Science Communication:

A brief guide

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Introduction

Communication skills are vital in most professions for which university students are trained, and such skills are ranked highly by employers. It is important, therefore, to learn some essentials about science communication, such as scientific writing, popular science writing, oral presentation and poster presentation, and to take every opportunity to practice these skills. They are tools for life!

Training and practicing science communication should occur throughout the curriculum. You might attend lectures in techniques for communication and you might write and present assignments. You might also write, present and defend your BSc/MSc/PhD thesis. Remember that research results will contribute to knowledge and development *only* if they are communicated effectively.

This brief guide to science communication includes some essentials in scientific writing, including tables and figures, some general writing tips, and a few words on writing a popular science article. We also give advice for making oral presentations and visuals, and for making a poster. The guide is based mainly on ideas and advice given in "Writing and Presenting Scientific Papers" (2nd ed., 2004) by B. Malmfors, P.C. Garnsworthy and M. Grossman, published by Nottingham University Press, UK (www.nup.com). The book, however, gives a lot more advice and details than are included here.

For guidance on writing a scientific text in Microsoft Word, see e.g. Malmfors (2006a). For an introduction to using Microsoft PowerPoint for producing visuals, see Malmfors (2006b), and for making graphs in Microsoft Excel, see Strandberg & Malmfors (2006).

Accurate, Brief and Clear

Science communication means sharing knowledge and it is important that the audience grasp the message and understand what is said. The ABC of written or oral communication is that it should be accurate, brief and clear!

For effective communication, you cannot think only of your topic and the message you want to deliver, but you must also consider the frames of reference of your expected audience and the questions they might have concerning the topic (Fig. 1). When preparing to write or to present, therefore, ask yourself the questions "Who? – Why? – What? – How?". For example, "Who do I address?, Why do I communicate this?, What do I emphasize?, How best do I deliver it?".

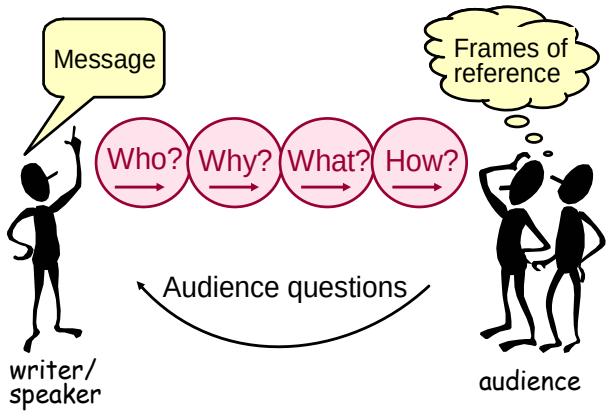


Figure 1. Some components of effective communication.

Science communication takes many forms, such as papers in journals, reports, conference abstracts, review papers, theses, research proposals, popular science articles, oral presentations and posters. The various forms have a lot in common, but they also differ with regard to purpose and audience.

Writing a scientific paper or report

Written documentation of research results requires precision. This includes providing a logical structure, distinguishing new results from old, citing original sources, differentiating and interpreting facts, and giving sufficient information for others to repeat or check what was done.

Scientific papers, reports and theses usually follow a standard format, with *sections reflecting the research process*. The following main sections usually are included: Abstract, Introduction, Materials and Methods, Results, Discussion (or Results and Discussion), Conclusion (not always under a separate heading) and References. In a report or thesis, there is often also a separate section - Literature Review. In a scientific paper, a brief review of literature is included in the Introduction (and in the Discussion). In a review paper, however, the sections on Materials and Methods and on Results are replaced by a Literature Review split into suitable sections.

The main purpose of each section of a scientific paper/report, as well as some essential details and comments, are summarized in Table 1.

Table 1. Sections of a scientific paper or report

Section	Main purpose	Essential details	Comments
Title	Tell what the paper/ report is about Arouse interest to read it.	Relevant to content. Informative, specific & concise. Not too long. Avoid uninformative words such as: "Investigation of …".	
Author(s)	List of who contributed intellectually.	If several authors: names in order of relative contribution, or other convention?	
Contents	List of contents (based on headings) and page numbers.	Incl. heading levels 1 & 2 only, or more? Created "automatically" in word processing if headings are defined in a style sheet.	Content list might be included in a report, but not in a scientific paper.
Preface	Specific information or background.	E.g.: target group, tell if the research published is a part of a larger research project, responsibilities of authors (if split). Acknowledgements might be included.	Preface might be included in a report, but not in a scientific paper.
Abstract	Short summary of the paper/report.	Abstract should "stand alone", i.e. be understood without having the rest of the text. No references to text, tables or figures in the paper/report, or to other literature. Emphasis on the objective, most important results, and conclusions.	The most read part of the paper/report. Published in abstracting journals. Abstract might be followed by list of key-words reflecting the content of paper/report.
Introduction	Why the topic is important and the research justified. Arouse readers' interest.	Background. Importance of topic. Objective of the research (or review paper). Hypothesis.	Usually includes a brief literature review (with references to sources) in scientific paper.

Table 1 continued on next page

Table 1 (continued)

Section	Main purpose	Essential details	Comments
Literature review	Review of published research results. What is known, and what is not known. Shows the gap in knowledge.	Relevant and objective facts, always with reference to sources. Results from several investigations on a topic might be summarized in a table. *Follow the publisher's instructions on how to cite references in the text, tables and figures.*	The literature review is usually split into sub-sections. Usually a separate section in a report, and constitutes a major part of a review paper.
Materials & Methods	What materials and methods you used. Info so others can repeat what you did.	Materials and methods used - describe methods not published before; if published - just give reference. Usually split into sub-sections, e.g. Experimental design, Animals, Chemical analyses, Statistical methods.	The section is not included in a review paper.
Results	What you found (facts).	Specific, informative, structured, clear - you present new knowledge! Give large parts of results in Tables and Figures – integrated in the text of the final publication.	All important results – both favourable and unfavourable. Split results into sub-sections.
Tables & Figures	Numbers in tabular form or in graphs. Other illustrations.	See advice given under heading Tables and Figures in the text below.	
Discussion	How you interpret your results. What your conclusions are (if not given under heading Conclusions).	Interpret your results clearly, concisely and logically – do not repeat Results section! Relate results to aim & hypothesis. Compare with results of others. Disc. possible limitations of the research. Your conclusions from the research results, and possible implications/recommendations /impact	Results and Discussion might be combined. Conclusions might be written under heading Conclusions.
Conclusions	What your conclusions are (if not given under heading Discussion).	Your conclusions from the main research results, as well as possible implications/recommendations/impact (if not given in Discussion section).	Usually included when Results & Discussion are combined.
Acknowl-edgements	Thanks for specific contributions to the research or publication.	E.g.: funding, supervision, field or lab assistance.	Might instead be included in Preface.
Reference list	Give info so others can find the publications referred to in the paper/report.	Reference list to be in accordance with the references in text, tables and figures. *Follow the publisher's instructions on how to write references in the reference list.*	All citations in the text must be in the reference list; all references must be cited in the text.
Attachment(s)	Additional info too much to include in the main text.	Attachments might be a questionnaire or derivation of formulas. Number each attachment and refer to it in main text.	Often included in a report, but normally not in a scientific paper.

The tense used in the text varies; in general the past tense is used to describe materials or methods and results (own and others'), whereas the present tense is used to write commonly accepted facts, e.g. in the introduction and in the conclusions.

Furthermore, remember always to give a reference to the source when you use text, tables, figures or ideas from other people. This must be done also when summarizing in your own words the work of others (see also the section "Copyright and Plagiarism").

Tables and Figures

Research results to a large extent are presented in tables and figures. It is important, therefore, to know some essentials of this topic:

- The same result should not be presented both in a table and in a figure (graph).
- If specific numbers are important – present the data in a table.
- If it is more important to show differences, trends, etc. – present the data in a graph.
- Each table and figure should be self-contained, so as to "stand alone", i.e. have no references to the text, to other tables or to figures in the paper/report. If the table or figure shows data from another source, however, a reference to the source must always be given. Ensure you do not infringe copyright.
- All tables and figures must be referred to in the text of the scientific paper/report.
- Each table must have a title/heading (above the table) that explains what the table shows. The title starts with the table number. The numbering of tables and figures is usually done in separate number series.
- Each figure should have a caption (usually below the figure) that explains what the figure illustrates. The caption starts with a figure number.
- Tables and figures are best read when placed in the text near to the comment that refers to them. In a manuscript delivered to a journal, however, tables and figures are usually separated from the text and placed at the end, but in the published paper they appear within the text.

Two examples of presenting data in a table are shown below: how the table should look and how it should not. A reference is given when the table presents data from another source. The reference is given either in brackets at the end of the table title, e.g. … (Johnson, 2005), or under the table as in the examples. Note that only horizontal lines should be used, and that they indicate the top, bottom and head of the table. Note also that the table title does not end with a full-stop (it's a heading), whereas footnotes under the table are ended with a full-stop.

A table should look like this

Table … Number of cattle in some world regions (millions)

	Year	
Region	1994	2004
Africa	196	235
Asia	441	445
Europe	188	135

Source: FAOSTAT (2005).

A table should not look like this

Table ... Number of cattle in some world regions (millions)

	Year	
Region	1994	2004
Africa	196	235
Asia	441	445
Europe	188	135

Source: FAOSTAT (2005).

For presentations and reports, it is sometimes clearer to present data in a graph. Bar charts (in columns) based on the above data are shown below; one good chart and one not good.

Chart with 2-dimensional bars

easy to see the height of the bars and their values on the Y-axis ⇨ GOOD

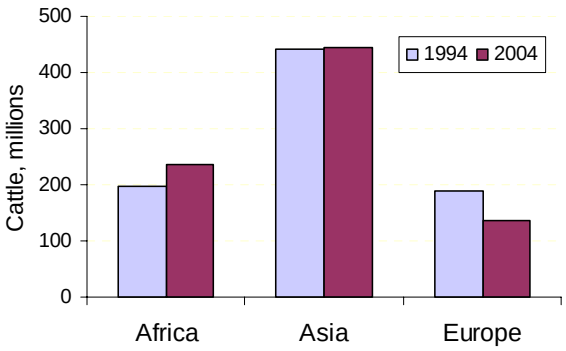


Figure ... Number of cattle in some world regions in 1994 and 2004 (FAOSTAT, 2005).

Three-dimensional visual effect

difficult to see the height of the bars and their values on the Y-axis ⇨ NOT GOOD

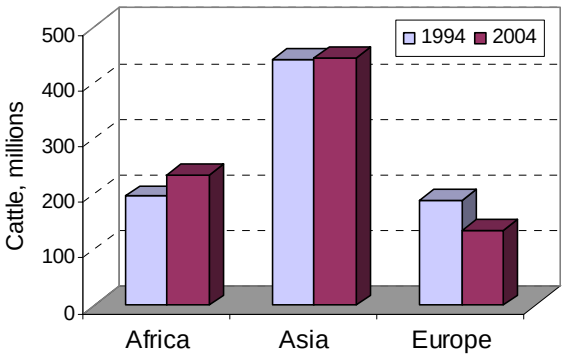


Figure … Number of cattle in some world regions in 1994 and 2004 (FAOSTAT, 2005).

Use the appropriate type of graph:

- Bar chart to compare items.
- Line chart to show a trend over time (events at equal distances) or over levels of treatment, and a Scatter chart (with or without lines) to show relationships between variables.
- Pie chart to compare segments with the whole.

A graph is easier to read if the explanation of what each bar, line, or pie-segment represents is placed as close as possible to the item. In a line diagram, for example, place labels near or at the end of the lines, and in a pie chart place each label within or near its specific segment. Check that lines, bars, segments and text can be distinguished when printed in black and white, or when reduced. Avoid using markers on lines, unless you find them necessary.

Note that a figure is not always a graph; it might be a flow diagram, a photograph, a drawing, or some other type of illustration.

Guidance on making tables and inserting pictures in MS Word is given in Malmfors (2006a). For some advice on making graphs in MS Excel, see Strandberg & Malmfors (2006).

Writing a popular science article

Research results often are communicated to audiences who are not specialists in your topic. When writing a popular science article it is important to:

- Adapt to the knowledge and experiences of the expected readers.
- Give an overview and put in context, give examples.
- Simplify results, avoid giving too many details, and still be accurate.
- Emphasize conclusions and possible implications.
- Use illustrations and informative headings, and use language that is easily understood. Avoid jargon.

Before finalizing your article, ask someone who is not familiar with the topic to read it and give you comments.

Some writing tips

Whether writing a scientific paper/report or a popular science article, you should read the advice below on how to get started and how to improve your writing.

- *Make an outline* of the contents to be included in the document; the outline should show the order of the contents. Having an outline facilitates splitting the writing into steps, without losing the overview and thread through it all. Discuss the outline draft with someone (e.g. your supervisor, if you have one) before starting to write the paper/report.

- *Start writing the sections you find easiest to write*; most likely that will be the materials and methods and the results. Strive to get words down – the text doesn't need to be perfect from the beginning. It is easy to revise the text when using word-processing software, and your text can be checked automatically for grammar and spelling errors. Before closing a writing session, write a few key words (more detailed than in the outline) on what to write in the coming section. That will motivate you to get back to your writing so you can continue where you left off.

- *Emphasize the most important.* Place the most important idea early in the sentence, and also in the title of the paper/report.

- *Make good transitions* between sentences in a paragraph. Transition words and phrases include "in addition, furthermore, on the one hand or on other hand, however, therefore, whereas, consequently, …". These transitions help the reader to see quickly how the sentence relates to the previous one. Another important issue is to make sure pronouns, such as "it, this, that, those …", refer to the appropriate noun.

- *Tighten your writing*, i.e. don't use more words than needed. For example: instead of writing "perform an investigation" – write "investigate"; instead of writing "take into consideration" – write "consider", etc.

- *Use parallel construction*, i.e. make comparisons in the same order for different variables, such as "Adult weight was higher for breed A than for breed B, whereas birth weight was lower for breed A than for breed B". Moreover, avoid using "respectively"; e.g.: "Average birth weights were 4 and 5 kg for breeds A and B, respectively" is more difficult to read because the reader has to go back in the sentence to get the information. Instead write "Average birth weight was 4 kg for breed A and 5 kg for breed B" so the reader reads the sentence once. "Average birth weights were 4 and 5 kg for breeds A and B, respectively".

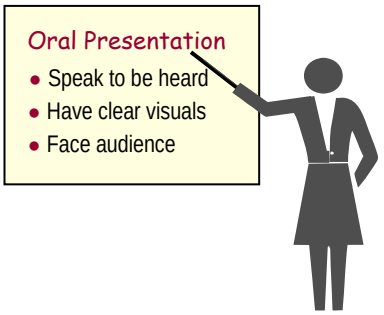
- *Abbreviations*. Commonly accepted abbreviations, such as "i.e., e.g., et al.", are used without explanation, whereas any "home-made" abbreviations must be defined when first used. Abbreviations should be "logical," "suggestive" and used only if really necessary.

Having written a draft, it is time to review and revise your text, tables and figures. Revising your text is an important part of your writing. A first step might be to read the text, paragraph by paragraph, checking if what you wrote is what you really meant to say, if what is said is easy to understand, if there are redundant words that could be eliminated, if some sentences are too long and should be split, etc. A second step might be to check the contents: Is anything important missing? Could something be deleted or shortened? Is the source given where appropriate? Is the title relevant? Can the tables and figures be improved?

After this revision, you might read through the entire draft and check the text for "fluency and thread", or coherence, i.e. that the different parts fit together; that transitions between sentences, paragraphs and sections are logical; and that there is no unnecessary repetition. A final check should include the agreement of citations in text (including tables and figures) and reference list. Check also if editorial requirements have been fulfilled.

A lot more details on how to improve your writing are given in Malmfors et al. (2004).

Oral presentation



Giving an oral presentation is a great opportunity to communicate ideas and facts - you are in contact with your audience! Successful presentations can be done in many ways, as long as you get your message across. The ABC of science communication, i.e. being accurate, brief and clear, should be fulfilled, however, and the presentation must be adapted to your audience.

Preparing the presentation

When preparing an oral presentation remember to ask yourself the questions "who?-why?-what?-how?" (see p. 1). What you include depends on the contents and main messages that you want to deliver; it also depends on the frames of reference of your audience. You might also anticipate some questions they might have, which will help you adapt your presentation to your audience.

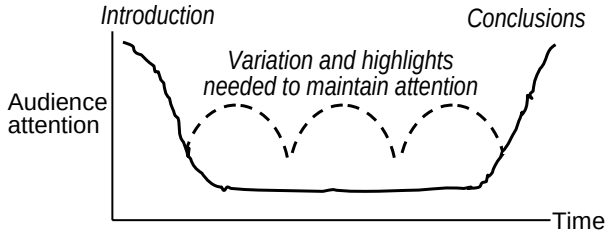


Figure 2. Audience attention varies during a presentation.

Audience attention varies during a presentation (Figure 2). It's high at the beginning (curiosity about what will come) and at the end (curiosity about your conclusions). To maintain attention also during the body of your presentation you might show illustrations or examples, and use analogies to present facts or results. In addition, you might discuss pros and cons, advantages and disadvantages, etc.

Using visuals in an oral presentation helps audiences better understand and retain the contents. Visuals can be shown as transparencies on an over-head projector or as slides in a slide projector. Where possible, visuals are best shown as an electronic presentation, using computer and LCD-projector. In a small room, a flipchart or white/black board can be used. You can create your visuals on a computer using presentation software. For an introduction to using Microsoft PowerPoint, see e.g. Malmfors (2006b).

Some essentials to consider when *creating visuals*:

- Be realistic about the number of slides that fit into the time you have been allotted for your presentation. Having too many slides might ruin your presentation.
- Don't overload slides with too much information. Each slide should be simple and easy to understand quickly.
- Make a good contrast between text and background, i.e. dark text on a light background or light text on a dark background. Choose colours that allow the presentation to be given with the room lights on.
- Use a large font size, minimum 24 point for the text, but preferably larger. Headings are usually larger than the text. A hint when using MS PowerPoint: check if your slides can be read in "Slide Sorter View" (zoom 100%).
- Fonts without serifs (e.g. Arial, Verdana) are considered easier to read in short text messages, such as in slides, whereas fonts with serifs (e.g. Times New Roman) are easier to read in text documents. For symbols, such as Σ, μ, or σ you can use the font Symbol.
- In slides, text in bullets is easer to read than text in paragraphs. Furthermore, words written in lowercase letters are easier to read than words written in all UPPERCASE.

- Photographs and other illustrations (e.g. Clipart) can enhance your presentation. Graphs often are easier than tables for the audience to understand quickly. If tables are used, then they should not be complex. For further advice, see section "Tables and Figures".

- Sequential build up in animation of slides can be useful in an electronic presentation. You might use it for bullet points, flow charts, line diagrams, or anything you want to appear sequentially. Many animation effects are available, but using too many effects can distract from the message; using the simple option "appear" is nearly always the best animation.

Having prepared your slide drafts, and also thought about what you want to say in your talk, it is time to do a first *rehearsal* of your presentation (preferably using a timer). Doing the first rehearsal before "finalizing" the slides saves time; you will most likely find that some slides should be revised, and possibly that the number of slides must be reduced. When that revision is done, more rehearsals are usually needed to "fine-tune" your talk and to make sure you will stay within the time allotted. Rehearsal is a key to a successful presentation!

You might want to have a *manuscript* to glance at during your presentation, but you should strive to talk as "freely" as possible. Do not read your talk from a full-text manuscript; if you do that you will lose contact with the audience. A good solution is to have a list of *key words* to aid your memory. One option is to use a "handout print" of your slides (e.g. two slides per page) and write the key words exactly where they are to be used. Having a paper copy of each slide is helpful, especially when using animation in an electronic presentation; then you know what will appear at the next click. If you want a small-sized manuscript, you can cut the handout page into two pieces.

Performing the presentation

When performing an oral presentation you might stand behind a lectern, or you might stand away from it to show more of your body language. It might be good to stand near the projection screen, so the audience can look at slides and see you at the same time; make sure, however, that you don't block anybody's view. Choose what makes you feel comfortable, assuming there is an option. If possible, visit the presentation room beforehand to check where to stand, the location of the screen, controls for lights, etc.

There are some basics that you should always fulfil in an oral presentation:

- Show interest and enthusiasm.
- Keep eye contact with your audience.
- Speak so that you are heard and understood.
- Use only visuals that can be seen clearly and that support your talk.

You might feel a little nervous when you get started. Don't worry, that's natural; it actually helps you to gather your thoughts and to focus on the task. You have a message of value to the audience, think of that! Remember also that the best way to cope with nerves is to be well prepared.

Because eye contact between speaker and audience is so essential, *keep the room light on* during your presentation; make slides with colours that allow for that. If it's dark in the room, then your audience can't see to make notes and gets tired easily. Face the audience as much as possible. If you point at something on the projection screen, keep the pointer in your hand nearest the screen so you don't turn your back on the audience. If you look at your slides on a computer screen, then just glance briefly at them and quickly resume eye contact with the audience.

Make sure everyone in the audience can hear what you say; *speak up and articulate*, but don't shout. Never hold your hand in front of your mouth when speaking. If you use a microphone, talk in conversational tone level. Before you start your presentation, get some instructions about how to use the microphone, e.g. how close to your mouth it should be, and how to turn it on and off. In

the discussion following your presentation, you could repeat briefly each question before you answer it. That helps the audience hear the question, lets the questioner know if you got it right, and gives you a few seconds to think of an answer. Give short answers and direct them to the whole audience; avoid a dialog.

For further advice on oral presentation and visuals, see Malmfors et al. (2004).

Poster presentation

Research findings and results of surveys or projects can be presented as a poster. A poster might be used as an alternative to oral presentation. Posters are usually presented in a poster session, with the poster's "author(s)" there to discuss and answer questions from the audience. Posters can be reused: they might, for example, be hung on walls in corridors at the university, where students and visitors can see them.

A poster should be attractive, audience adapted, brief and clear; it should focus on the main messages. Don't overload your poster; the details can be given in a handout. The poster should be seen easily from a distance to attract viewers. A poster of research results includes normally a few words about the objective and methods, but the main focus is on results and conclusions. An illustration of a poster is in Figure 3. The font sizes recommended are for the final, printed poster. Note that there should be a balance between text and illustrations, and that the background should neither distract from the message nor make the text difficult to read.

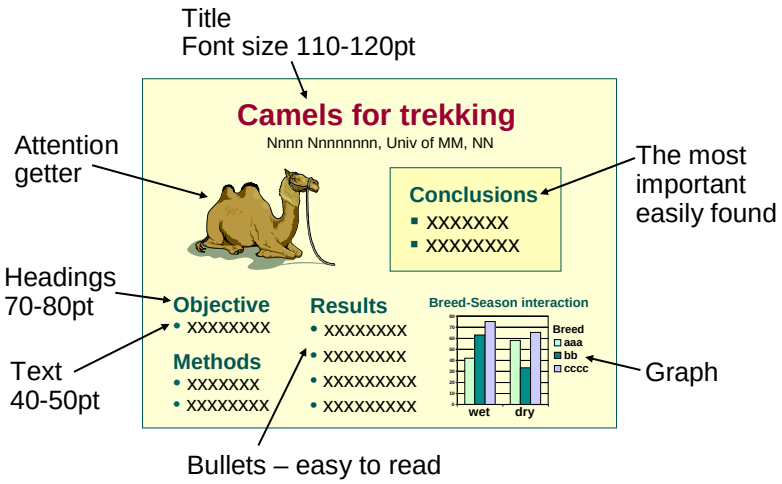


Figure 3. Illustration of a poster.

The poster can be designed and created on a computer, using presentation software (e.g. MS PowerPoint) or specific poster software. To get the poster on paper you might print individual parts of it as A4 sheets (text and illustrations), and mount them on a unifying background. If you have access to a poster printer, however, you might print the poster as a single-sheet. In each case, check the prescribed dimensions for height and width of your poster *before* designing it!

Copyright and plagiarism

Accuracy is a key issue in science communication: accuracy includes clearly indicating which results and ideas are yours, and which belong to others. Using other peoples' text, tables, figures or ideas (published and unpublished) in your writing or presentations as if they were your own, without giving reference to the source, is *plagiarism*. Furthermore, the materials you use from others are usually protected by *copyright*; copyright is established as soon as original materials are created in a form that could be copied. A copyright (©) notice might be placed on the work to identify the copyright holder, but the work normally is protected without that. Plagiarizing or

infringing copyright can carry serious penalties. Efficient electronic search systems exist today to detect plagiarism.

Compiling the "present state of knowledge" is an important part of a scientific paper/report, and it is the main part of a review paper. So, you cannot avoid writing or presenting what others have found. Therefore, you have to acknowledge the source by referencing it in the text/table/figure, such as (Abebe & Lee, 2004), and by giving the complete citation in the list of references. Moreover, showing that you have thoroughly reviewed and summarized what has been done (and by whom) in the field you write about will give you credits. Some advice on referencing the source when compiling the work of others is given in Table 2.

***Table 2. Referencing the source when compiling the work of others*[1]**

What you plan to use	Advice
Text paraphrasing, i.e. describing in your own words what someone else has published.	⇨ Give reference.
Quoting text exactly.	⇨ Surround text with quotation marks "…" and give reference. Seek permission from publisher/author if more than a few lines of text are included in the quotation.
Tables, figures or illustrations that you have not modified.	⇨ Give reference. Seek permission from publisher/author.
Tables, figures or illustrations that you have modified.	⇨ Give reference. Indicate that it is not exactly the original, e.g.: After NN (2001), or Modified from …, or Adapted from …
Ideas someone has given you in conversation, interview, letter, e-mail.	⇨ Give reference (according to rules for personal communication).
Generally accepted facts (common knowledge).	⇨ No reference. But, make sure it is common knowledge. If not certain – give a general reference, e.g. a textbook.

[1] Follow your publisher's instructions (e.g. your university) on how to write references in text and in reference lists.

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