	9	2		
	Clothes	-	100	-100		

c. Month Expenses

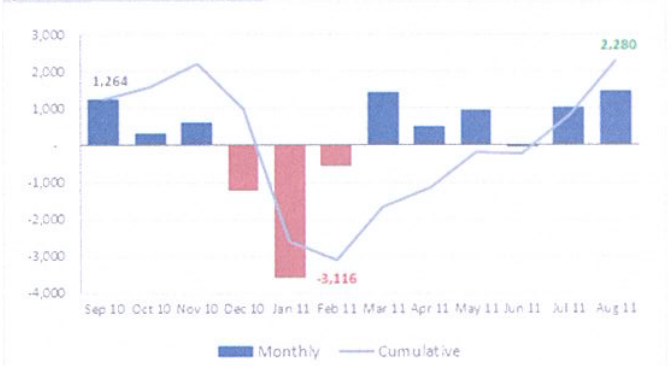
#	Expense Detail	
1	Grocery	590
2	Condo Fees	440
3	Gas	267
4	Golf	221
5	Car Insurance	153
6	Pub Dining	132
7	Fast Food	128
8	Cable / Internet	110
9	ATM withdrawal	100
10	Car Rental	98
	others	254

Savings Projection

p12 Months

!	Activity	12m trend Actual	12m trend Actual:Budget	Actual $	Budget $	Variance $	Actual:Budget	Variance %	Actual:Budget%
	Savings			11,500	12,000	-500		96%	
	Dine Out			8,864	4,800	4,064		185%	
	Entertainment			6,556	2,400	4,156		273%	
	Misc			5,635	-	5,635			
	Travel			4,466	4,800	-334		93%	
	Car Expense			3,839	4,839	-1,000		79%	
	Grocery			3,682	6,000	-2,318		61%	
	Clothes			1,875	1,200	675		156%	
	Interest			348	-	348			
	Bank Fees			134	107	27		125%	

p12 Months Residual Pay



p12M > Budget

#	Activity	Var.
1	Entertainment	4,156
2	Dine Out	4,064
3	Clothes	675
4	Interest	348
5	House Expense	222
		9,465

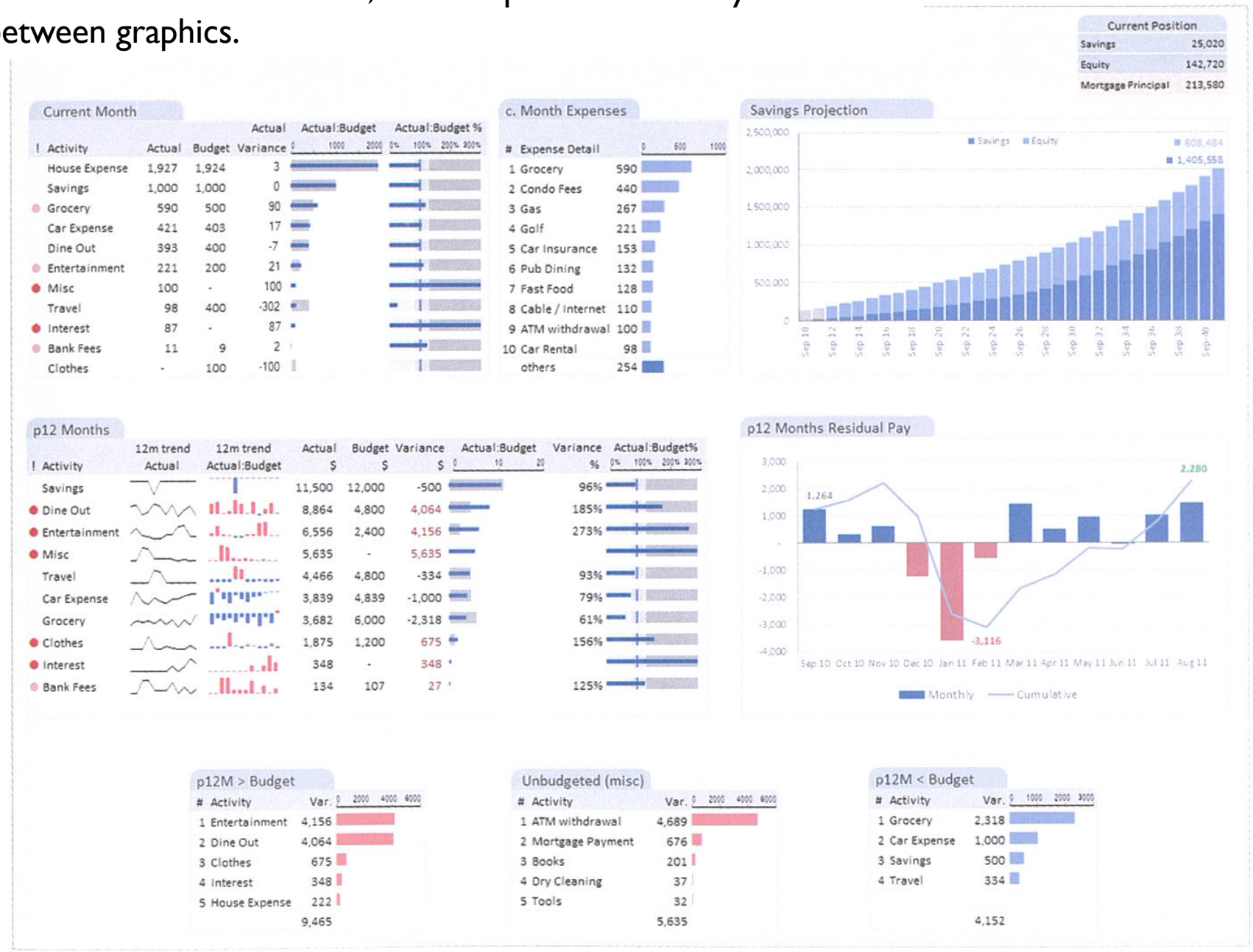
Unbudgeted (misc)

#	Activity	Var.
1	ATM withdrawal	4,689
2	Mortgage Payment	676
3	Books	201
4	Dry Cleaning	37
5	Tools	32
		5,635

p12M < Budget

#	Activity	Var.
1	Grocery	2,318
2	Car Expense	1,000
3	Savings	500
4	Travel	334
		4,152

There is a lot of information here, but the colors are simple, no distractors or extra details, and comparisons are easy within and between graphics.



Summary: Dashboard Design

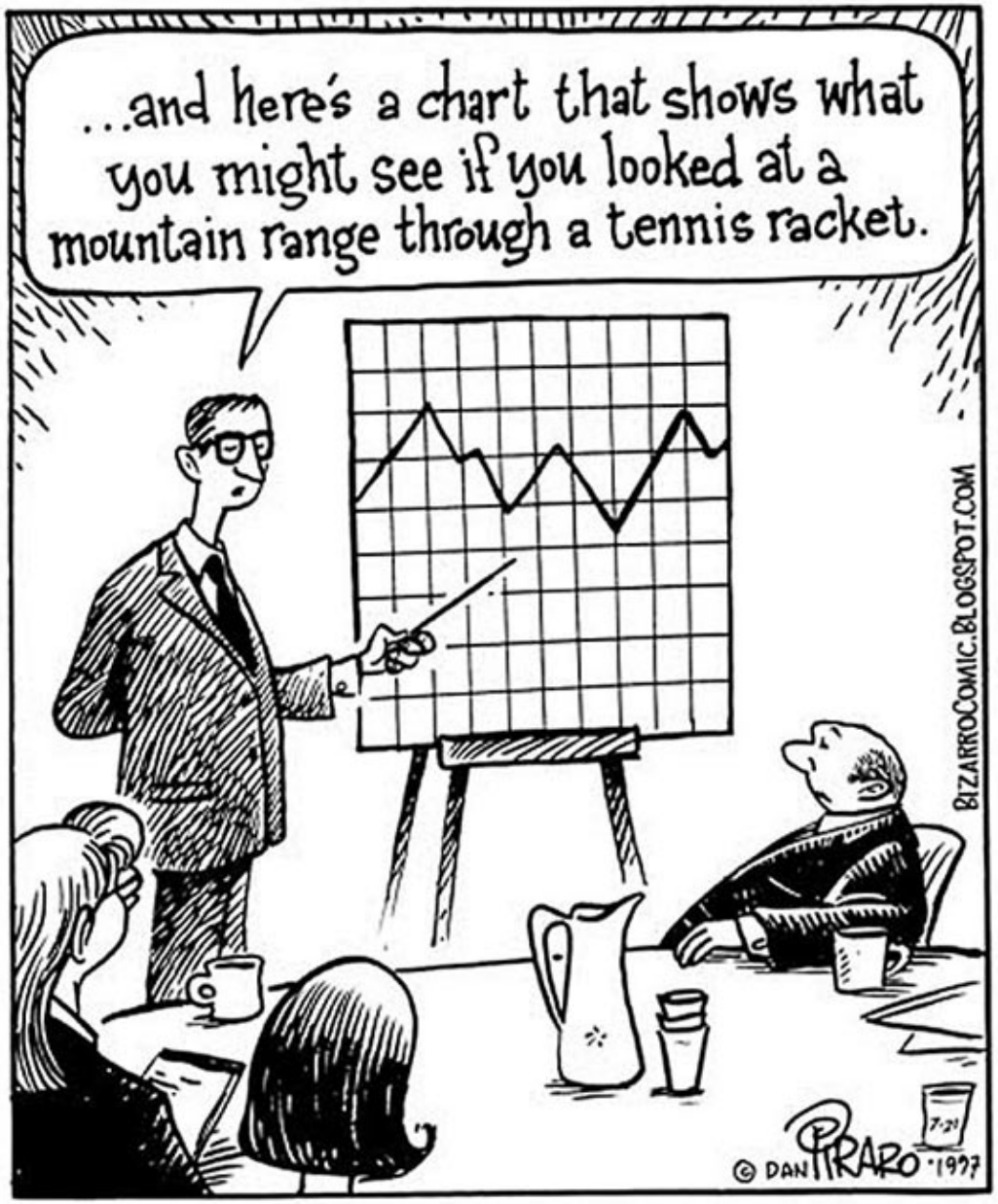
- Simplicity vs. Achieving Objective
- Visual Appeal vs. Meaningless Variety and Poor Design
- As with individual graphics, each product will be unique to the data and the context…
- …and always look from the consumer's perspective.

Recommendations for the MLDS Center

Recommendations

- Remember the requests of the stakeholders
  - Ease and familiarity
- Match the type of graphic to the purpose of the data
  - Table or graph?
  - Type of graph?
- Use attributes, such as form and scale, to highlight details, trends, or patterns that explain the objective
- When creating dashboards, remember to balance objective with content
  - Consider splitting expansive ideas into multiple screens
  - Simplicity

Goal:
Effectively communicate with data!



References

Alverson, C. Y., & Yamamoto, S. H. (2013). Talking with teachers, administrators, and parents: Preferences for visual displays of education data. *Journal of Education and Training Studies, 2*(2), 114-125.

Anderson, N. (2015, March 26). At U-Va, a price hike for some will fund a price cut for others. *The Washington Post*. Retrieved from http://www.washingtonpost.com/local/education/at-u-va-a-price-hike-for-some-will-fund-a-price-cut-for-others/2015/03/26/6e17d26a-d31f-11e4-ab77-9646eea6a4c7_story.html

Few, S. C. (2012). *Show me the numbers: Designing tables and graphs to enlighten.* Burlingame, CA: Analytics Press.

Few, S. C. (2013). *Information dashboard design: Displaying data for at-a-glance monitoring.* Burlingame, CA: Analytics Press.

Tufte, E. R. (2001). *The visual display of quantitative information* (2nd ed.). Cheshire, CT: Graphics Press.

Wainer, H. (2005), *Graphic discovery: A trout in the milk and other visual adventures*. Princeton, NJ: Princeton University Press.