#	Many-Facet Rasch Measurement : Facets Tutorial Mike Linacre - 1/2012
1.	**Tutorial 1. Software operation and basic concepts** ***Welcome!*** • *Facets* software operation • Data entry methods, including Excel • Facets, elements, persons, items, raters • Simple dichotomous and polytomous analyses • Measurement rulers This tutorial includes a quick run-through of the operation of the computer program, *Facets*.
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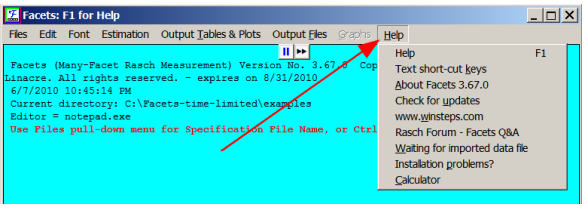
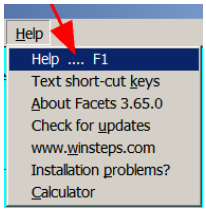
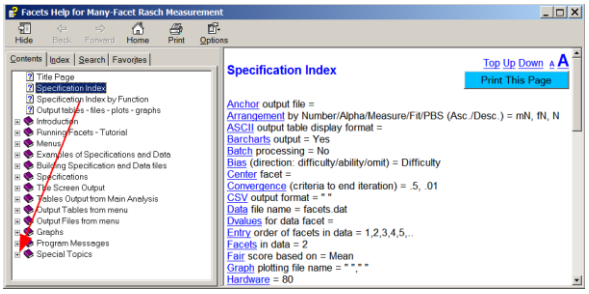
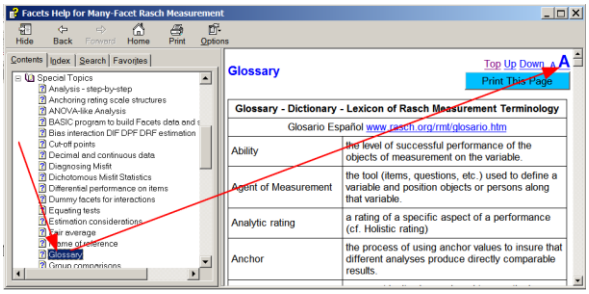
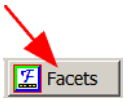
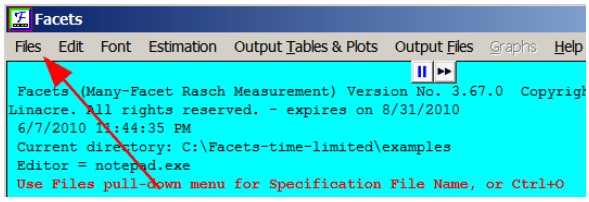
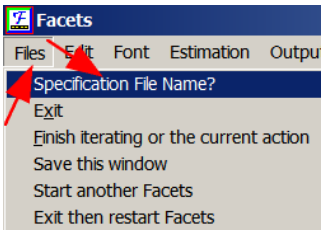
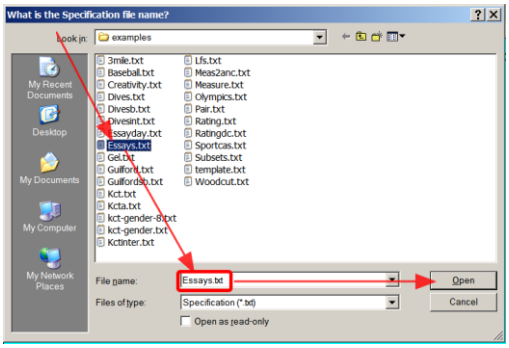
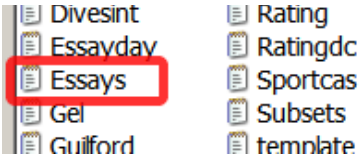
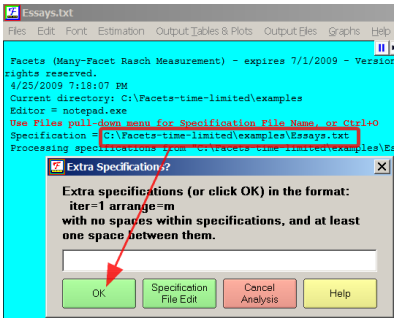
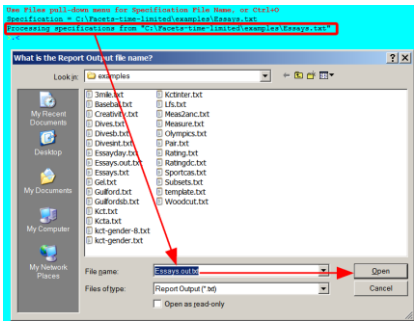
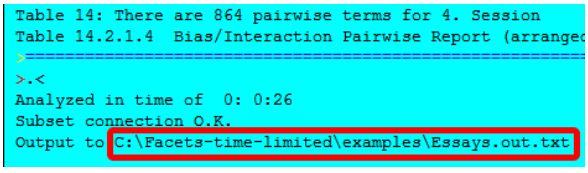
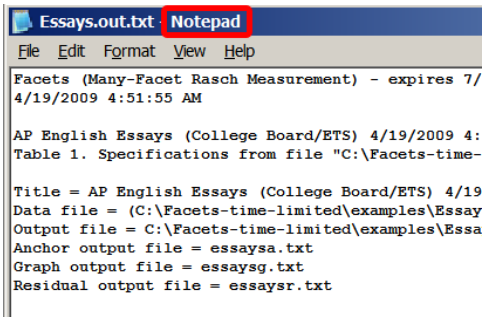
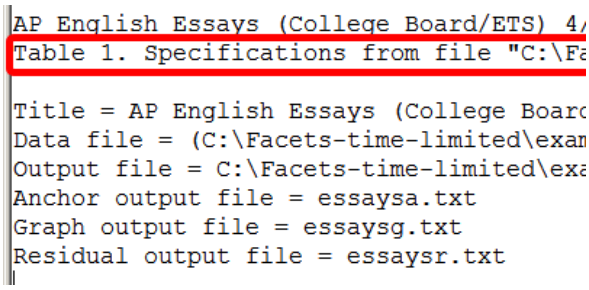
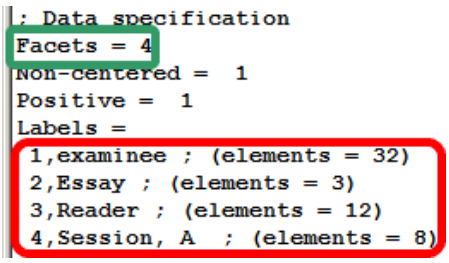
13.	**A. Running the *Facets* Program**	
14.	You can launch *Facets* at any time by double-clicking the short-cut on your desktop. You can also drag *Facets* specification files onto the *Facets* short-cut to launch them.	
15.	Launch Facets. The main *Facets* window displays. The Facets program performs "Many-Facet Rasch Measurement", MFRM. Notice the menu bar across the top of your screen. Let's look at the **Help** function. Position your mouse to Help, and then left-click on it.	

16.	Now click on "Help F1" to activate the Help screen. You can also press your F1 at most times to activate Help.	
17.	Facets Help screen displays. This contains the same information as the Facets manual, facets.pdf, which is in your Facets folder. Left-click on the ⊞ next to "**Special Topics**" to expand the topic list.	
18.	Then left-click on "**Glossary**" to display a glossary of Rasch technical words. You may find this useful if you don't understand the meaning of a word in this Tutorial. *Please tell me if you need to know the meaning of a word not in this Glossary.* Click on "A" to increase the size of the text. Click on "A" to decrease its size. You can leave this Help window open if you want to. It will close automatically when this run of *Facets* ends.	
19.	On your Windows task bar (usually the bottom of your screen), click on *Facets*	
20.	The *Facets*-analysis window displays. The Facets program performs "Many-Facet Rasch Measurement", MFRM. Notice again the menu bar across the top of your screen. We want to select a file to analyze, so click on **Files**	
21.	Click on **Specification File Name?** Many researchers use both *Facets* and Winsteps, so to avoid confusion, the analysis file is called the "specification file" for *Facets* and the "control file" for Winsteps. They have the same function, but many differences.	

22.	The **examples** folder displays. Yours may look different if you have chosen a different Windows style. These are the example specification and data files. Click on **Essays.txt** or **Essays** Then click on **Open** (or double-click on **Essays.txt** or **Essays**)	
23.	You may not see the **.txt** suffix with your file names. That is OK, but if you want to display the suffixes, follow the procedure in **Appendix 1** at the end of this document.	
24.	The Specification file name, **C:\Facets\examples\Essays.txt** is now shown in the *Facets* window and the **"Extra specifications?"** box displays. This box is useful for giving last-minute instructions to *Facets*, but we won't do that now, so Click on **OK**	
25.	The specifications (instructions to *Facets*) in the file "Essays.txt" are processed to make sure that they specify a viable analysis. When there are many specifications, this can take considerable time, so a progress bar: >.....< is shown on the Facets Analysis window. Then you are prompted for the Report Output file name. One is suggested **"Essays.out.txt"**. We will accept it, so Click on **Open**	
26.	The analysis runs. On my computer it takes 34 seconds for this small dataset when run without interruption. The analysis output report is written to our output file **"Essays.out.txt".**	

27.	**B. The Output File of Tables = Output Tables File**	
28.	The output file, **"Essays.out.txt"**, is displayed in an Editor window by *NotePad.* Most *Facets* input and output files and windows are text files. They are usually displayed and edited with NotePad. NotePad needs to display with a fixed-space font, such as *Courier New,* and a small font-size so that this displays neatly. **Appendix 2** explains how to do this. If you want *Facets* to use a different text-editor, such as WordPad or TextPad, see **Appendix 3**	
29.	Let's scroll down this output file to see what *Facets* tells us about *Essays.txt.* The output file is divided into many output Tables and Sub-Tables. The first one is Table 1. **Table 1 summarizes the *Facets* specifications.** This is helpful if want to save your analysis output and then remind yourself later of what you did. It is also useful when the analysis didn't come out how you expected. Look at Table 1 - This answers the question "Are the specifications what you intended them to be?"	
30.	There are two lines in Table 1 that are crucial to a successful analysis. Green box: "**Facets =**" reports how many facets there are in your analysis, and Red box: "**Labels =**" reports how many elements have been defined in each facet. If these numbers are incorrect, then the analysis is almost sure to be wrong.	
31.	**What are "facets"?** Most statistical analyses have rectangular datasets. The rows are cases, subjects, persons, ... The columns are items, probes, tasks or other variables. The *Facets* program can analyze this type of data, but it can do much more. In our terminology, a typical rectangular dataset is a "two-facet" analysis. The rows are one facet. We label (or name) that facet by what it means to us, so we might label the rows, "Facet 1. Students" or "Facet 1. Patients". The columns are another facet, so we might call them "Facet 2. Items". In a rectangular dataset, we imagine that (something about the row) + (something about the column) → (the data value, observation, response at the intersection of the row and the column) *Some facets:* *"Tasks" and "prompts" provide the context, e.g., when the "task" is an essay: "write an essay".* *"Items" are the immediate probes to which the raters respond, e.g., item 3 is "grammar".* *"Persons", "Subjects", "Cases", "Objects of measurement" are what is being rated.* *"Rating scale" is not a facet. It is the definition of the response structure, e.g., a "performance" rating scale could be "0=deficient, 1=acceptable, 2=good, 3=excellent", but sometimes items are called "scales".*	

32. **Three facets:**
But the situation can become more complicated. What if this is a piano competition? Each candidate plays 3 piano sonatas and each of those 3 performances is rated by several judges? Then

(something about the candidate) + (something about the piano sonata) + (something about the judge) → (the data)

This is a 3-facet analysis: Facet 1. Candidates + Facet 2. Sonatas + Facet 3. Judges.
There is nothing special about the numbering of the facets. So we could specify:

Facet 1. Judges + Facet 2. Candidates + Facet 3. Sonatas.

We number the facets in the way that is best for our own thoughts, and best for us to tell other people what we have discovered. Facet 1 is usually the facet that is most important to us.

33. The Essays.txt analysis has 4 facets. This is what we imagine:

examinees + essays + readers + sessions → data

So what is going on? This is an essay examination. Each examinee writes several essays. The essays are rated by the readers. There are so many essays that it takes several reading sessions to read all the essays. The original purpose this analysis was to discover if it makes any difference if an essay is rated in the first session (when the readers may be fresh) or in the last session (when the readers may be tired).

```
; Data specification
Facets = 4
Non-centered =  1
Positive =  1
Labels =
 1,examinee ; (elements = 32)
 2,Essay ; (elements = 3)
 3,Reader ; (elements = 12)
 4,Session, A  ; (elements = 8)
```

34. **What are elements?**
Elements are the specific individuals, items, raters, etc., in each facet that interacted to produce a specific observation or data-point. So our **analytical model** becomes:

an examinee + an essay + a reader + a session → a data point, observation, response, rating

It is essential to conceptualize this clearly. Many difficulties in interpreting the output of *Facets* can be traced back to failing to think through the analytical model.
So, within each facet is a list of elements. Each element must be specified. This is done by giving each element a number, for instance, the examinee number in the examinee facet.
An item element in the item facet can also be labeled with the entire text of the item.

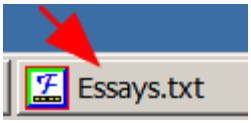
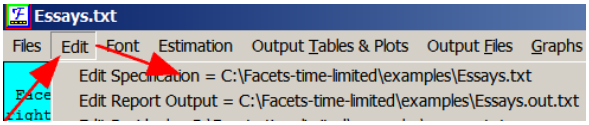
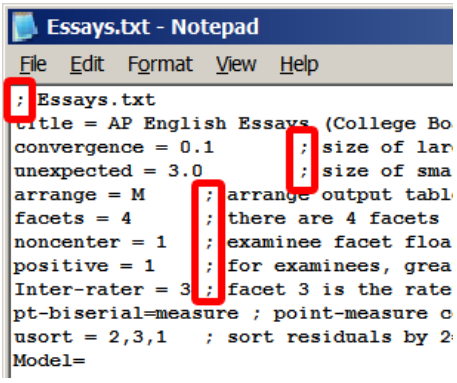
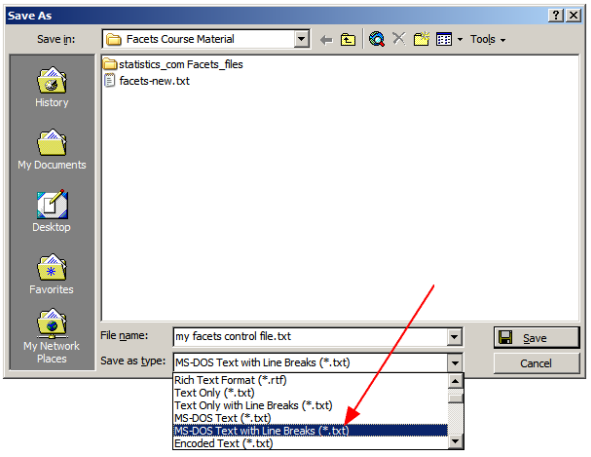
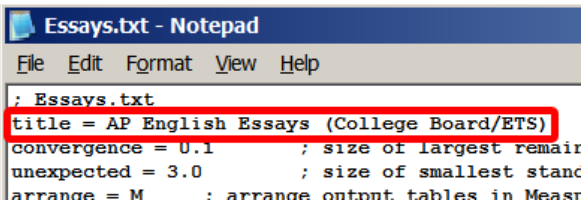
35. In the *Essays.txt* analysis, there are **4 facets.** The facets are called, "examinee, Essay, Reader, Session".
Table 1 reports that we have defined:
32 examinee elements, so there are 32 examinees
3 Essay elements, so these are 3 Essays
12 Reader elements, so there are 12 Readers
8 Session elements, so there are 8 Sessions.

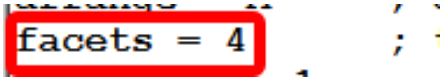
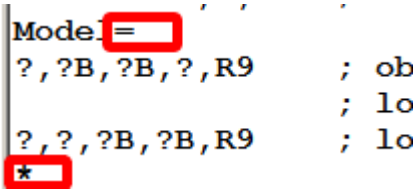
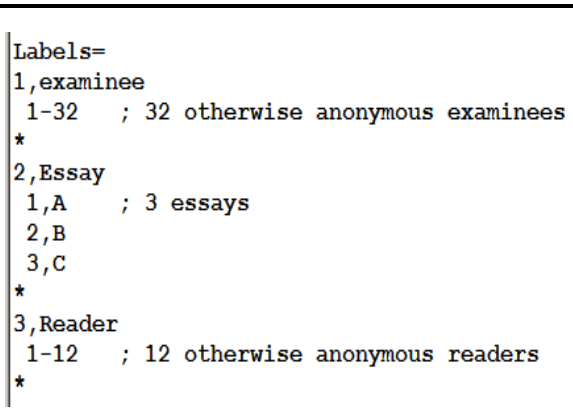
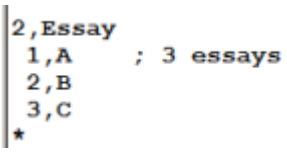
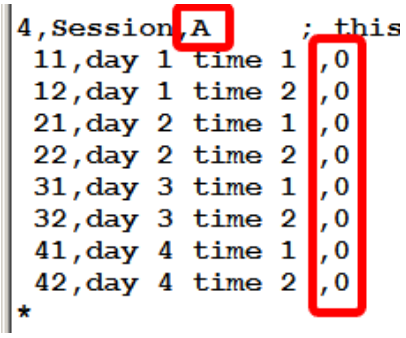
```
; Data specification
Facets = 4
Non-centered =  1
Positive =  1
Labels =
 1,examinee ; (elements = 32)
 2,Essay ; (elements = 3)
 3,Reader ; (elements = 12)
 4,Session, A  ; (elements = 8)
```

36. Scroll down *Essays.out.txt* to **Table 2. Data Summary Report.**
This tells us how many data points or observations have been input. Here it says 1152.
Is this what we expected? If not, we need to examine the data file. Here is the judging plan:
each of the 32 examinees wrote 3 essays, and each essay was rated by 12 readers
= 32 x 3 x 12 ratings = 1152 ratings. *Exactly!*

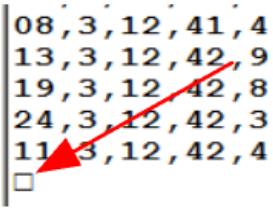
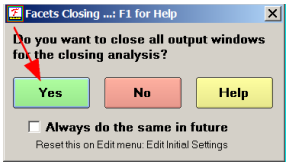
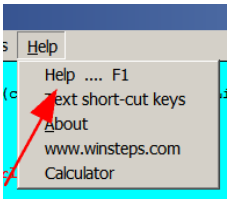
```
Table 2. Data Summary Report.

Assigning models to "C:\Facets-time-limited\exampl
Total lines in data file = 1152
Total data lines = 1152
Responses matched to model: ?,?B,?B,?,R9,1 = 1152
    Total non-blank responses found = 1152
Valid responses used for estimation = 1152
```

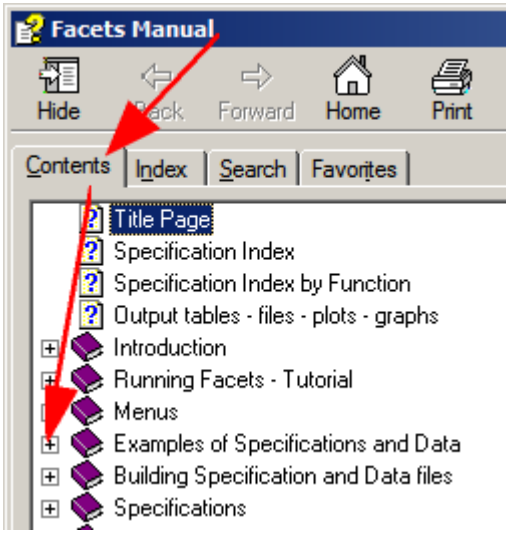
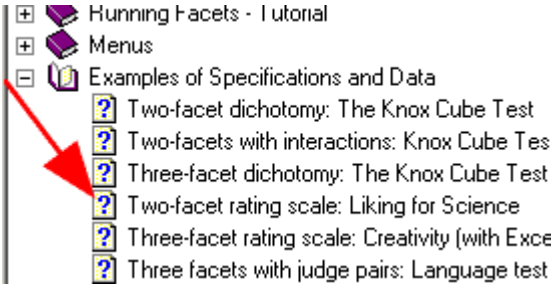
37.	Each reader rated all 32 x 3 = 96 essays only once. This required 8 sessions, with each reader rating 12 essays per session. In the original research study, they omitted to collect a few ratings, so those observations were *imputed* (given reasonable values in the data file) because the original analysis required complete data. *Facets* does not require complete data.
38.	*Imputed:* this usually refers to responses or other values that are decided by the analyst instead of being observed. For instance, on a Binet intelligence test, the scoring imputes correct answers to all easy items that were not administered, and the scoring imputes incorrect answers to all difficult items that were not administered. *Facets* does not require data to be imputed.
39.	

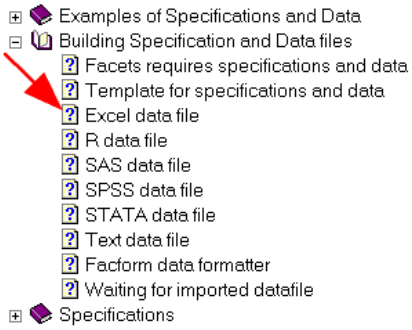
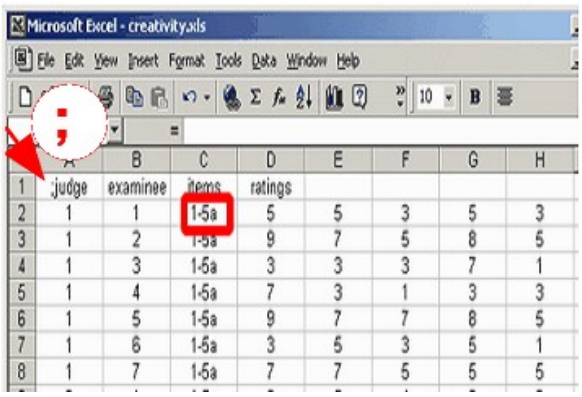
40.	**C. The Specification and Data File**	
41.	Before we go further down the output, look at the *Essays.txt* specification and data file. Click on the *Facets*-analysis window, or on *Essays.txt* in the Windows task bar on the bottom of your screen.	
42.	On the *Facets* menu bar, Click on "Edit" Click on "Edit Specification = ... Essays.txt" Essays.txt is the disk file which contains the control instructions for the *Facets* program for this analysis, and also the data.	
43.	This opens a NotePad window displaying *Essays.txt*. Almost all the files we use with *Facets* are standard .txt text files. Notice the **";" semi-colons.** These start comments. Everything to the right-side of a semi-colon is ignored by the *Facets* program. This is how we can write notes to ourselves to remind ourselves what we are doing. We can also put ; semi-colons in the data in the same way. So, the first line of Essays.txt starts with ; and so is a comment.	
44.	*Facets* specification and data files are standard ".txt" text files. You can create one yourself using NotePad, or in Word, etc., then saving as a **MS-DOS Text with Line Breaks (*.txt)** or "ASCII" file. You can verify the format of your file. *Does it open correctly with NotePad?*	
45.	The second line is: **title = AP English Essays (College Board/ETS)** This specification defines the Title to put at the top of every *Facets* output Table. This is the format for *Facets* control specifications: **specification word = value** Specification words can be written in lower-case "title=" or upper-case "TITLE=" or a mixture "Title=". Only the first two or three letters matter, so that "Title=" is the same as "Ti=" is the same as "Titel=".	 There is a complete list of specifications in *Facets* Help and also in the online version of *Facets* Help at: www.winsteps.com/facetman/spindex.htm

46.	"facets=4" specifies that there are 4 facets in the analysis. This is the most important specification. We want to specify that the data are the outcome of the combination of 4 facets.	 facets = 4 is the same as facets=4
47.	Some specifications can contain lists of instructions to *Facets*. Here "Model=" has a list. There is nothing after the =. The next line "?,?B,?B,?,R9" is a value for the "Model=" specification. The list of values for "Model=" ends with "*". We'll talk much more about the "Model=" specification.	
48.	Further down there is a more complicated list. This is "Labels=". It defines the names of the facets and also the elements within each facet. "1, examinee' means: the label (name) for Facet 1 is "examinee". Then follows the definition of the elements within the facet: "1-32" means: the elements in the examinee facet are numbered 1, 2, 3, ..., 30, 31, 32. We don't know anything more about them. The examinee element list ends with "*"	
49.	2, Essay - facet 2 is named "Essay". 1, A is the first Essay element. This essay is named A. Element 2 is essay B. Element 3 is essay C. The list ends with "*" Names (labels) for the facet number and element numbers are not required, but please use them. They make the output easier to understand.	 1, A is the same as 1 = A
50.	Facet 4 is a "dummy" facet. We use dummy facets when we don't want the facet to change the overall measures, but we do want to investigate the facet. In this case, the overall results are based on: **examinee + essay + reader → rating** but we wonder, "Does the **session**, when this particular rating was done, make any difference?" - "Is there an interaction between reading session and reader leniency?" To investigate interactions we can use dummy facets. Dummy facets can be specified explicitly by ",A" (for "Anchor") after the facet label, and zeroes in the third value position of each element, or by ",D" (for "Dummy") after the facet label.	 or 4, Session, **D** 11, day 1 time 1 With "D", a numeric value is not specified

51.	○ *Let's clarify element numbering:* There is flexibility about how you enter the *Labels=* for the elements. 1. The element numbers can be out of order: Labels= 1, Examinees 3, Maria 1, Anna * 2. The element numbers can be any numbers in the range 1-1200000000: Labels= 1, Examinees 34839845, Maria 1287931 ; element labels are not required * 3. If element numbers appear twice, then they are combined: Labels= 1, Examinees 1-5, Girl ; element numbers in a range 3, Maria * is processed as: Labels= 1, Examinees 1, Girl 2, Girl 3, Maria 4, Girl 5, Girl * *4.* Element 0 is allowed if *Keepzero=* is set to a different value: Keepzero = 999 ; element 999 means "no element number for this facet" Labels= 1, Gender 0, Female 1, Male *	*Specification file is written as:* Labels= 3, Persons 34523 76543=Fred 27 463 34523 27 = Maria *	*Facets processes the specifications as:* Labels= 3, Persons 27 = Maria 463 34523 76543 = Fred *
52.			

53.	**D. *Facets* Data Formats**	
54.	After the facet and element labels comes the data. The data can also be placed in a separate file. First there is "data=". Then one line for each data point. Each line here has one element number for each facet and one data value. "05,1,1,11,4" means element 5 of facet 1 (examinee 5) and element 1 of facet 2 (essay A) and element 1 of facet 3 (reader 1) and element 11 of facet 4 (session: day 1 time 1) combine together to produce a rating of 4 on the rating scale.	data = 05,1,1,11,4 01,1,1,11,5 13,1,1,11,4 09,1,1,11,3 29,1,1,12,4 25,1,1,12,5 *or* data = 05 1 1 11 4 In the data, blanks and tabs can also be used as separators.
55.	**Missing data?** *Missing responses?* Code with a non-numeric, such as "m" or omit the observation from the data file.	data = 23, 5, 2, 6, m ; the value is not known for this observation
56.	The data ends with the last line of the specification file: 11,3,12,42,4 Ignore the final □. It is not needed and can be deleted. It is the obsolete MS-DOS end-of-file code. *Facets* ignores it.	
57.	Close the NotePad window, we can open it again when we need it. During a typical *Facets* analysis, we open and close many windows. We can also have many *Facets* analyses active at the same time.	
58.	If you see a "Closing" window at any time, then click on "Yes"	
59.	There are other data formats. Let's look at them in *Facets* Help. If Help is on your task bar, then click on it, or if *Facets* is active, click on your F1 key or the *Facets* menu bar, "Help": Click on Help F1	 

60.	Click on "Contents" if it is not the top tab. Click on "Examples of Specifications and Data"	
61.	Click on "Two-facet rating scale: Liking for Science" The "Liking for Science" data have a 3-category rating scale: 0-1-2. The bottom category, category 0, is "Dislike" ☹. Then 1= "Neutral" 😐, 2 = "Like" ☺	
62.	When the Help page displays, Scroll down to "data=". This is a 2-facet data file. The data-points could be entered as: data= 1, 1, 1 ; person 1 rates item 1 in category 1 😐 1, 2, 2 ; person 1 rates item 2 in category 2 ☺ but every person rated 25 items, so we can use the compressed form: 1, 1-25, 1, 2, ... ; person 1 rates items 1 to 25 with 25 ratings. Using this compressed form considerably shortens the data file.	data = 1, 1-25, 1,2,1,1,1,0,2,0,1,2,2,2,2,0,2,1,1,2,2,0,2,1,0,2,0 1 rated item 1 with 1, but item 2 with 2 etc. | 75, 1-25, 1,2,0,0,1,1,0,1,1,2,1,2,2,2,2,1,0,2,2,0,2,0,0,1,0 is the same as data= 1, 1, 1 1, 2, 2 1, 3, 1 .....
63.	Let's imagine each person is rated by judges 1 and 2 on items 6 and 7, then we might like the data to be: person element number, 1-2, 6-7, (4 ratings) but Facets does not support this at present, so we need to do: person element number, 1, 6-7, (2 ratings) person element number, 2, 6-7, (2 ratings) or person element number, 1-2, 6, (2 ratings) person element number, 1-2, 7, (2 ratings)	data= 1-12, 1-25, .. is not valid We can't double-index our data.

64.	We can also use tabs and blanks as data field separators	1 1-25 1 2 1 1 1 0 2 0 1 2 2 2 2 0 2 1 1 2 2 0 2 1 0 2 0
65.	If your data immediately follow your specifications in your Facets specification file, then data = (your data) But if your data are in a separate file (but in Facets data format), then data = name of separate file	data = filename.txt .txt is a standard MS-DOS text file. data=filename.xls .xls is a standard Excel-format worksheet
66.	You can also keep your data in an Excel file (also R, SAS, SPSS and STATA files). In *Facets* Help, click on "Building Specification and Data files" click on "Excel data file"	
67.	Scroll down the "Excel data file" Help page until you can see the Excel spreadsheet. You can see here that the Excel file has the same layout as the *Facets* text data. This is 3-facet data. Judge 1 rates examinee 1 on items 1 to 5, with ratings 5, 5, 3, 5, 3. In column C, we expect to see 1-5 meaning "1 to 5". So why does it say "1-5a"? This is to prevent Excel automatically converting 1-5 into -4 ! *Facets* will ignore the "a" In cell A1, "; judge" - ; makes this row a comment.	
68.	What if my data contain an element-number not in the *Labels*= list in my specification file? Then its observations are ignored, but the element-number is shown in **Table 2** of the Facets output. You can copy-and-paste the missing element numbers from your output file into your specification file.	Example: I removed one element number in Guilford.txt: *Labels=* *1,Senior scientists* *1=Avogadro* *3=Cavendish* * Then, in Table 2 in the Report Output file: *Table 2. Data Summary Report.* ..... *1, Senior scientists, ; facet 1* ***2 =*** * So, I can copy-and-paste **2 =** into Guilford.txt. Then that element number will not be missing.

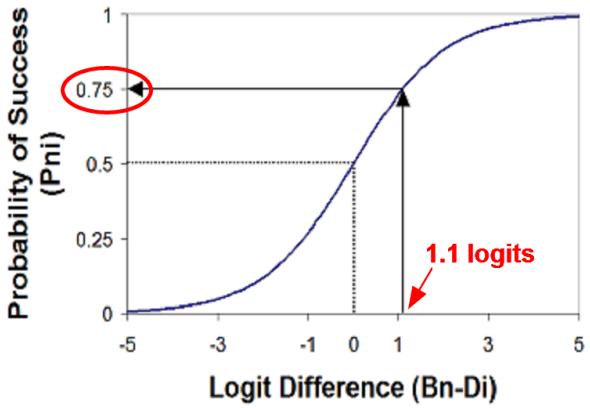
69.	What if my data file contains element labels instead of element numbers? Yes, you can have element labels (but not element ranges) in your data. These are matched with the element labels in your specification file:	Labels= 2,Essay 1,A ; 3 essays ..... Data= 1 A 1 6 .....
70.	There are other *Facets* data formats, but what you have seen should be enough for you to construct your own data files.	
71.		

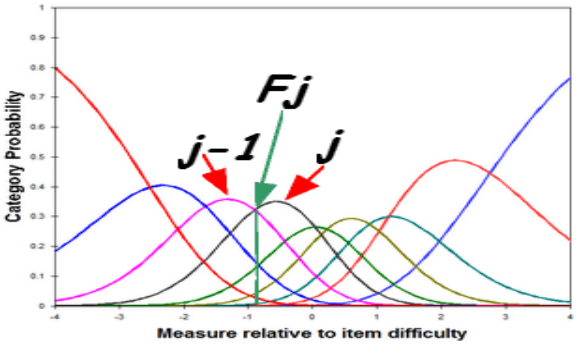
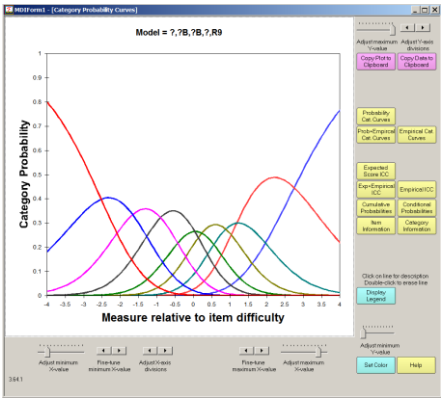
72.	E. Table 7: Counts and Measures	
73.	On your Windows taskbar, click on *Essays.out.txt* the Tables Output File, which was produced by your Facets analysis of "Essays.txt". Scroll down to **Table 7**. Table 7 reports the essential statistics of each element of each facet, starting with Facet 1, "examinees". These statistics tell us the meaning of the data from an objective-measurement perspective.	Table 7.1.1 examinee Measurement Report (arranged by MN). | Total Score | Total Count | Obsvd Average | Fair-M Avrage | Measure | Model S.E. | Infit MnSq | Infit ZStd | | 96 | 36 | 2.7 | 2.66 | -1.62 | .16 | .55 | -2.2 | | 111 | 36 | 3.1 | 3.08 | -1.25 | .15 | 1.27 | 1.1 | | 124 | 36 | 3.4 | 3.44 | -.96 | .15 | .66 | -1.5 | | 127 | 36 | 3.5 | 3.52 | -.90 | .14 | 1.32 | 1.2 | | 138 | 36 | 3.8 | 3.82 | -.68 | .14 | 1.06 | .3 | | 140 | 36 | 3.9 | 3.88 | -.64 | .14 | 1.77 | 2.6 |
74.	The first three columns of this Table probably look familiar. There is the "Total Score", the sum total of all the ratings this examinee received. There is the "Total Count", how may ratings the examinee was given. Each examinee wrote 3 essays, and each essay was rated holistically by 12 readers, so there were 3 x 12 = 36 ratings per examinee. The average rating, the "Observed Average", for the first examinee is the Total Score, 96, divided by the Total Count, 36, which is 96/36 = 2.667 = 2.7.	| Total Score | Total Count | Obsvd Average | | 96 | 36 | 2.7 | | 111 | 36 | 3.1 | | 124 | 36 | 3.4 | | 127 | 36 | 3.5 |
75.	Let's skip the fourth column for the moment and look at the "Measure" column. At first glance, these don't look like the measurements you are familiar with in cooking or carpentry, but they are similar. The measures are positive and negative, like temperatures near freezing point, or heights above and below sea level. They are in decimals, like temperatures. These measures are not in meters or minutes, but in a special unit called a "logit" - we'll talk more about this. But first, *what do we mean by measurement?*	| Measure | | -1.62 | | -1.25 | | -.96 | | .64 | | .82 | | .92 |

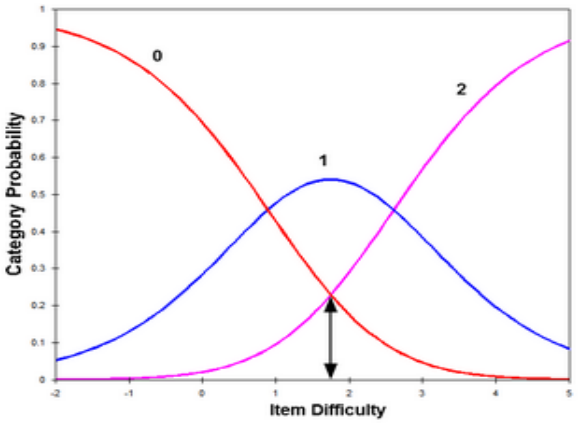
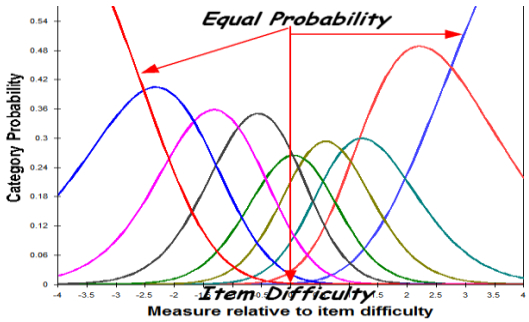
76.	**F. Practical Additive Measurement: Norman Campbell and the Social Scientists**
77.	There was a big argument back in the 1930s. The question being debated was ***"Is psychological measurement possible?"*** The *hard* scientists, the physicists, led by Norman Campbell said "Measurement requires an operation, such as putting lengths end-to-end, or piling up weights. That's the only practical way we can *add (concatenate) one more unit of fixed size to the existing amount*, however large that is. Psychological measurement is impossible because you can't add one more unit of fixed size to measures of intelligence or emotion. You can't concatenate people's heads!"
78.	Norman Campbell laid out the philosophy underlying physics in his book *"Physics: The Elements" (1920).* Measurement is central to physics, and Norman Campbell, a practical man, took an operational view of additive measurement. To paraphrase, **"Measurement means that adding one more unit *adds the same amount* no matter how much there is already."** *"Adding one more unit"* means the simple addition of 1 to the measurement number. But "adds the same amount" is more complicated. It means defining an **operation** that increases the amount we have by a certain, constant amount. For weight, the constant amount is one gram or one pound, and the operation is "piling up". For length, one meter or one foot, and the operation is "putting end to end" (technically "concatenation"). For temperature, the constant amount is one degree, and the operation is "heating". Norman Campbell could not imagine how we could define a unit of attitude and then **construct** a process that would change an attitude by a known amount. Nor could the social scientists, so they gave up .....
79.	The *soft* scientists, the social scientists, led by Stanley Stevens invented their own definition of measurement: "**Measurement** is the **assignment** of numbers to objects or events according to rule" (Stevens, S. S. 1946. *On the theory of scales of measurement. Science,* 103, 677-680). These different definitions of measurement (*measurement by construction* vs. *measurement by assignment*) have caused confusion in Science ever since. For social scientists, any number is a measurement, provided you can imagine some rule that assigns the numbers. For everyone else, measures have to be constructed to conform to the strict objective criteria of arithmetic.
80.	**G. Georg Rasch (1901-1980)**
81.	In the 1950s, Georg Rasch showed how the strict arithmetical measurement criteria of the physical scientists can be applied to social science phenomena. Georg Rasch did this with his Rasch models, which he called "Models for Measurement." Georg Rasch was a poorly-paid mathematics instructor in Denmark who consulted in statistics in order to support himself. He didn't know that social-science measurement is impossible. Instead, he was faced with the practical problems of his clients, problems which needed practical solutions. The Danish Government had a particular problem with their educational tests. Rasch came up with a practical solution based on log-odds transformations. It worked well, but the social scientists found it too complicated (as many still do) and the mathematical statisticians found it too simplistic (as many still do). So Georg Rasch made little progress with his measurement ideas until he was invited to present a course of lectures at the University of Chicago in 1960. Only one person attended all the lectures and that was Benjamin D. Wright, and even he had more pressing things to do for the next few years. Then, in 1964, Ben had some data analysis problems of his own, and thought that perhaps Georg Rasch would have some ideas how to solve them, and, besides, a trip to Denmark would be fun. This got Ben interested again and ... but you can read the full story (*Optional Reading* at #149) - and it was Ben who spread the Rasch "model for measurement" around the world ...

82.	So, what had Georg Rasch discovered, invented, constructed, that was able to overcome Norman Campbell's objections? Georg Rasch had devised a model that can be used to "concatenate heads" in a psychological way that parallels Campbell's method of "concatenating rods" in a physical way. If you want to read about how this can be done, and obtain other insights into what "measurement" really means, read *Optional Reading* at #149.
83.	You may be wondering: "I signed up to learn a statistical method, why are we wasting time with history and philosophy?" Lord Acton (1832-1902) answera: "The knowledge of the past, the record of truths revealed by experience, is eminently practical, is an instrument of action, and a power that goes to the making of the future." Especially in the area of social-science measurement, old misconceptions continually afflict us, and we find ourselves in disputes that should have been resolved long ago. For instance, the constructed-additive-measures of Rasch models contrast with the assumed-additive-scores of "classical test theory" (see *Optional Reading* at #149) and the assumed-additive-measures of most "Item Response Theory" models (see *Optional Reading* at #149).
84.	

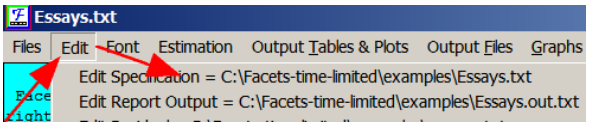
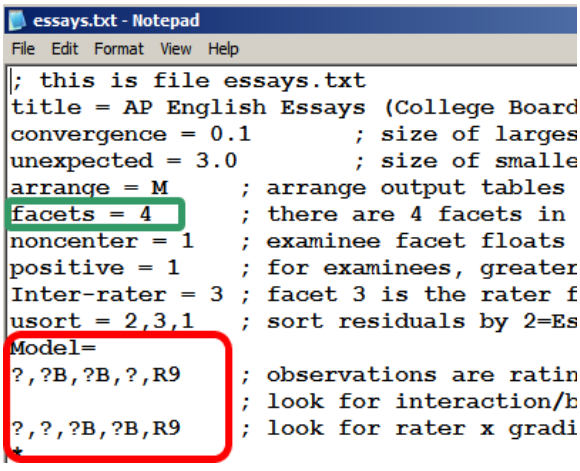
85.	**H. The Rasch Dichotomous Model**	
86.	Georg Rasch presents several mathematical models in his book *"Probabilistic Models for Some Intelligence and Attainment Tests" (Chicago, 1980)* (see *Optional Reading* at #149). His model for dichotomous (right/wrong, yes/no, present/absent) responses by persons to items has become known as "***the*** Rasch model". Georg Rasch wrote it in multiplicative form using Greek letters. Later authors wrote it in exponential form also using Greek letters. But both of these obscure the essential additive process, so I prefer to write the model in log-odds form using the more familiar Latin (Roman) letters.	
87.	The **Rasch dichotomous model** specifies the probability, P, that person *n* of ability B_n succeeds on item *i* of difficulty D_i	$\log_e(P_{ni}/(1-P_{ni})) = B_n - D_i$ addition and subtraction are "additive"
88.	*Probability:* I think in "frequentist" terms. The probability of an event is the proportion of times the event would happen if we could repeat the operation a great many times. So a probability is always between 0 (never happen) and 1 (always happen). P is the probability of success, and 1-P is the probability of failure. Since either success or failure must always happen, when we add their probabilities they must sum to: 1 = (P) + (1-P)	
89.	**I. Probabilities, Logarithms and the Rasch Model**	
90.	To help understand other Rasch models, let's be explicit that success is a score of "1", and failure is a score of "0" on an item. Then the **Rasch dichotomous model** specifies the probability, P_{ni1}, that person *n* of ability B_n succeeds (scores 1) on item *i* of difficulty D_i and similarly P_{ni0} is the probability of failure (scores 0).	$\log_e(P_{ni1} / P_{ni0}) = B_n - D_i$ $P_{ni1} + P_{ni0} = 1$
91.	*Additive Measurements:* B_n and D_i are distances in "logits" (equally-sized log-odds units) along the latent variable (what we are measuring) relative to the local origin (our choice of starting point). A "latent variable" is something which we can have more or less of, but which we cannot measure directly, such as "mathematics ability" or "patient quality of life". We conceptualize it to be a straight line marked out in equal-interval units. *"Logits"* are *"log-odds units":* Look at the Rasch equations. On the left is "$\log_e$", this means the "natural (or Napierian) logarithm". For more about logarithms, look at **Appendix 4**. The logarithm is computed for P_{ni1} divided by P_{ni0} which is the ratio of two probabilities. A ratio of probabilities is called the "odds". So, on the left-side of the equation we have log(odds). These provide the units for the arithmetic on right-side of the equation, so B_n and D_i are measured in "log-odds units", abbreviated "logits"	
92.	What if the probability of success is the same as the probability of failure? Then both probabilities are 0.5. The odds of success are 0.5/0.5 = 1, and the logarithm of the odds is log(1) = zero. The difference between ability and difficulty is zero. So the ability and the difficulty are the same. *Exactly what we expect!* When I encounter an item of exactly the same difficulty as my ability, I can't predict whether I'm going to succeed or fail. My prediction would be like tossing a coin ...	$P_{ni1} + P_{ni0} = 1$ $P_{ni1} = P_{ni0} = 0.5$ $\log_e(P_{ni1} / P_{ni0}) = \log_e(0.5 / 0.5) =$ $\log_e(1) = 0 = B_n - D_i$ $B_n = D_i$

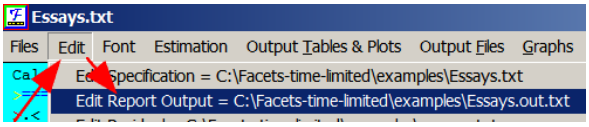
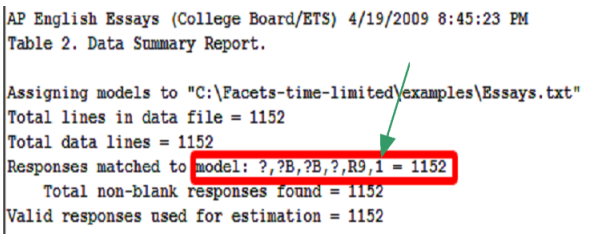
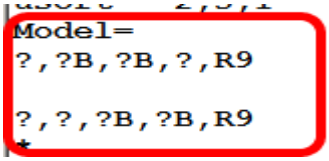
93.	If I'm sure to succeed, then my probability of success is 1 and my probability of failure is zero. My logit ability B_n will be plus-infinity relative to any item of finite difficulty, D_i I am infinitely more able than the item is difficult.	$P_{ni1} + P_{ni0} = 1$ $P_{ni1} = 1, P_{ni0} = 0$ $\log_e(P_{ni1} / P_{ni0}) = \log_e(1 / 0) =$ $\log_e(\infty) = +\infty = B_n - D_i$ $B_n = +\infty$
94.	If I'm sure to fail, then my probability of success is 0 and my probability of failure is one. My logit ability B_n will be minus-infinity relative to any item of finite difficulty, D_i I am infinitely less able than the item is difficult.	$P_{ni1} + P_{ni0} = 1$ $P_{ni1} = 0, P_{ni0} = 1$ $\log_e(P_{ni1} / P_{ni0}) = \log_e(0 / 1) =$ $\log_e(0) = -\infty = B_n - D_i$ $B_n = -\infty$
95.	Suppose I, am 1.1 logits more able, B_n , than the item is difficult, D_i , then my log-odds of success on the item are 1.1. My odds of success are exp(1.1) = 3 successes for each 1 failure. My probability of success is 3/(3+1) = .75 and my probability of failure = .25. Then, on average, I will succeed on items of that difficulty 75 times out of 100.	Ability - Difficulty: $B_n - D_i = 1.1$ Log-odds: $\log_e(P_{ni1} / P_{ni0}) = 1.1$ Odds: $P_{ni1} / P_{ni0} = e^{1.1} = 2.718^{1.1} = 3$ Probabilities sum to 1.0: $P_{ni1} + P_{ni0} = 1$ Success: $P_{ni1} = 0.75$ Failure: $P_{ni0} = 0.25$
96.	We can draw a picture of the relationship between ability and probability. It is called the "logistic ogive", as shown in the adjacent plot. I've shown on the plot how an ability advantage of 1.1 logits is equivalent to a probability of success of 0.75. And a zero logit difference corresponds to a 0.5 probability of success. The logistic ogive has an interesting history of its own: (see *Optional Reading* at #149).	

97.	**J. Rasch Polytomous Models**	
98.	In performance assessment, we encounter rating scales (such as: *none, some, plenty, all)* more often than dichotomies *(yes, no)*. So we are interested in models (mathematical conceptualizations) for rating scales. The family names for this is "polytomous models". "Poly-tomous" means "many cuts". Y "Dicho-tomous" means "two cuts" = "right / wrong", "yes / no". "Tricho-tomous" means "three cuts" = "no / perhaps / yes", "against / neutral / in favor". A Likert scales has "5 cuts" = "strongly disagree / disgree / neutral / agree / strongly agree".	
99.	**K. The Rasch-Andrich Rating Scale Model**	
100.	David Andrich (now at the University of Western Australia) published a conceptual break-through in 1978. He perceived that a rating scale could be thought of as a series of dichotomies. Each pair of adjacent categories forms a local "higher category / lower category" dichotomy within the rating scale.	
101.	The **Rasch-Andrich Rating Scale Model** specifies the probability, P_{nij}, that person *n* of ability B_n is observed in category *j* of a rating scale applied to item *i* of difficulty D_i as opposed to the probability $P_{ni(j-1)}$ of being observed in category *(j-1)*	$\log_e(P_{nij} / P_{ni(j-1)}) = B_n - D_i - F_j$ The rating scale $\{F_j\}$ is the same for every item
102.	We now have a new location on the latent variable, F_j, the "**Rasch-Andrich threshold**", also called the "step calibration" or "step difficulty" or Greek letter τ "tau". It is the point on the latent variable (relative to the item difficulty, D_i) where the probability of being observed in category j equals that of being observed in category j-1. This plot shows the probability curves for each category of the rating scale in Essays.txt, according to the Rasch model.	
103.	We can look at these curves. Click on the *Facets* menu bar, "Graphs" menu, These curves display in the Graph window. We'll talk much more about these curves.	

104	In the Rasch-Andrich model, the rating scale structure {Fj} is defined to be the same for all items. This is ideal for many applications, such as Likert scales *(Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree),* where the response structure for each item is intended to be the same. Then the probability curves (the rating scale structure) slide up and down the latent variable to match the item difficulty. Here is an example from the 3-category "Liking for Science" data, lfs.txt. This is a more difficult (challenging) item, so the rating scale structure is located at the black arrow, around the item difficulty of D_i = 1.75 logits *relative to the latent variable* ("absolute")	 Item difficulty is where "the top category = the bottom category" probabilities
105	How do rating scale structures align with item difficulty? The answer is simple: the item difficulty is located at the point where the highest and lowest categories are equally probable. In the Figure, the curves are drawn *relative to the item difficulty,* so the item difficulty is at "0" on the plot. This is the point where the highest and lowest categories are equally probable. You can see these curves on your screen.	
106	Please close the Graphs window	

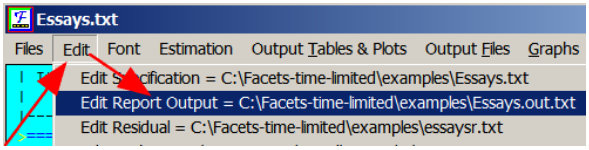
107.	**L. Rasch-Masters Partial Credit Model**	
108.	In 1982, Geoff Masters (now the Chief Executive of the *Australian Council for Educational Research)* went a step further than David Andrich. Geoff was investigating multiple-choice questions and the fact that some distractors (incorrect options) are closer to being correct than others. Shouldn't the examinee obtain "partial credit" for choosing a partially-correct answer? We expect the partial-correctness structure to be different for the different sets of distractors for different items, so Geoff constructed a version of the Rasch rating-scale model where the rating scale (partial-credit scale) is specific to each item.	
109.	The **Rasch-Masters Partial Credit Model** specifies the probability, P_{nij}, that person *n* of ability measure B_n is observed in category *j* of a rating scale specific to item *i* of difficulty measure (or calibration) D_i as opposed to the probability $P_{ni(j-1)}$ of being observed in category *(j-1)*	$\log_e(P_{nij} / P_{ni(j-1)}) = B_n - D_i - F_{ij}$ or $\log_e(P_{nij} / P_{ni(j-1)}) = B_n - D_{ij}$ *the rating scale is unique to the item*
110.	The rating scale structure $\{F_{ij}\}$ is now specific to item *i.* It works exactly like the rating scale structure for the Rasch-Andrich model. But there is a conceptual difference. We can think about the item difficulty and then impose the rating scale structure on it, $\{D_i + F_{ij}\}$, or we can think about the combination, $\{D_{ij}\}$. Mathematically they are the same thing. In MFRM, it is usually more straightforward to conceptualize and communicate the item difficulty separately from the rating scale structure, so we will use the $\{D_i + F_{ij}\}$ notation. The $\{F_{ij}\}$ are called the "Rasch-Andrich thresholds" even when the model is not the Rasch-Andrich model.	
111.	**M. Rating Scale Model for Item Groups**	
112.	Many assessments, observations instruments and surveys are composed of subsets of items which share the same rating scale. For instance, Items 1 to 10 could be Likert "agreement" items. Items 11-20 could be "frequency" items *(never, sometimes, often, always).* Items 21-30 could be "quantity" items *(none, a few, a lot, all).*	
113.	The **Rasch-Grouped Rating Scale Model** specifies the probability, P_{nij}, that person *n* of ability B_n is observed in category *j* of a rating scale specific to a group of items, *g*, applied to item *i* of difficulty D_i as opposed to the probability $P_{ni(j-1)}$ of being observed in category *(j-1)*	$\log_e(P_{nij} / P_{ni(j-1)}) = B_n - D_{gi} - F_{gj}$ *the rating scale is unique to the group of items*
114.	Notice the subscript "g". This specifies the group of items to which item i belongs, and also identifies the rating scale structure that belongs to the group $\{F_{gj}\}$.	
115.	*Facets* also implements Rasch polytomous models for the binomial trials and Poisson counts. These are rarely used.	

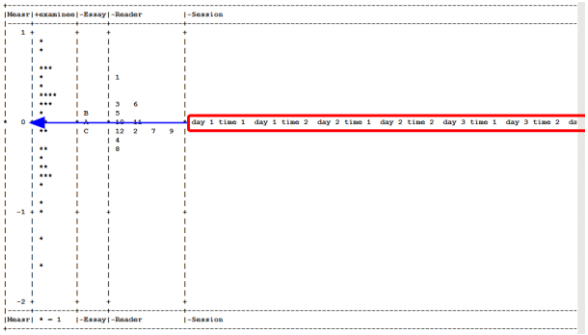
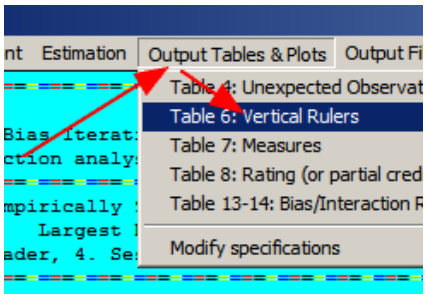
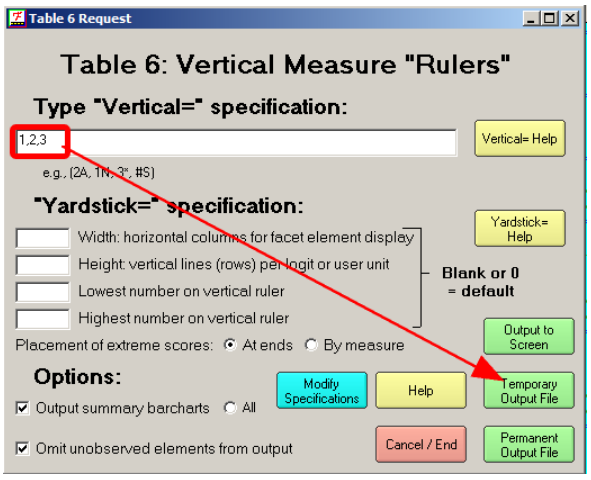
116	**N. Many-Facet Rasch Models**	
117	Rasch Models can be expanded to as many facets as we like. The essential aspect is that the *measures* of the *elements* of the *facets* add (or subtract) to produce the *observations:* Two facets: persons and items Three facets: persons, items and raters Four facets: persons, items, raters and occasions, or persons, items, raters and tasks Five facets: persons, items, raters, occasions, tasks Six facets: persons, ... also One facet: tennis players or chess players or paired comparisons	
118	Here is a **Many-Facet Rasch Model**. It specifies the probability, P_{njimk}, that "person *n* of ability B_n is observed by judge j of leniency L_j in category *k* of item *i* of difficulty D_i while performing task *m* of difficulty T_m" as opposed to the probability $P_{njim(k-1)}$ of the person being observed in category *(k-1)*. *You can see that these can become complicated, so it is helpful to think in terms of the phyical situation.* Here is an example: "Suzie (n, person) is rated as 3 (k, category) by Prof. Chin (j, judge) on grammar (i, item) in Essay C (m, task)" But, if you think of judges as "more or less severe", S_j, instead of "more or less lenient", L_j, then the direction (and mathematical sign, + or -) of the judge's leniency/severity measure is reversed.	Judge Leniency, L_j $\log_e(P_{njimk} / P_{njim(k-1)}) = B_n + \mathbf{L_j} - D_i - T_m - F_k$ or Judge Severity, S_j $S_j = -L_j$ so that $\log_e(P_{njimk} / P_{njim(k-1)}) = B_n - \mathbf{S_j} - D_i - T_m - F_k$
119	**O. The Models= Specification**	
120	Now let's look at the *Essays.txt* specification file. Do you remember how to get there? Of course, you do! It may be on your task bar. Or this picture gives you a clue →	
121	Essays.txt displays in a NotePad window .... **green box: facets=4**, so the data are conceptualized to have been produced by an additive combination of the elements of 4 facets. "Additive" means combined by addition and subtraction, not by multiplication nor division nor by any other way. red box: Now we are interest in the section starting *Model=* This specifies exactly which Rasch models are to be used. The first model is: **?,?B,?B,?,R9** The B's control a secondary analysis. We can ignore them right now, so the active Model= specification is: Model= ?,?,?,?,R9	

122.	Model= ?,?,?,?,R9 Notice there are 4 ?'s. These correspond to the 4 facets. The first ? controls the selection of elements in the first facet. The second ? controls the second facet, and so on. ? means "any element". So the first ? means "any element of facet 1". The final R9 specifies what are valid observations. R9 means "on a rating scale whose highest category is category 9 (or less)." This prevents Facets analyzing numbers greater than 9, such as data-entry errors, as valid data. But allows any numbers less than or equal to 9, such as a rating scale of 1, 2, 3. ?,?,?,?,R9 means "any element of facet 1 adds to any element of facet 2 adds to any element of facet 3 adds to any element of facet 4 producing an observation on a rating scale whose highest category is 9 or less." All the data will match this model specification, so the second model specification ?,?,?B,?B,R9 is only there for the secondary "B" analysis. We can ignore it for now.	
123.	Close the NotePad edit window	
124.	**P. *Facets* Output: Table 2**	
125.	Look at the *Facets* Report Output file, *Essays.out.txt* It may be on your Windows task bar. If you have closed it, you can open it again from the *Facets* Edit menu.	
126.	Table 2 is informative. It tells us how many of the observations in our data file matched our model specification. In this example all 1152 did. This is what we intended. Do you see it says the model specification is ?,?B,?B,?,R9,1 This is what we put in our specification file, except for the ",1". This is the default value assumed by *Facets* and means "every observation matched to this model is given a weight of 1". This is usually what we want.	
127.	Since all observations matched the first model specification, there were no observations left over for the second model specification in Essays.txt (see adjacent picture), so it is not shown in Table 2. In the model specifications, the Bs control a secondary bias/interaction analysis (which is a feature of a later Tutorial). Here, we want to look for bias between facets 2 and 3, and then bias between facets 3 and 4. So we need an extra model specification for this.	

128	But let's imagine a situation where the two model specifications differ. Item 1 is a dichotomy, all the rest of the items are polytomies sharing the same rating scale: Models= ?, ?, 1, D ; the dichotomous item: element 1 of facet 3 ?, ?, ?, R4 ; all the other items are polytomies 1, 2, 1, M ; another model specification * Here is what happens: Facets reads the observations from the Data=. Each observation is matched with the Models= specifications, **starting from the top of the list.** All the responses to item 1 (facet 3) will match the first model specification: ?, ?, 1, D All the responses to the other items will not match the first model specification, but will match the second: ?, ?, ?, R4 There will be no unmatched observations for the third model specification: 1, 2, 1, M But Models= 1, 2, 1, M ; "M" means: "treat as missing data" ?, ?, 1, D ; the dichotomous item: element 1 of facet 3 ?, ?, ?, R4 ; all the other items are polytomies * Some observations will match the first model specification: 1, 2, 1, M Others will match the second model specification: ?, ?, 1, D Everything else will match the third model specification: ?, ?, ?, R4

129	**Q. A Quick Glance at Measure Estimation**	
130	*Model*= specifies how the data are imagined to be produced by the element measures. X_{nirs} is the "observation" or the "data point" or the "rating" produced when examinee *n (of ability B_n)* writes essay *i (of difficulty D_i)* and is rated by reader *r (of severity R_r)* in session *s (of challenge S_s)* using a rating scale defined by its Rasch-Andrich thresholds $\{F_k\}$.	Model equation: $B_n - D_i - R_r - S_s - \{F_k\} \rightarrow X_{nirs}$
131	*"Saying the algebra out loud"* - Algebra is like shorthand. It can be fast and convenient. But it can also be easily misunderstood. So please say your Model= equations out aloud, giving the meanings of the cryptic terms, such as B_n, to make sure the model specifies what you intend.	
132	But we don't have those measures. We only have the data. So we have to run the model backwards, from the data toward the estimates of the measures. In the estimation equation, the ^ (the "hat") above the letter means "This is only an estimate!" We will discover whether it is good estimate, or a bad estimate, by means of fit statistics.	Estimation equation: $X_{nirs} \Rightarrow \hat{B}_n - \hat{D}_i - \hat{R}_r - \hat{S}_s - \{\hat{F}_k\}$
133	Look at Essays.out.txt, the Report Output Table, scroll down to **Table 3. Iteration Report.** This shows the progress of the estimation process. *Facets* makes an initial guess at each of the measures. *Facets* then uses the model equation to "predict" the first observation. This predictions is compared with the real observation. *Facets* does this for every real observation. This process is called an "iteration through the data". Table 3 shows the summary statistics produced at the end of each of 35 iterations through the data.	**Table 3. Iteration Report.** +---+ | Iteration | Max. Score Residual | Max. Logit Change | | | Elements % Categories | Elements Steps | |---| | PROX 1 | -1.3350 | | PROX 2 | .0165 | | JMLE 3 142.6080 20.3 -244.1686 | .5983 2.4617 | | JMLE 4 -48.8685 -11.4 12.9068 | -.2959 .1707 | | JMLE 5 -28.6433 -4.5 17.3535 | -.1272 -.1596 | ..... | JMLE 33 .1277 .0 .0531 | -.0006 -.0006 | | JMLE 34 .1095 .0 .0450 | -.0005 -.0005 | | JMLE 35 .0914 .0 .0381 | -.0004 -.0005 | +---+
134	At the end of each iteration through the data, *Facets* improves the estimated measures. The improvement is based on the differences between the person, item, rater, etc., raw scores for the predicted data and the person, item, rater, etc., raw scores for the real data. The raw scores are the "marginal sums of the scored responses" for the examinees, essays, readers. For categories, the raw scores are the counts of observations in each category. *Facets* does this iterative process until the differences between the predicted raw scores and the actual raw scores are negligibly small. For Essays.txt this takes 35 iterations, and the worst of the final very small differences are shown. When the differences are too small to matter, the iterative process has "converged", and the final set of estimates of the measures is reported. **"Score":** Sometimes "score" means "score on an item by a person" = "data point, observation, scored response". Sometimes "score" means "raw score" = "marginal score, marginal sum of all the scored responses by a person (or all the scored responses to an item)".	
135		

136	**R. Table 7: Measures**	
137	Look at the *Facets* Report Output file, Essays.out.txt If you have closed it, you can always open it again from the *Facets* Edit menu.	
138	Scroll down to **Table 7.1.1** Here we see scores, counts, measures (abilities) and other statistics for the examinees. red box: At first, the "Measure" column is unfamiliar. The numbers are in logits. **green box:** The measures for low scores are negative, and the measures for high scores are positive. And there are decimal places. So the measures do look somewhat like temperatures. And, just like temperatures, the measures are on an equal-interval scale (one more score-point means the same amount extra on the latent variable, no matter what the measure is). Raw scores and percentiles are not equal-interval. One more score-point in the middle of the range usually means less than one more score-point near the extremes.	Table 7.1.1 examinee Measurement Report +----------------------------------- | Total Total Obsvd Fair-M| | Score Count Average Avrage|Measure |-----------------------------+------- | 96 36 2.7 2.66| -1.62 | 111 36 3.1 3.08| -1.25 ....| | 218 36 6.1 6.06| .64 | 229 36 6.4 6.37| .82 | 235 36 6.5 6.54| .92 |-----------------------------+------- **green box:** The lowest observed total score for an examinee is 96. This corresponds to the lowest ability measure, -1.62.
139	Scroll down to **Table 7.2.1**. red box: These are the measures (difficulties) for the essays. Look at the observed scores, the sum total of all the ratings of that essay (across all examinees and readers). **green box:** The highest observed score is 1913 this corresponds to the lowest difficulty measure, -.11. Do you notice? For Facet 1, the examinee abilities, low score → low measure, but for Facet 2, the essay difficulties, high score → low measure.	Table 7.2.1 Essay Measurement Report (a +----------------------------------- | Total Total Obsvd Fair-M| | Score Count Average Avrage|Measure |-----------------------------+------- | 1913 384 5.0 4.92| -.11 | 1854 384 4.8 4.76| -.02 | 1762 384 4.6 4.51| .13
140	How does *Facets* know to do this? The answer is the specification in our specification file, *Essays.txt:* *Positive = (or Negative =).* *Positive=1* means facet 1 is positive: "higher score implies higher measure", but all other facets are negative: "higher score implies lower measure"	; examinee facet floats positive = 1 ; for examinees, greater Inter-rater = 3 : facet 3 is the rater f or Negative = 2, 3 ; facets 2 and 3 are negative
141	In education, the usual convention is "abilities are positive, all other facets are negative." But in healthcare, the usual convention is "all facets are positive". This is set by	all facets are positive: Positive = 1, 2, 3, 4, 5, ... or Negative = 0 ; no facets are negative
142		

143	**S. Table 6: The Measure "Rulers"**	
144	Mentally picturing the measures in Table 7 can be difficult, and comparing the measures of the different facets can be overwhelming, so, in Essays.out.txt we scroll to Table 6.0, the "All Facet Vertical Rulers". Oops! Table 6 has disappeared to the right of my screen. The problem is facet 4, Session. This is a "dummy" facet. All its elements have their measures anchored (fixed) at 0 logits. In Table 6.0, it is a long line at 0 logits. It is telling us nothing. So let's remove it from Table 6.	
145	On the *Facets* menu bar, Click on "Output Tables & Plots" Click on "Table 6: Vertical Rulers"	
146	In the Table 6 dialog box, we only want to show facets 1 (examinees), 2 (essays) and 3 (readers) so red box: type **1,2,3** into the "Vertical=" specification box (to replace "Y"). We only want to glance at our new output, so there is no need to make a permanent copy of it: Click on "Temporary Output File" If you want to find out more about **Vertical=**, click on the "Vertical= Help" button.	

147 Table 6.0 displays.
On the left is the measurement "ruler", labeled "Measr". Its values are in logits. Then each column shows the elements of a facet positioned on the ruler.

red box: Look at the column heading "+examinee". "+" means that the examinees are oriented so that ***higher** scores mean higher measures.* Examinee 10 had the top score.

green box: Look at the column heading "-Essay". "-" means that the Essays are oriented so that ***lower** scores mean higher measures.* Essay B has the highest measure, so it has the lowest score. It is the most difficult essay.

green box: Look at the column heading "-Reader". Is reader 1 the most lenient reader, giving the highest ratings? Or the most severe rater giving the lowest ratings?

"-" means "low score implies high measure". Reader 1 has the highest measure, so must have the lowest overall score. This means Reader 1 gave the lowest ratings and so is the most severe rater.

blue box: On the right-hand side is a representation of the rating scale from 1 to 9. Notice that categories 3, 4, 5 and 6 are of different lengths. Each category corresponds to a different amount of the latent variable.

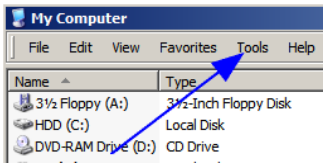
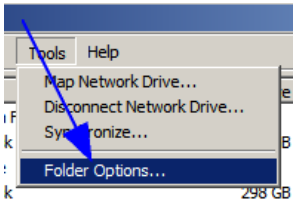
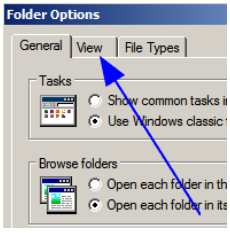
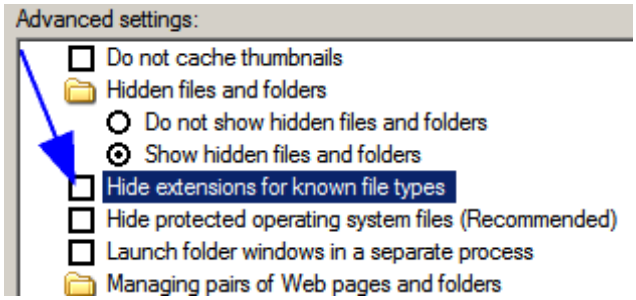
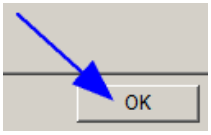
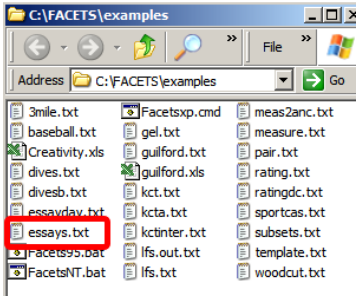
```
AP English Essays (College Board/ETS)  04-13-2007 03:48
Table 6.0  All Facet Vertical "Rulers".

Vertical = (1A,2A,3A,S) Yardstick (columns lines low hi
------------------------------------------------------
|Measr|+examinee        |-Essay|-Reader          |Scale|
------------------------------------------------------
+   1 +                +      +                + (9) +
|     | 10             |      |                | --- |
|     | 1              |      |                |     |
|     |                |      |                |     |
|     | 19  22  26     |      |                |  6  |
|     | 20             |      | 1              |     |
|     | 15             |      |                |     |
|     | 13  23  7   8  |      |                | --- |
|     | 16  5   6      |      | 3   6          |     |
|     | 12             | B    | 5              |  5  |
*   0 * 25  32         * A    * 10  11         *     *
|     | 17  9          | C    | 12  2   7   9  |     |
|     |                |      | 4              | --- |
|     | 11  30         |      | 8              |     |
|     | 18             |      |                |     |
|     | 3   4          |      |                |     |
|     | 14  2   28     |      |                |  4  |
|     | 27             |      |                |     |
|     |                |      |                |     |
|     | 21             |      |                | --- |
+  -1 + 29             +      +                +     +
|     |                |      |                |     |
|     | 31             |      |                |     |
|     |                |      |                |  3  |
|     |                |      |                |     |
|     |                |      |                |     |
|     | 24             |      |                |     |
|     |                |      |                |     |
|     |                |      |                | --- |
|     |                |      |                |     |
+  -2 +                +      +                + (1) +
------------------------------------------------------
|Measr|+examinee        |-Essay|-Reader          |Scale|
------------------------------------------------------
```

148

149 *Optional readings:*
#81 - Georg Rasch and Ben Wright: the early years: http://www.rasch.org/rmt/rmt0.htm
#82 - Measurement and Concatenation: *"Measurement, Meaning and Morality"* - http://www.rasch.org/memo71.pdf
#83 - Classical Test Theory (CTT): http://en.wikipedia.org/wiki/Classical_test_theory
#83 - Item Response Theory (IRT): http://en.wikipedia.org/wiki/Item_response_theory
#86 - *"Probabilistic Models for Some Intelligence and Attainment Tests" (Chicago, 1980)* Foreword: http://www.rasch.org/memo63.htm - Book at: http://www.rasch.org/models.htm
#96 - History of the logistic ogive - http://www.rasch.org/rmt/rmt64k.htm

150 Close all windows.

Appendix 1. Displaying file name suffixes

On your desktop, click on **My Computer** or any folder	
Click on **Tools**	
Click on **Folder Options**	
Click on **View**	
Un-check **"Hide extensions for known file types"**	
Click on **OK**	
Close unwanted windows	
Suffixes will now display in folder file lists	

Appendix 2. Changing the text appearance in NotePad

Oops! A Table may display too big or ragged.
We need to display this text in a fixed-space font, such as Courier New, and also a smaller font so everything fits in the window.

```
|ENTRY   RAW                      MODEL|  INFIT  | O
|
|NUMBER SCORE COUNT MEASURE S.E.
OBS% EXP%| ACT                          |
|-----------------------------------+----------+----------+-
```

On the NotePad menu bar,
Alt+O or click on Format pull-down menu
Alt+F to change the Font
Font: Courier New
Font style: Regular
Font size: 7 (You can type in values not listed)

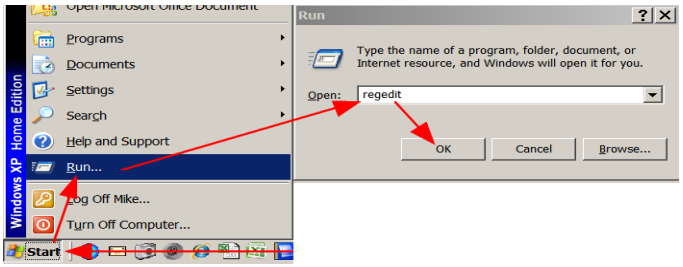
The Table now displays neatly

Alter the Font size if the Table is too big or too small.

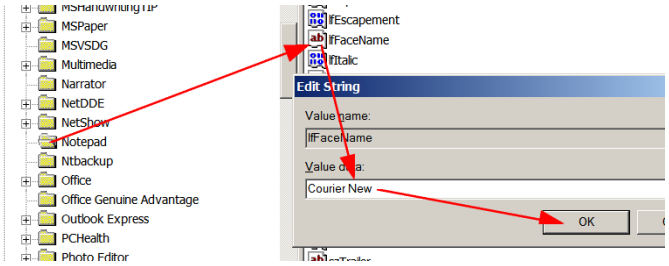
```
|ENTRY    RAW                      MODEL|    INFIT   |   OUTFIT  |PTMEA|EXACT MATCH|                                  |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%  EXP%| ACT                              |
|-----------------------------------+----------+----------+-----+-----------+----------------------------------|
|     23     40     74      2.18    .21|2.41   6.3|4.11   9.0|  .00| 40.5  65.0| Watch a rat                      |
|      5     35     74      2.42    .22|2.30   5.6|3.62   7.3|  .05| 52.7  68.1| Find bottles and cans            |
|     18    143     74     -3.15    .47|1.50   1.2|1.23    .5|  .14| 94.6  93.4| Go on picnic                     |
|     19    139     74     -2.48    .36|1.08    .4|1.10    .4|  .30| 90.5  88.0| Go to zoo                        |
|     20     48     74      1.83    .20|1.33   2.0|1.82   3.7|  .42| 54.1  61.1| Watch bugs                       |
|     12    135     74     -2.04    .31| .70  -1.2| .51  -1.0|  .45| 86.5  83.7| Go to museum                     |
|     13    125     74     -1.29    .25|1.22   1.1| .94    .0|  .47| 78.4  74.3| Grow garden                      |
|     10    128     74     -1.49    .26| .78  -1.1| .57  -1.1|  .50| 78.4  77.1| Listen to bird sing              |
|      8     52     74      1.67    .20|1.10    .7|1.21   1.2|  .51| 47.3  59.0| Look in sidewalk cracks          |
|     16     81     74       .60    .19| .97   -.2| .95   -.3|  .51| 60.8  57.3| Make a map                       |
```

To make permanent (default) changes in NotePad font face and size:

Windows "Start"
Click on "Run"
Type in "regedit"
Click on “OK”

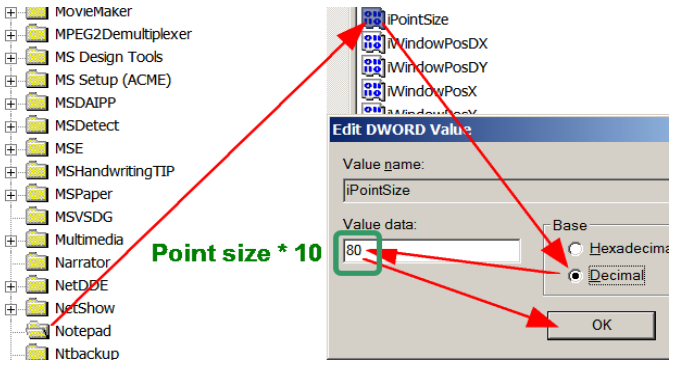


Registry Editor:
Click on the + in front of "HKEY_CURRENT_USER”
Click on the + in front of “Software”
Click on the + in front of “Microsoft”
Click on “Notepad"
For the type face:
Double-click on "lfFaceName"
Type in “Courier New”
Click on “OK”



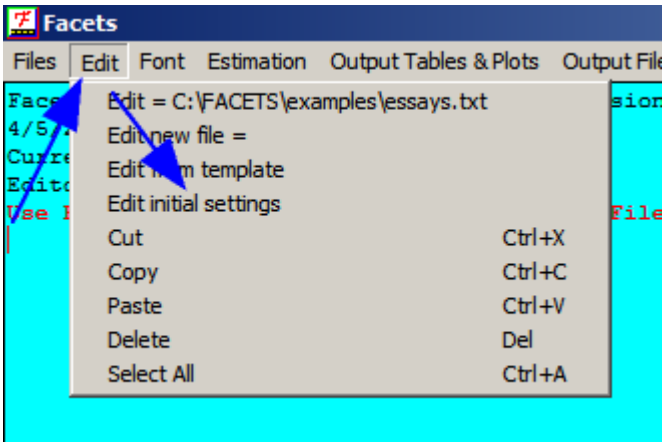
For the font size:
Double-click on "iPointSize"
Click on "Decimal"
Type in 80 (for point-size 8 multiplied by 10)
Click on “OK”

Close registry 

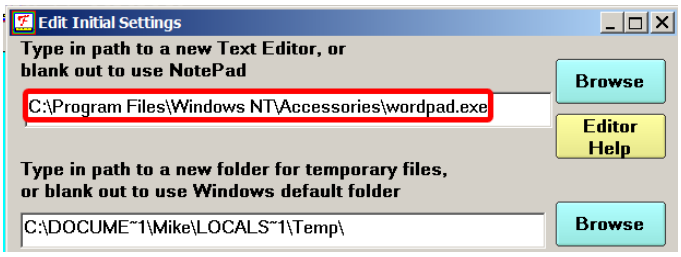


Appendix 3. Changing the text-editor used by *Facets*

In the *Facets* main window,
Click on **"Edit"**
Then
Click on **"Edit initial settings"**

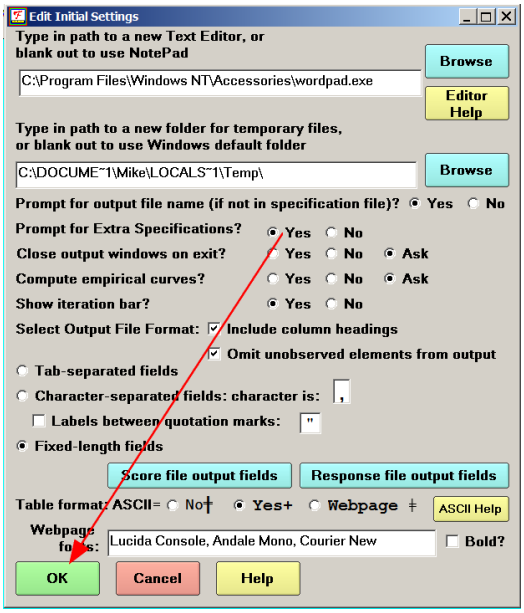


In the top box, type in the path to your preferred text editor, or use the Browse button to locate it.
I've entered the path to WordPad on my computer.



Then click **OK** to save this setting.

The next file you access from the "Edit" menu will be opened by your specified editor



Appendix 4. What are Logarithms?

Let's start with squares, 2 x 2 = 4 and cubes, 2 x 2 x 2 = 8 We can see that it takes two 2's to make 4 so let's write them 2^2 and it takes three 2's to make 8 so let's write them 2^3. Then what about $2^{2+3} = 2^5$?	$2^2 = 2 \times 2 = 4$ $2^3 = 2 \times 2 \times 2 = 8$ $2^{2+3} = 2^5 = 2 \times 2 \times 2 \times 2 \times 2 = 32 = 4 \times 8 = 2^2 \times 2^3$
The superscripts ^{2} and ^{3} are called "powers", and we've discovered that multiplying numbers is the same as adding powers. We can do this with non-integers:	$1.4142 \times 1.4142 = 2 = 2^1 = 2^{1/2} * 2^{1/2}$ $1.4142 = 2^{1/2}$ = square-root(2)
And powers work for negative numbers	$2^1 = 2 = 4 / 2 = 2^2 / 2^1 = 2^2 * 2^{-1} = 2^{2-1}$
So, we have the general rule of powers of 2:	$2^{x+y} = 2^x * 2^y$
This works exactly the same way if we change the "base" value from 2 to 10.	$X = 10^x$ $Y = 10^y$ $X * Y = 10^{x+y}$ $10^{x+y} = 10^x * 10^y$
Now x and y are called "exponents" and "10" the base. So this is an "exponential" form.	$X * Y = 10^x * 10^y = 10^{x+y}$
We can rewrite this "exponential" form into "logarithmic" form. "Log" is short for "Logarithm".	$\log_{10}(X) = \log_{10}(10^x) = x$ $\log_{10}(X) = \log_{10}(10^y) = y$ $\log_{10}(X*Y) = \log_{10}(10^{x+y}) = x+y$
This is very useful. We can transform a multiplication X*Y into and addition log(X) + log(Y). This saves a huge amount of effort when the multiplication is done by hand, and was why logarithms were invented around 1617.	$\log_{10}(10^x) + \log_{10}(10^y) = x+y = \log_{10}(10^{x+y})$ $\log_{10}(X) + \log_{10}(Y) = x+y = \log_{10}(X*Y)$
In Rasch work, we use a special base, called "e". This has the value e = 2.718.... And the logarithms are then called "natural" or "Napierian" logarithms.	$2.3026 * \log_{10}(X) = \mathbf{\log_e(X)}$ $\log_{10}(X) = 0.4343 * \mathbf{\log_e(X)}$
Once we alert the reader what base we are using, "e" from here on, we can omit it.	$\log(X) + \log(Y) = \log(X*Y)$
Here are some important facts about logarithms: the logarithm of 1 is zero	$\log(1) + \log(1) = \log(1*1) = \log(1)$ so $\log(1) = 0$ this is the same as saying $x^0 = 1$
the logarithm of plus infinity is infinity	$\log(\infty) = \infty$
the logarithm of zero is minus infinity	$\log(0) = -\infty$
the logarithm to the base "e" of "e" is 1	$\log_e(e) = 1$
the logarithms of negative numbers don't exist	log (-1) = Oops!