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Scientific Writing in Engineering

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Introduction

Poor writing can deface brilliant ideas. The pressure of producing presentable research results frequently leads to a research focus misbalance between "doing the work" and "disseminating the work", or between "scientific working" and "scientific writing". However, scientific working is inextricably intertwined with scientific writing. Scientific research projects generally comprise several stages, each characterized by its own complexity. Tasks such as theoretical investigation, literature review, development of methodologies, implementation of methodologies, design of experiments, laboratory or field experimentation, data processing, and results interpretation usually occupy the bulk of efforts made by researchers towards meeting the objectives of scientific research projects.

Publishing research project results is the only legitimate outlet for "letting the public know" what has been achieved within research projects. Therefore, ensuring high-quality scientific writing in research projects is of equal importance as, e.g., experimenting in the laboratory. Nevertheless, many researchers still focus solely on improving research project results and overlook scientific writing as a matter of secondary importance, counting on the quality of the results to compensate for poor writing quality.

Scientific writing encompasses all scientific disciplines, and literature on scientific writing is both excessive and diverse, with guidelines case-specifically developed for different disciplines. The diversity in scientific writing guidelines comes as a result of the diverse nature of scientific disciplines, which calls for variability in the extent of theoretical investigation, in the rigor of mathematical formulations, and in experimentation among different disciplines. In engineering, producing quality scientific writing entails providing a clear, yet concise and plain, flow of arguments explaining the research motivation and

the set of actions taken to meet the research objectives. Due to the typically complex methods developed within engineering research projects, presenting results requires particular attention to ensure the comprehensibility of research project outcomes. For example, engineering research projects with computationally expensive implementations may generate extensive results, but only part of which should be presented for serving the purpose of disseminating research findings. Evidently, organizing the presentation of engineering research project outcomes requires considerable attention.

To foster a culture of diligence in presenting research project results in engineering, it is important to start at an early stage of scientific working. To this end, this book aims at providing a practical guide to scientists, engineers, and engineering students engaging in scientific writing, assembled from the long-standing experience of the authors in advising students via teaching and supervision of theses as well as via writing research articles. The difficulties faced by engineering students in developing personal writing styles in English are substantial, particularly since, in doing so, the majority of scholars need to overcome linguistic barriers. Notwithstanding native or non-native speaker skills, the authors of this book have been observing recurring writing mistakes in several types of scientific texts, such as student reports, bachelor's and master's theses, doctoral theses, conference papers, research articles, research proposals, and fellowship applications. It is therefore envisaged that by grouping together mistakes systematically repeated in scientific texts, a practical guide can be assembled offering scientists, engineers, and engineering students a quasi "on-the-job" training session in scientific writing by providing working examples of actual scientific texts.

Having accumulated abundant examples of mistakes in scientific writing in engineering over many years, this book aims at helping scholars in the engineering domain avoid more than 90% of systematic writing mistakes in student scientific texts. The examples, taken from working versions of real scientific

texts, offer scholars the chance to make an easy analogy between own scientific texts and the examples provided in this book.

This book ***aims at***:

- Providing recommendations for effective scientific writing in engineering.
- Offering examples of repeatedly encountered mistakes in scientific writing in engineering that scholars can easily relate to.
- Helping scholars develop own writing styles by illuminating fundamental concepts of preparing scientific texts.

This book ***is not***:

- A comprehensive guide for scientific writing in engineering; the list of recommendations and examples focusing on the most common mistakes made by engineering students is by no means exhaustive.
- A handbook for self-teaching English; an independent-user level of understanding of the English language is a prerequisite for using this book.

Elementary scientific writing rules, principles of composition, and elements of style are not covered in this book. The reader is expected to be familiar with the most basic rules, principles, and elements, for example:

- Keep related words together.
- The number of the subject determines the number of the verb.
- A participial phrase at the beginning of a sentence must refer to the grammatical subject.
- Do not explain too much.

It should be noted that the recommendations included in this book concern cases frequently encountered in scientific writing in engineering. Therefore, the discussion on grammatical rules and guidelines is accordingly limited in scope by eliminating cases of grammatical rules not directly applying to the examples provided in the book. Furthermore, grammatical rules may be characterized by ambiguity in application from different linguistic viewpoints. In cases of ambiguities, the authors formulate recommendations based on personal experience, while respecting standard practice in scientific writing. Finally, it should be emphasized that the recommendations included in this book concern the usage of American English, whose use is widespread in scientific writing, and some recommendations may vary when applied to other forms of English, such as British English. This book, consisting of two parts, is intended to serve as a guide for efficient scientific writing for scientists and engineers as well as for engineering students at the undergraduate level (e.g. bachelor's students, diploma students) and at the post-graduate level (e.g. master's students, doctoral students, postdoctoral students).

Part A includes a brief discussion on the fundamentals of scientific text structuring, organized in five sections. In Section I, recommendations on how to structure an abstract are provided. The points of interest that need to be included in an abstract are outlined, and the succession of arguments is explained. Section II discusses the structure of an introduction, elaborating on how the scientific topic is introduced, how the problem statement is formulated, how the literature review is performed, how the own approach is presented, and how the scientific text is organized. Section III covers the main part of a scientific text, by providing recommendations on the contents and the succession of the textual units of the scientific text. In Section IV, the structure of summary and conclusions is discussed, and Section V provides recommendations on structuring the acknowledgments and the references of scientific texts.

Part B includes the list of recommendations on scientific writing, comprising seven sections. Principles of composition are discussed in Section I, essentially complementing the contents of Part A by providing detailed information on how to structure individual textual units that are clear and easy-to-follow. Section II discusses use of English in scientific writing with recommendations pertaining to grammar, syntax, vocabulary, and orthography. A set of useful tips in scientific writing are listed in Section III, and in Section IV recommendations on creating figures are provided. Section V includes recommendations on writing in mathematics and particularly on inserting mathematical formulas and equations. In Section VI, recommendations on referencing according to styles frequently used in scientific writing in engineering are given. Finally, Section VII summarizes the minimum requirements expected in formal email correspondence.

Part A

Structuring in Scientific Writing

Nowadays, due to the highly competitive environment characterizing most branches of industry and academia, appearances have been gaining increasing importance. In industrial and commercial fields, entire departments are dedicated to promotion and marketing, with the sole goal of increasing product salability not only by emphasizing product features but also by ensuring that the packaging is appealing. In academia, appearances are associated with scientific writing, which essentially builds the picture for promoting the "product" of research projects. Although the analogy between commercial products and scientific writing may be somewhat unorthodox – and the famous English saying prompts readers "not to judge a book by its cover" – it is common knowledge, particularly in the scientific community, that an impeccable scientific text goes a long way in disseminating research project outcomes. Furthermore, since the vast majority of research projects are financially supported by public or private funds, it is of paramount importance to ensure that research project outcomes are adequately and properly documented to be readily available to stakeholders, which may include public or private organizations, the general public, and the scientific community.

The task of organizing research project outcomes into publishable material is non-trivial. Particularly in engineering research projects, documenting processes, methods, and outcomes is frequently deemed as a matter of secondary importance and, sometimes, grossly overlooked. Moreover, it is not uncommon that research projects require intensive and laborious efforts of

research groups brought together from different scientific disciplines, institutions, and nationalities. Therefore, presenting research project outcomes is often not a "one-person-task" with requirements on bridging interdisciplinary gaps and traversing regional constraints coming to the forefront. Moreover, advances in most scientific fields have been swift in the last decades of the 20th century, thus leading to ever increasing complexity in research projects and adding to the difficulty in properly presenting research project outcomes. Poor documentation usually has a noticeable impact on the quality of scientific writing, resulting in objectives, novelties, and outcomes of research projects being underrated. In addition, research project findings may be debated, e.g. as a result of ambiguities in formulation.

Diligent documentation adds to the credibility of authors by enabling independent researchers in the scientific community to recreate processes followed within research projects and to check the validity of research project outcomes. Furthermore, well-documented research projects generally enhance the quality of scientific writing. Broadly speaking, from the viewpoint of the authors of this book, a well-written scientific text should perform satisfactorily with respect to the four following points:

- **Completeness.** The text should be detailed enough (i) to adequately cover existing aspects of the topic being investigated and (ii) to extend the current research status of the topic. Incomplete approaches to research topics may risk being viewed as "case studies" not introducing actual novelties or being regarded as studies of limited scientific contribution and, consequently, be dismissed.
- **Correctness.** Methods within a research project being correctly implemented and processes being correctly applied seem as prerequisites calling for no further discussion. However, this point focuses on the correctness of documentation and on the correctness of transferring the project methods, processes, and documentation into scientific writing.

Part B

Recommendations on Effective Scientific Writing in Engineering

Preparing scientific texts is non-trivial. Notwithstanding the content of the scientific research project discussed within a scientific text, which might be rich in material and findings, confronting a blank document is sometimes overwhelming for inexperienced authors. As has already been discussed, for effectively conveying the message that accompanies the outcome of scientific research projects, authors need to first devote extra care to structuring scientific texts. However, effective scientific writing requires more than well-structured texts. Frequently, attention to details in scientific writing is what distinguishes an easy-to-follow scientific text from a text that may be likely to lose credit on account of careless writing. As a result, in addition to ensuring proper structuring, it is recommended to authors to "walk the extra mile" in correcting, proofreading, and polishing scientific texts. The result – eradication of the majority of writing errors – increases the acceptance of scientific texts as well as the credibility of the research findings.

To enhance the readability of scientific texts, authors are advised to account for the diligent organization of all elements used for preparing the texts. Part B of this book provides recommendations on effective scientific writing in engineering. Naturally, having all these recommendations *a priori* in mind when producing the first draft of a scientific text is difficult particularly for inexperienced authors. Hence, it is important to conduct iterations when preparing scientific texts to continu-

ously update the texts until an acceptable level of compliance with user-defined standards of scientific writing has been met. Moreover, for proofreading the final text (or even intermediate versions of the text) it is often considered good practice to invite independent readers who can objectively judge upon the comprehensibility of the scientific text.

The recommendations on effective scientific writing in engineering include principles of compositions within textual units, use of English, specific writing tips, preparation of figures, writing in mathematics, formatting of references, and formal email correspondence. The aforementioned elements are discussed in detail in the following sections. In the examples taken from real scientific texts, the original versions are shown on the left, and the corrected versions are shown on the right.

Section I
Principles of Composition

Composing scientific texts is much more than merely putting together scientific research results with underlying theories and expecting readers to fully grasp research findings. Part A has covered the first important step on scientific writing, which is developing proper structures for scientific texts. However, if the content of textual units realizing the structures is poorly organized, scientific texts are at high risk of being overlooked or even discredited.

Following up on the general recommendations on paper structuring given in Part A, this section focuses on the next step towards preparing scientific texts. Specifically, the basic principles of composition are discussed, including the organization of content within textual units and the formulation of arguments using paragraphs. Authors are invited to take particular care to respect the principles of composition so as to avoid losing focus during writing, for example, to ensure that text flow within a paragraph is logical.

1. **State the message of scientific texts clearly.** Make sure the message of the scientific text is clear. Unexperienced scholars tend to discuss too many aspects of a research problem to prove their broad knowledge to readers. Frequently, the aspects of the research problem involve material from different disciplines, and including too much information from some disciplines may be redundant for the research objective of the scientific text. Redundant information may obscure the message and create confusion to readers. Consider the following example, an extract of a student report.

Section II
Use of English in Scientific Writing

Adopting basic composition principles in scientific writing is the first important step in preparing scientific texts. However, merely following basic composition principles can only get authors as far as ensuring proper layouts for scientific texts and appearances that are easy to digest by the readership. Generally in written material, there is a common notion that "the devil is in the details". In other words, despite having defined perfect text structures and having started to prepare scientific texts with all composition principles in consideration, mistakes at the use-of-English level (i.e. grammar, syntax, vocabulary, and orthography) may be critical to the credibility of scientific texts. As a result, authors of scientific texts are advised to pay particular attention to scientific writing elements related to the use of English to ensure completeness, correctness, and clarity as well as accuracy and consistency throughout the texts.

This section is dedicated to recommendations on scientific writing related to the use of English. The recommendations cover a wide range of use-of-English elements that are frequently encountered in student scientific texts. These elements include an elaborate, yet not exhaustive, list of grammatical rules, syntactical rules, and word usage tips. The recommendations of this section aim to equip authors with tools to achieve enhanced levels of detailed attention to the use of English during the preparation of scientific texts.

7. **Explain terms at first usage and make sure the word choice is correct.** Terms that the readership may be less likely to be familiar with should be explained at first appearance. Use simple language as long as the word choice is correct and adequately conveys the message of the scientific text. Keep in mind that the study described may be complex, but the language could be simple.

Example (Journal paper)

"It will be shown that the adaptive sampling strategy improves the convergence rate and the robustness of *the surrogate model*."	"It will be shown that the adaptive sampling strategy improves the convergence rate and the robustness of *surrogate models. Surrogate models are*… [brief explanation]."

In this example, the reader is assumed not to be familiar with surrogate models. Unfortunately, neither surrogate models in general nor "the surrogate model" have been introduced earlier. As a result, the reader is left in uncertainty regarding the specific surrogate model the author refers to and the reason for mentioning the surrogate model altogether.

8. Acronyms.

8.1 Define acronyms at first appearance and avoid introducing an acronym that is not used again in the remainder of the text. Acronyms should be defined at first appearance in the text with a parenthetical reference after the full term. Once an acronym is defined, it should be used for all subsequent references to the term. If there are no subsequent references to the term, i.e. the acronym is not used elsewhere in the text, do not define the acronym; instead, use the full term once. Note that non-proper nouns are not capitalized (Recommendation 29). Also note that abstracts are treated as separate documents (Section A.I) and an acronym defined in the abstract must also be defined in the text the abstract describes.

Example (Journal paper)

"Because of the possibilities provided by modern *IT*, …"	"Because of the possibilities provided by modern *information technology (IT)*, …"

Section IV
Figures

Lousy figures can ruin brilliant articles. Visual excellence means well-designed presentation of complex ideas communicated with clarity, precision, and efficiency [4]. Artwork in scientific texts intends to express ideas or to introduce facts or results that would be too long or (almost) impossible to be explained through words.

The recommendations in this section reflect the most common mistakes related to figures the authors of this book have observed in texts written by scholars of all academic levels. It is not the intention of the authors to provide an exhaustive guideline for creating figures. The reader is expected to be familiar with the basic principles of creating figures in scientific articles, such as:

- **Identify the message.** Every figure should clearly convey a message. Before creating figures, make sure that the underlying message is clearly identified. A message clearly identified is a strong guide for the creative design process of figures.
- **Add clear figure captions.** Whether describing a new idea, introducing a new model, illustrating an experimental setup, or presenting results, not every detail is self-explanatory by a figure. Therefore, figures should be accompanied by clear captions that explain important details.
- **Avoid chartjunk.** Students tend to show their extensive work conducted on a subject through a plenitude of data sets included in their text. Chartjunk refers to all unnecessary or confusing visual elements found in figures that do not improve the message (in the best case) or that add confusion (in the worst case) and should thus be avoided [5].

Section V
Writing in Mathematics

Almost all scientific texts in engineering contain at least some mathematical notations. Usually, methods are expressed through mathematical formulas and equations, for example within the "methodology" textual unit of the "main part" (Section A.III). As a result, formulas and equations hold a central role in the comprehensibility of research approaches presented in scientific texts. Regardless of the quality of scientific research results, if "the math" is obscurely described or if the description contains inaccuracies and errors, it is likely that reviewers of the scientific text will be negatively predisposed towards accepting the text. It is, therefore, of paramount importance for authors to ensure clear and detailed presentation of mathematics pertaining to own approaches.

This section contains some basic recommendations on how to formulate mathematical formulas and equations in scientific writing in engineering. Putting together this list of recommendations inevitably entails drawing elements from the scientific field of mathematics. However, the field of mathematics has own rigorous guidelines on scientific writing, which, in part, may contradict corresponding guidelines in engineering. Therefore, in this section, an adaptation of mathematical formulation recommendations from the field of mathematics to the field of engineering is attempted, keeping these recommendations in accordance with previous parts of this book.

In general, formulas and equations represent parts of speech. Hence, authors should pay particular attention when using mathematical symbols to ensure that what is intended to be communicated is indeed what is printed in the text. In addition, authors should keep in mind that mathematics is about communicating ideas. Frequently, mathematical representations of methods realizing own approaches are far too complicated for

the readership to follow without any text. Therefore, authors are invited to balance the use of formulas/equations and text when explaining methods to enhance the readability of scientific texts and to effectively convey the ideas behind the formulas or equations.

Regarding the formatting of formulas and equations, usually scientific texts come with formatting guidelines by the publisher, similar to the guidelines provided for figures (Section B.IV). Authors are advised to look into formatting guidelines prior to starting preparing scientific texts to include the corresponding settings to mathematical editors in advance and, thus, to avoid the tedious work of adjusting the format at the end of writing.

46. **Number formulas and equations sequentially.** Formulas and equations that are referenced in the text must be numbered in a sequence to enable quick referencing. Numbering is usually placed at the end of the equation/formula line. It should be noted that not all formulas and equations must be numbered but only those that are actually referenced in the text. As formulas and equations are usually aligned in the middle of the line or indented at a publisher-specified distance from the beginning of the line, placing numbering at the end of the line might not be straightforward. A frequent solution in word processors is to enter a right-oriented tabulator on the right end of the text area and send the cursor there after entering the equation/formula using the "tab" key. Inserting formulas and equations in tables is a workaround that is not recommended because it may cause formatting problems.

Section VI
Referencing

Scientific research projects almost never stand alone. In other words, scientific research is rarely isolated, and researchers typically build own approaches on existing research within the scientific field. When writing about research findings, it is imperative that authors make due allowance to literature sources on which own approaches are based or which are used to develop own thoughts relevant to the research problem. Attributing appropriate acknowledgement to literature sources is achieved through referencing.

Referencing may include citations, in-text citations, references, quotations, and reference lists [6]. Particularly for inexperienced authors, it is important to distinguish between the various referencing types and to understand when to use which. A *citation* essentially serves as an acknowledgement to an existing source, which is represented by an alphanumeric expression embedded in the text usually placed within parentheses or square brackets. A similar term used in scientific writing is the *in-text citation*, which denotes a brief description of the approach being cited with limited paraphrasing ("paraphrased in-text citations", Recommendation 25). The term *reference* is wider and encapsulates all information necessary for mentioning the work of other researchers related to the research topic of the scientific text. This information may include names, dates, and bibliographic information. In this context, a citation may be viewed as a subset of a reference, and citations are usually linked to the bibliographic information of references. *Quotations* represent word-by-word repetitions of existing scientific text extracts (see also Recommendation 25). Consequently, to avoid copyright issues, quotations are generally very limited and must be explicitly indicated by including the respective texts within quotation marks. Finally, *reference lists* include the bibliographic information of all

references used in a scientific text. However, it is worth mentioning that a reference list does not necessarily match a "bibliography", which is a list of all sources consulted while preparing the text, whether cited or not.

With respect to referencing, the majority of scientific texts focus on citations and references, accompanied by reference lists, which are usually placed at the end of scientific texts. Perhaps the most important task of referencing is to define the formatting style to be used. In this direction, a plethora of referencing styles have been developed over the years, each usually tailored to one scientific discipline [7]. Two of the most well-known referencing styles are the "Vancouver" style used in medical sciences and the "Harvard" style frequently adopted in civil engineering. The choice of style is usually dictated by the publisher who provides detailed guidelines on how to format references. Otherwise, authors are left free to select a referencing style and must consistently stick to it.

In general, references aim at fulfilling the following goals [8]:

- Placing the own approach into the proper context by referring to authoritative literature.
- Providing the readership with sufficient background to criticize the work presented in the scientific text.
- Enabling readers to compare and contrast the own approach with similar approaches in the scientific field.
- Giving credit to information sources utilized for developing the own approach.
- Providing gateways for further reading related to subtopics, a more extensive presentation of which may fall beyond the scope of the scientific text.

57. References must be complete and formatted consistently. Consistency in style and term usage is of paramount importance, as also mentioned in Recommendation 9. Consistency in formatting references should draw additional

attention from authors, since, due to the relatively limited extent of reference lists, formatting inconsistencies in reference lists are usually blatant and indicate sloppy work. Authors must be careful to stick to the guidelines of the referencing style used. Even if no particular referencing style is followed, authors must make sure that an individual referencing format is adopted for each type of source. For example, authors must consistently use one format for scientific journal articles, one format for conference papers, one format for books, one format for book chapters, one format for technical reports, and one format for websites.

Example (Journal paper)

Newmark, N. M., *1959*. 'A method of computation for structural dynamics'. ASCE Journal of Engineering Mechanics, *85*: 67-94. Smyth, A. and Wu, M. (2007). "Multi-rate Kalman filtering for the data fusion of displacement and acceleration response measurements in dynamic system monitoring". Mechanical Systems and Signal Processing, *Vol. 21, No. 2, pp. 706-723*.	Newmark, N. M. *(1959)*. "A method of computation for structural dynamics". ASCE Journal of Engineering Mechanics, *85(3)*: 67-94. Smyth, A. and Wu, M. (2007). "Multi-rate Kalman filtering for the data fusion of displacement and acceleration response measurements in dynamic system monitoring". Mechanical Systems and Signal Processing, *21(2): 706-723*.

The formatting on the left is an example of incompleteness and inconsistency in referencing scientific journal articles. The author has made a bad combination of Harvard style (first reference) and IEEE style (second reference). There are also discrepancies from IEEE referencing guidelines; e.g. the IEEE style dictates numbering the references, plac-