Thesis Writing for Scientists and Engineers
The Results and Discussion Sections

I: SITUATING THE RESULTS/DISCUSSION

A Master's level dissertation that has a clear single experimental focus may be organised to follow a very simple linear structure where different chapters present different aspects or stages of the research process.

Here is an example from Metallurgy and Materials:

When reporting on a complex research project with multiple stages, analyses and experiments, a PhD thesis is likely to have more than one section on results and/or discussion.

Task 1

Look at the following example of a chemical Engineering thesis investigating ice cream.

Highlight the various sections where results are presented and discussed. Also notice how this writer has broken down the discussion sections in each case into sub-sections.

II. THE RESULTS SECTION

Have a quick look at the data in these graphs, taken from a paper:

TABLE 1. The Acquisition of Prescribed Drugs by Men and Women in Different Age Groups

	Measures of Drug Acquisition		
	Percent obtaining ≥1 prescription drug in 2 years	Mean number of different drugs obtained in 2 years	Mean number of prescriptions obtained in 2 years
Ages 18–29			
Men (n = 109)	47	.87	1.48
Women (n = 137)	74*	2.21*	6.81*
Ages 30–44			
Men (n = 124)	49	1.15	2.30
Women (n = 111)	69*	2.07*	7.00*
Ages 45–59			
Men (n = 80)	58	1.46	6.20
Women (n = 90)	68	2.24**	7.32
Ages 60 and over			
Men (n = 81)	65	2.02	10.70
Women (n = 125)	71	2.36	12.96
Total sample			
Men (n = 397)	53	1.31	4.54
Women (n = 465)	71*	2.24*	8.64*
Total (n = 862)	63	1.81	6.73

* Difference between men and women in this age group is significant at $P \leq 0.001$ level.
** Difference between men and women in this age group is significant at $P \leq 0.05$ level.

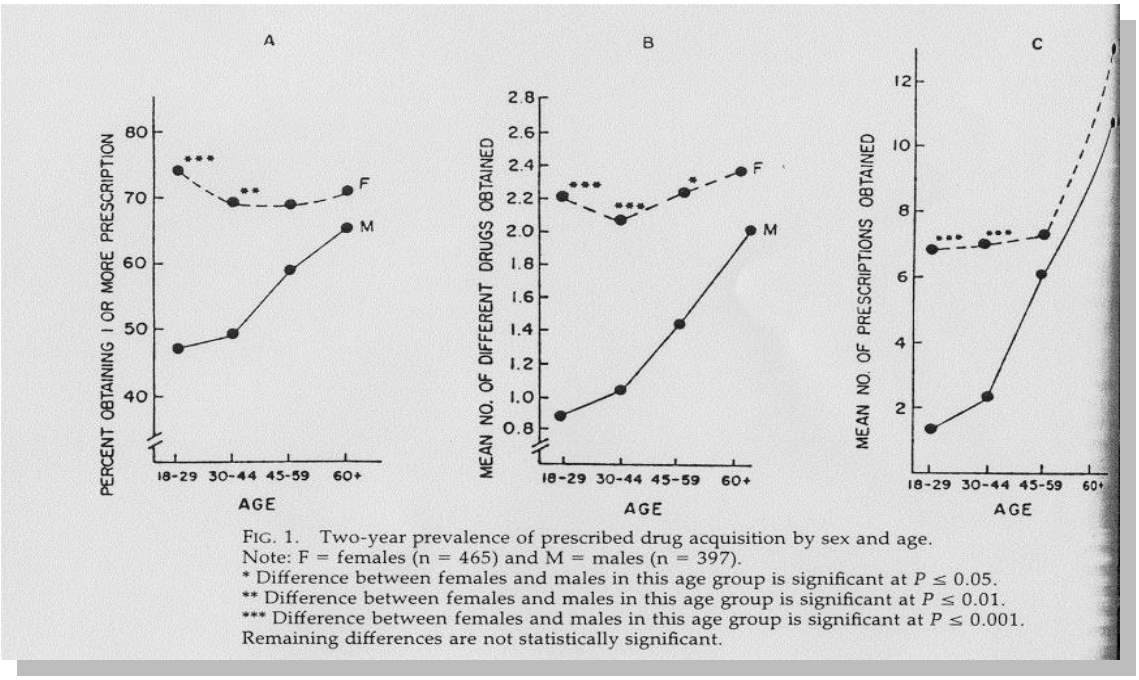

FIG. 1. Two-year prevalence of prescribed drug acquisition by sex and age.
Note: F = females (n = 465) and M = males (n = 397).
* Difference between females and males in this age group is significant at $P \leq 0.05$.
** Difference between females and males in this age group is significant at $P \leq 0.01$.
*** Difference between females and males in this age group is significant at $P \leq 0.001$.
Remaining differences are not statistically significant.

Note that :

1. Both tables and figures have a **legend**. In this paper the legend for a table is above the table while the legend for a figure is below it.

Check what the normal practice in your subject is.

2. **Table** is written out in full while **Figure** is abbreviated to Fig.

Task 2

Read the text taken from the **results section** from this paper. Refer back to the table and figure above.

Discuss with your neighbour in which order the results have been presented:

Sixty-three percent of the sample obtained at least one prescription drug in the 2-year period as measured by the pharmacy records. Seventy-one percent of the women received at least one prescription drug compared to 53% of the men (Table 1). The women also received a higher number of different drugs (X = 2.2 for women and 1.3 for men) and a higher number of original and refill prescriptions (X = 8.6 for women and 4.5 for men). The relationship between gender and drug use acquisition varied by age group. Gender differences were greater during the child-bearing years of 18 to 44 and largest during the peak child-bearing years 18 to 29. All six comparisons between men and women under 45 years old yielded significant differences.

To illustrate the gender by age interactions, we plotted the drug acquisition rates for each sex by age group (fig 1). It can be seen that there are large differences among men and women in the 18 to 29 year old group, but that drug acquisition rates converge in the later years. As expected, men obtained more drugs as they age, presumably as they develop the chronic diseases for which drugs are prescribed. However, the proportion of women obtaining medication and the number of different types of drugs obtained remain fairly high across the life span. Only the number of prescription items increased as women grow older.

Task 3

Discuss together: in what order would you present the following information[i]?

National newspaper circulations for January with percentage change year on year

National Morning Quality, Circulation, Yr/Yr • The Daily Telegraph, 703,249 -9.37 • Financial Times, 400,827 -6.46 • The Guardian, 300,540 -12.38 • The Independent, 186,940 -6.64 • The Times, 521,535 -13.22	**National Sunday Quality, Circulation, Yr/Yr** • Independent on Sunday, 155,460 -4.94 • The Observer, 351,019 -16.49 • The Sunday Telegraph, 525,088 -8.72 • The Sunday Times, 1,113,195 -3.67
National Morning Popular • Daily Mirror, 1,218,425 -10.86 • Daily Record, 323,831 -8.60 • Daily Star, 779,376 1.41 • The Sun, 3,006,565 -4.43	**National Sunday Popular** • Daily Star Sunday, 358,814 -0.20 • News of the World, 2,984,469 -1.54 • Sunday Mail, 395,126 -10.63 • Sunday Mirror, 1,124,620 -9.60 • The People, 532,975 -10.36
National Morning Mid Market • Daily Express, 674,640 -8.38 • Daily Mail, 2,120,347 -3.64	**National Sunday Mid Market** • Sunday Express, 585,023 -9.58 • Sunday Post, 337,398 -7.88 • The Mail on Sunday, 2,048,008 -4.07

III. THE DISCUSSION SECTION

Task 4

Quickly look at the discussion section from the previously mentioned paper and discuss what differences you can immediately see between the Results and Discussion sections.

(Ignore the letters (a) to (g) for now - they refer to the steps described below)

(a) Women obtain more prescribed drugs and prescriptions, but only in some age groups and drug categories. Sex differences are of greatest magnitude in the child-bearing years and in the drug categories that are used to prevent or treat female-specific conditions. **(b)** The disproportionate use of other

prescribed drugs by women also can be attributed to the higher use of drugs by the women who have experienced a full-term pregnancy, female-specific surgical procedures, or other sex-specific diagnoses or complaints (as recorded by the physician).

(c) The results reported here are similar to the findings of other reports based on more objective information. For example, Swedish reports based on pharmacy data show that the difference between male and female drug use in that country varies considerably from one drug class to another, with extremely large differences in the categories associated with women's reproductive role and much smaller differences in the use of expectorants, bronchodilators, cardiovasculars, and other drugs having less association with women's reproductive role. **(c)** A recent US study based on detailed physician reports also showed that 5 of the 10 drugs most frequently ordered for 15 to 24-year old women related to women's reproductive role, including two oral contraceptives, two prenatal vitamins, and a vaginal fungicide. **(c)** Our drug use findings also are similar to findings concerning sex differences in physician utilization. For example, we have found that simply excluding women who gave birth during the study significantly narrowed sex differences in use of outpatient facilities. **(c)** Earlier studies seem to have substantially exaggerated the magnitude of sex differences in physician utilization and medication use and provide little basis to support the hypothesis of physician bias.

(d/e) There are several possible reasons why we found only a slight sex difference in Psychotherapeutic drug use. Unlike many studies documenting the higher use of psychotropic drugs among women, we avoided the use of self-report and proxy respondents. Second, our study was conducted in a rural and culturally homogeneous area that is served by a highly regarded and accessible multispecialty group practice and its affiliates. It is possible that psychosocial factors may play a much more important role in other geographic areas or among other groups of patients and physicians. For example, we have noted a significant association between reported psychological distress and the use of nonprescription meditation in this population. One plausible interpretation for these findings is that the people in this area are more stoic and less likely to use the medical care system in response to psychological distress, preferring self-medication and other nonmedical methods of coping.

(d) It is important to note other limitations of investigations of this type. First, the sample was small, and there was some attrition as a result of patient and pharmacist refusal. However, we have no reason to believe that our conclusions were substantially affected by this attrition. Most important, we

had no fully objective assessment of physical condition despite access to medical records. Nor did we evaluate the appropriateness of the drugs that were prescribed. **(d)** Therefore, we cannot exclude the possibility that younger men had many problems that went unrecognized and untreated. Nor can we say that the women really needed all the drugs they received, that the disproportionate use of drugs among young women was solely related to their reproductive role, or that psychosocial factors were irrelevant to the ways in which their care was delivered. Despite all of the adjustments, the female rate of drug acquisition remains slightly higher, especially in younger age groups. **(f)** Thus, it is likely that both physical and psychosocial factors influence the way in which men and women perceive, label and respond to their needs and symptoms, and the way in which physicians respond to their patients. **(h)** However, as researchers continue to investigate these issues, it is critical that they collect more objective and detailed data and that they disaggregate the types of patients, diseases, symptoms and drugs being investigated.

Elements of the discussion section

Discussion sections tend to have 3 **stages**:

Stage 1: summary of the results

Possible steps:

[a.] stating the results
[b.] general comment on the results

Stage 2: evaluation of the results

Possible steps:

[c.] comparing the results with standard values/ previous research/ theory (judging the acceptability, justifications)
[d.] limitations of the results
[e.] explanation of unexpected results
[f.] claims/ hypothesis
[g.] reference to previous research in support of the hypothesis

Stage 3: conclusion

Possible steps:

[h.] recommendations: suggestions for improvement of the experiment, or for a method of improving the results for future research

Remember that within each of the three stages not every step will be present and some steps may be more fully developed than others.

Task 5

In the example above, the various stages have been developed at length. However, these stages can appear in much shorter discussion sections at the paragraph level.

Look at the examples of steps in the article above (task 3). Then identify the steps in the following short discussion section from a journal article[ii]:

> A clear deficit is apparent between the mechanical functionality of the human respiratory system and the current technology imposed to provide training. The design specification outlined identifies these shortcomings and highlights the areas that need to be approached so that a suitable technology can be developed. The solutions presented here fulfil the specification to varying degrees and overcome the limitations of existing technologies. Further development is required particularly to permit user evaluations.

IV. LANGUAGE

A. The language of comparison

This is likely to be found in step [d]: comparing the results with previous research.

1. Similar findings

The	finding result figure	is similar to agrees with is in agreement with is consistent with	that found by Smith et al. (2000)
			that predicted by the Jones formula

2. Different findings

The	finding result figure	differs from is in contrast with is higher/lower than is at variance with is contrary to	that found by Smith et al. (2000)
			that predicted by the Jones formula

3. No explicit reference to difference/similarity

An alternative is to report the results found in the literature side by side with the results you have obtained without actually stating the difference. ['They found x, we found y.'] Look at this example:

> Arnt and Meeks (2001) have recently published a compilation of results showing total hydrocarbon concentration in the range 10-100 ppb C in a

variety of rural areas. They also report their measurements made during a study of the aerosol in the Great Smokey Mountain National Park. They measured about 100 ppb C of gas-phased hydrocarbon, of which only 16% was vegetative. **Our measurements in Abustamanai show** about the same total amount of gas-phase hydrocarbon; **however, the average vegetative contribution was about 40%.**

Here the writers simply report two pieces of research and then present their own contrasting result. Notice the use of 'however'.

B. The language of explanation

This is likely to be found in step [g]: explanation of unexpected results.

The tendency is to do this in a cautious style using hedging, e.g.

This discrepancy	may be might be could be is likely to be appears to be	the result of ... due to ...

C. The language of claims

This is used in step [h].

The following paragraphs which show the move from an observation to a claim:

Observation	However, a higher number of Conventional Seat Dentists who agree that their neck is supported while seated also reported neck pain.
Claim (cautious)	... dentists using Bambach seats are younger than the dentists using Conventional seats, which may imply that younger dentists are more aware about the working posture when compared to older dentists.

Observation	30.6% of the dentists work without taking any rest breaks.
Claim (confident)	The results indicated that a higher number of Conventional Seat Dentists who do not take regular rest breaks had bodily pain.

As a writer and researcher, you will need to decide when your claims should be expressed more tentatively and when, instead, you present enough evidence and support to make a stronger assertion.

Task 6

1) Which of the verbs help you make cautious claims, and which confident ones? Complete the table.

show, demonstrate, suggest, imply, indicate, signify, mean, denote, reveal, represent, confirm, establish, assert, hold.

cautious	confident

The meaning of reporting verbs

Words like 'indicate' and 'imply' are reporting verbs. They are commonly used in literature reviews and discussion sections.

2) Look at the reporting verbs (in bold) in the following journal extract[iii]:

Several oxidised derivatives of alpha-pinene, e.g. pinonic acid, have been found in naturally occurring aerosol particles (Crittenden 1996) and one might expect that oxidised terpene compounds could constitute a large, nonanthropogenic fraction of aerosol particles in rural, forested areas. Went (1980) **suggested** that such compounds are responsible for the blue haze found in mountain areas of the eastern United States. Recent experiments by Stevens et al in the Great Smoky Mountains (1998), Weiss et al in the Shenandoah Valley (2000) and Pierson et al in the Allegheny Mountains (1998), however, **show** that natural hydrocarbons were not significant contributions to the haze in these mountain areas during the periods of observation. These results do not **indicate** that Went's conjecture was incorrect but that sulfate aerosol particles transported into the region now dominate atmospheric light scattering. The extent of gas-to-particle conversion of terpenes is a subject of controversy. Duce (1998) **concluded** that the bulk of gaseous terpenes from vegetation are rapidly converted to particles although he **recognised** that some contradictory evidence existed and **remarked** that more work was necessary. Conversely Hull (1999) **argued** that under ambient conditions terpenes react to form gas-phased products.

- **show** reports the observation as 'fact'
- **suggest** shows that the writer is more or less neutral about the idea being presented.
- **argue** gives some indication that the writer may attack or disprove the idea later in the report

Positive (Factive)	Neutral	Neutral to Negative
show	suggest	argue

Where would you place the other reporting verbs used in the extract in the table above?

- indicate
- conclude
- recognise
- remark

A word of caution is needed here as reporting verbs may indicate more/less agreement depending on the ideas that are expressed in subsequent sentences and/or other evaluative language used.

3) What is the difference between the following in terms of the writer's stance (the position he/she has of the idea being reported?). How does the language used help you to understand the value of the reporting verb **argues** in each case?

Smith (2006) argues convincingly that universities should hold teaching classes on Saturdays.

Smith (2006) argues that universities should hold teaching classes on Saturdays. However, this is not practical in many cases and staff and students have been found to reject proposals for weekend teaching (Foster et al. 2008; Green, 2009).

Smith (2006) argues that universities should hold teaching classes on Saturdays. A similar proposal for weekend teaching is also presented by Brown et al. (2010), who point out the benefits in terms of greater flexibility for teaching and learning.

Task 7

Add the following to the table:

demonstrate declare contend claim state prove report reveal conjecture speculate imply

Task 8: Homework Task

Contributors to the journal *Nature* were asked whether for them '*X indicates that'* is closer to the strong '*X shows/demonstrates that'* or the weak '*X suggests that'.* Below are two typical replies, one from the USA and one from the UK.

Make notes about the meaning of the words in the table, based on these replies:

	US example	**UK example**
imply **prove**	_____	
show **demonstrate**		
indicate		
suggest		

1. Physicist, Harvard University, USA

I would say that "indicate" is somewhere in between "show/demonstrate" and "suggest". I would use "show" or "demonstrate" if it is possible to come to the conclusion logically, without involving any guess or intuition or experience. It is similar to proving a theorem in mathematics. You just use rules of logic and, starting from the data or results of an experiment, you can come to the conclusions. In very many cases it is not possible to come to the conclusion without involving some reasonable assumption or even some intuition. In other words some human factor is involved. In this case one cannot be absolutely sure that the conclusions are correct.

On the other hand the conclusion would seem natural to a person who has experience in the relevant field. In such cases I would use the term "indicate". The term "indicate" is used more frequently in experimental physics than in theoretical physics. Probably this term should not be used in perfectly precise disciplines such as mathematics. I do experimental physics and I use the term "indicate" quite frequently. In experimental physics one has to make sure that the data are correct. On the other hand the conclusions are not always obvious. Therefore some guessing may be involved. The term "suggest" would be used if there is considerable doubt that the conclusion is correct. The term tells that more work has to be done before one can be sure what is the right conclusion.

2. Biologist, Cardiff University

I think that "suggests" is usually used in scientific literature when trying to draw an inference from the evidence. Suggests is one of the weakest verbs for this purpose. "The evidence suggests the conclusion" means to me that it triggers the thought but further reflection might lead to dismissing the idea. Usually what is required is further evidence, of course! "Shows" and "demonstrates" are, I agree with you, much stronger than "suggests". To me they mean that the evidence is good and trustworthy. However, there is also an implication that while this can happen, or be made to happen, in an experiment, other evidence needs to be taken into account to reach a conclusion. In this way, "shows" or "demonstrates" is different in my mind from "implies" or "proves".

The word "indicates" is stronger than "suggests" to me, because it doesn't just trigger the thought but it actually points the ways forward. This may be because of the way we use the words in general conversation. I think "suggest" is often used as a proposal requesting agreement (e.g. I suggest we go to Cardiff), so there is nothing definite about it. Its use in scientific language may have picked up these associations. On the other hand "indicates" cannot be used this way. "I indicate we go to Cardiff' is nonsense whereas "the route map indicates we are going to Cardiff' can be used. So, "indicates" means to me that some objective indicator has flagged the result, whereas "suggests" means to me that someone has thought about it and there is therefore a more subjective element. In challenging evidence that indicates you would need to challenge the evidence whereas in challenging evidence that suggests you might just need to challenge the idea of the suggester.

Follow-up tasks

- Tonight, read some articles in your subject.
- Look at verbs used for making claims in the Discussion section.
- What verbs are used and how do they affect the strength of the claims?
- What other words or phrases do writers use to make claims?

D. The language of support

This is likely to happen in step [g], where references are made to previous research, in support of a hypothesis.

HYPOTHESIS	From the similarities ... it appears that one of the chemicals tested, chlorogenic acid, or a closely related compound may be present in quite large quantities throughout the cocoa pod.

SUPPORT/ REFERENCE TO OTHER SOURCES	... The presence of chlorogenic acid or a closely related substance in cocoa pod material has been reported previously by Griffiths (1998) and Holden (1999).

E. The language of recommendation

In step [h], the writer makes suggestions for the improvement of the experiment, for a method of improving the results or for future work to extend the research.

Example:

The application of the proposed approach for estimating the QOS (Quality of Service) of existing roads in their planning stage could be of great importance for road planners and road authorities. In order to develop the practical procedures based on this model, it would be necessary to use data collected for a variety of roads along the lines of the road study. These data would allow the formulating of better QOS equations and also the definition of the relationships between the subjective evaluations by drivers and the corresponding objective characteristics of driving conditions and road elements. These studies should be repeated periodically for updating the QOS equations and procedures according to changes in the drivers' perceptions, which would reflect changes in vehicle construction, road building materials etc.

Task 9

What are the missing words in these conclusion sections from of journal articles?

1. Future studies _____ to determine how the interplay between these regulatory domains determines the pro-death activity of AR in prostate cancer cells upon stress stimulation.[iv]

2. In the future, more effort _____ to be focused on determining the full breadth of H1-mediated protein-protein interactions, as well as on mapping the domains responsible and identifying the mechanisms through which they act. This will lead to clarification of the many gaps in our current understanding of the molecular basis for the multifunctional nature of the linker histone family.[v]

3. Prophylaxis, does, however, have other uses not addressed by these authors: for example, prior to inspection for caries, or in the acclimatisation of an anxious or young patient. Given the limited number of high quality studies and reviews available, further research is clearly _____ before any changes in clinical practice can be justified.[vi]

KEY

Task 1

Task 2

The writers chose to present the results in the following order:

1. **total percentage men and women** (Table 1, column 1, bottom)
2. total percentage women (column 1)
3. total percentage men (column 1)
4. mean number (different drugs) women (column 2)
5. mean number (different drugs) men (column 2)
6. mean number (prescriptions) women (column 3)
7. mean number (prescriptions) men (column 3)
8. age group (rows 1-4)
9. age group 18-29 (Table 1, rows 1-2; Fig. 1)
10. the later years (Table 1, other rows; Fig 1.)
11. **life span** (Table 1, Fig. 1)

*The results went from the **general** to the specific and back. Not every single result was given, but the important categories were discussed.*

Task 3

Suggestion:

You could comment on the percentage change first (with one exception all newspaper sales are down). Then there could be a comparison between morning and Sunday papers (no clear trends). You could end with a comparison in sales of the different types of papers (in order of sales: popular, mid-market, quality).

Task 4

No numbers, percentages or other statistics are given, but there is more detail and analysis. Comparisons are made to other studies (similarities, differences, importance of the research...). The language indicates that a discussion section is evaluative, for example:

(b) The disproportionate use of other prescribed drugs by women **also can be attributed to** the higher use of drugs by the women who ... **(c) (c)**
(c) Our drug use findings **also are similar to findings** concerning
(c) Earlier studies **seem to have substantially exaggerated** the magnitude of sex differences in physician utilization and medication use and **provide little basis to support** the hypothesis of physician bias.
(d/e) There are **several possible reasons why** we found only a slight sex difference...
It is possible that psychosocial factors may play **a much more important role** in other geographic areas or among other groups of patients and physicians...
One plausible interpretation for these findings is ...
(d) It is important to note other limitations of investigations of this type. First, the sample was small, and there was some attrition as a result of patient and pharmacist refusal. However, we have **no reason to believe that** our conclusions were substantially affected by **(d) Therefore**, **we cannot exclude the possibility that** younger men had many problems that went unrecognized and untreated. **Nor can we say that** the women really needed ...
(f) Thus, it is likely that both physical and psychosocial factors ...

(h) However, as researchers continue to investigate these issues, **it is critical that** they collect more objective and detailed data and that they disaggregate the types of patients, diseases, symptoms and drugs being investigated.

Task 5

Possible solution:

(a) A clear deficit is apparent between the mechanical functionality of the human respiratory system and the current technology imposed to provide training. **(b)** The design specification outlined identifies these shortcomings and highlights the areas that need to be approached so that a suitable technology can be developed. **(f)** The solutions presented here fulfil the specification to varying degrees and overcome the limitations of existing technologies. **(h/d)** Further development is required particularly to permit user evaluations.

Task 6

1)

cautious	**confident**
suggest imply	*show demonstrate indicate signify mean denote reveal represent, confirm establish imply assert hold*

Note that 'imply' has 2 meanings:

1. **indicate the truth or existence of something by suggestion rather than explicit reference** (cautious) e.g. *This distance modulus would imply a main-sequence turn-off age of 12 Gyr, worsening the age discrepancy.*[vii]
2. **suggest as a logical consequence** (confident) e.g. *Although sediments become coarser near the top of the sequence, implying slightly shallower and more energetic conditions, our observations indicate that ....*[viii]

2)

Positive (Factive)	**Neutral**	**Neutral to Negative**
show indicate	suggest conclude recognise remark	argue

3) **Smith (2006) argues** convincingly that universities should hold teaching classes on Saturdays**. [implies agreement]**

Smith (2006) argues that universities should hold teaching classes on Saturdays. However, this is not practical in many cases and staff and students have been found to reject proposals for weekend teaching (Foster et al. 2008; Green, 2009). **[opposing ideas introduced by 'however' indicate a more negative stance]**

Smith (2006) argues that universities should hold teaching classes on Saturdays. A similar proposal for weekend teaching is also presented by Brown et al. (2010), who

point out the benefits in terms of greater flexibility for teaching and learning.
[further/similar support indicates a more neutral or even positive stance]

Task 7

Positive (Factive)	Neutral	Neutral to Negative
show indicate *demonstrate* *prove* *reveal* *imply (meaning 2)*	suggest conclude *declare* *state* *report* *imply (meaning 1)*	argue *contend* *claim* *conjecture* *speculate*

Task 8

	US example	**UK example**
imply **prove**	_____	• conclusion reached, no need for other evidence
show **demonstrate**	• possible to come to conclusion logically • more used in theoretical physics, maths	• evidence is good and trustworthy but other evidence needs to be taken into account to reach a conclusion
indicate	• conclusion seems natural to the experienced but guessing may be involved • used more in experimental physics	• result based on evidence • objective indicators involved
suggest	• when there is considerable doubt that the conclusion is correct, not sure if the right one is reached	• about ideas that are not definite (like in spoken language) • subjective elements involved • some evidence that triggers ideas but further evidence is needed

Task 9

are needed/ needs / needed

[i] Taken from *www.pressgazette.co.uk/story.asp?storycode=45046*
[ii] http://journals.pepublishing.com/content/y66306j630868n0l/fulltext.pdf
[iii] pubs.acs.org/doi/abs/10.1021/es00113a006
[iv] http://www.nature.com/cr/journal/vaop/ncurrent/full/cr201065a.html
[v] http://www.nature.com/cr/journal/v20/n5/full/cr201035a.html
[vi] http://www.nature.com/ebd/journal/v11/n1/full/6400704a.html
[vii] http://www.nature.com/nature/journal/v465/n7295/full/nature09045.html#/
[viii] http://www.nature.com/nature/journal/v465/n7295/full/nature09038.html