Intelligent Systems Reference Library 153

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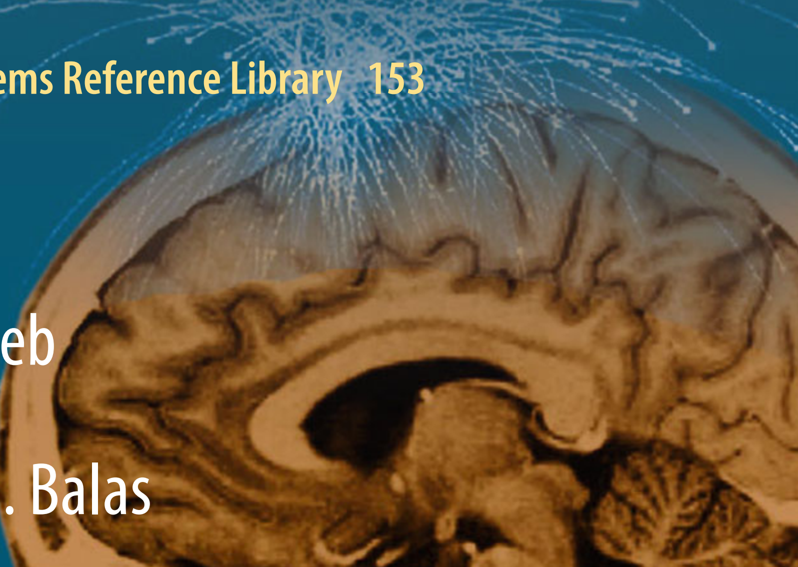

Engineering Research Methodology

A Practical Insight for Researchers

Springer

Intelligent Systems Reference Library

Volume 153

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Preface

This book deals with skills base useful to build upon during one's early days in research so as to have a successful career in research either in academia or in the industry. Research in the field of engineering requires a specific skill set different from other scientific communities. The bibliographic databases which are useful for the literature review are different, and the dilemma as to whether the research output should be in the form of a patent or a journal paper is a significant problem that is often not considered or dealt with in most books on research methodology. Engineering research also involves working with equipment, statistical data, algorithms, and mathematics, in varying degrees and combinations.

Engineering research is generally driven by industries and is therefore categorized by timelines and deadlines, and powered by customer requirements, especially in engineering research performed in industries and research laboratories. Engineering research also comes with the ways and means to deal with criticisms from reviewers of the papers submitted, research advisors, research laboratory managers (in case of industrial laboratories), and so we have presented some tips in this regard even though purists may not consider it a part of research methods or research methodology and have by and large not dealt with this topic in the prevalent books on this topic.

The art of effective search and literature review, analysis and synthesis of prior art, critical and creative reading, taking notes while reading, as well as specialized aspects related to a stream of engineering like reading datasheets and reading mathematics and algorithms, are all described in this book.

Most research methodology books do not deal with the subject matter of patents (or intellectual property rights). However, the subject and importance of patents and the requirements of patentability are today equally important to academic researchers as have always been to the research engineers in the industrial research laboratories. Ethical (and research misconduct) issues related to research practice and authorship have also been enumerated in detail for the benefit of researchers.

The technical writing skills and strategies needed in engineering research, apart from the structure and approach of developing a journal paper that would have a higher chance of acceptance, are presented. The language and writing skills including the care that is needed while writing mathematical equations in a journal paper, and also the process of journal publication, are dealt with in great detail in this book.

Research management and planning are important skills to develop so as to prioritize the tasks at hand, set and achieve the milestones as agreed upon with the advisor or laboratory managers, manage ones effort skillfully to maximize output, and manage the goals and objectives of a dissertation in a timely and productive manner, and so we have addressed these issues in detail in this book.

Research outcomes enable the researcher to reap the benefits, only if such skills are married with effective communicating skills, compelling slides with proper distribution of content, and appropriate focus on relevant content. All these are critical attributes that a researcher should develop to be successful in the research career, and so we have provided some practical guidelines from both academic and industrial research perspectives to improve and develop presentation skills.

The raging debate as to whether the impact factors of journal papers are of any practical value or not, and a quantitative analysis of the quality of Ph.D. in India, is also studied in this book.

In summary, this book provides a comprehensive and methodological approach to research that spans philosophical perspectives of research, practical matters of doing research, diverse research methods like qualitative and quantitative research methods, literature reviews, ethics and ethical approval, intellectual property protection, and even patent searching. It is hoped that this book will enable the engineer to learn about the basics and fundamental aspects of engineering research and position the researcher to design and engineer the research processes in one's own field and topic so as to achieve the ultimate objective which is about making a contribution to the creation of new knowledge.

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Chapter 1
Introduction: What Is Research?

Research refers to a careful, well-defined (or redefined), objective, and systematic method of search for knowledge, or formulation of a theory that is driven by inquisitiveness for that which is unknown and useful on a particular aspect so as to make an original contribution to expand the existing knowledge base. Research involves formulation of hypothesis or proposition of solutions, data analysis, and deductions; and ascertaining whether the conclusions fit the hypothesis. Research is a process of creating, or formulating knowledge that does not yet exist.

Booth et al. [1] explains that the research cycle starts with basically a practical problem: one must be clear what the problem being attempted to solve is and why it is important. This problem motivates a research question without which one can tend to get lost in a giant swamp of information. The question helps one zero in onto manageable volume of information, and in turn defines a research project which is an activity or set of activities that ultimately leads to result or answer, which in turn helps to solve the practical problem that one started with in the first place as shown in Fig. 1.1.

The building up of background for doing research includes one to acquire the ability to connect different areas. The purpose is to prepare the mind for active work as opposed to becoming a repository or an encyclopedia. Research is not just about reading a lot of books and finding a lot of, gathering a lot of existing information. It is instead adding, maybe small and specific, yet original, contribution to that existing body of knowledge. So, research is about how one poses a question which has relevance to the world that we are living in, and while looking for that answer one has to be as systematic as one can be. There must be a balance between what is achievable in a research program with a finite endpoint and also, the contribution it is going to make. The objective of a good research program is to try and gain insight into something. Or indeed, to try and solve a problem. Good research questions develop throughout the project actually and one can even keep modifying them. Through research, one would like to make, or develop, new knowledge about the

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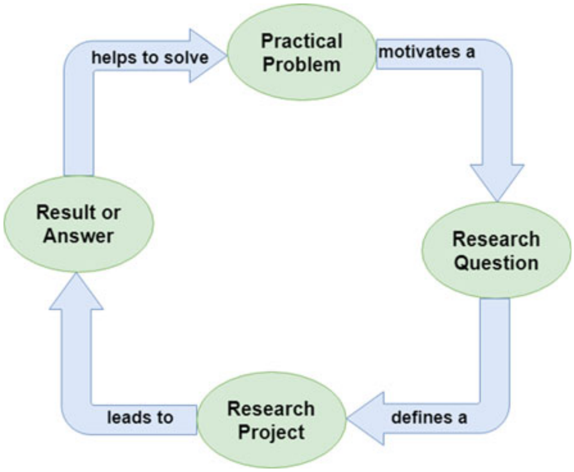

Fig. 1.1 The research flow diagram [1]

world around us which can be written down or recorded in some way, and that knowledge can be accessed through that writing or recording.

The ways of developing and accessing knowledge come in three, somewhat overlapping, broad categories:

(i) Observation is the most fundamental way of obtaining information from a source, and it could be significant in itself if the thing that we are trying to observe is really strange or exciting, or is difficult to observe. Observation takes different forms from something like measurements in a laboratory to a survey among a group of subjects to the time it takes for a firmware routine to run. The observational data often needs to be processed in some form and this leads to the second category of knowledge, the model.

(ii) Models are approximated, often simplified ways of describing sometimes very complex interactions in the form of a statistical relationship, a figure, or a set of mathematical equations. For instance, the modeling equation captures the relationship between different attributes or the behavior of the device in an abstract form and enables us to understand the observed phenomena [2].

(iii) The final category is a way of arranging or doing things through processes, algorithms, procedures, arrangements, or reference designs, to get a certain desired result.

The categories of knowledge as enumerated above are shown in Fig. 1.2.

Good research involves systematic collection and analysis of information and is followed by an attempt to infer a little bit beyond the already known information in a way that is a significant value addition. Usually, engineering research is a journey that traverses from a research area (example: Control Systems), to the topic (example: Control of Microbial Fuel Cells) and finally onto the problem (example: Adaptive Control of Single Chamber Microbial Fuel Cells) (Area → Topic → Problem). Getting a good problem to solve is more than half the work done. However, sometimes

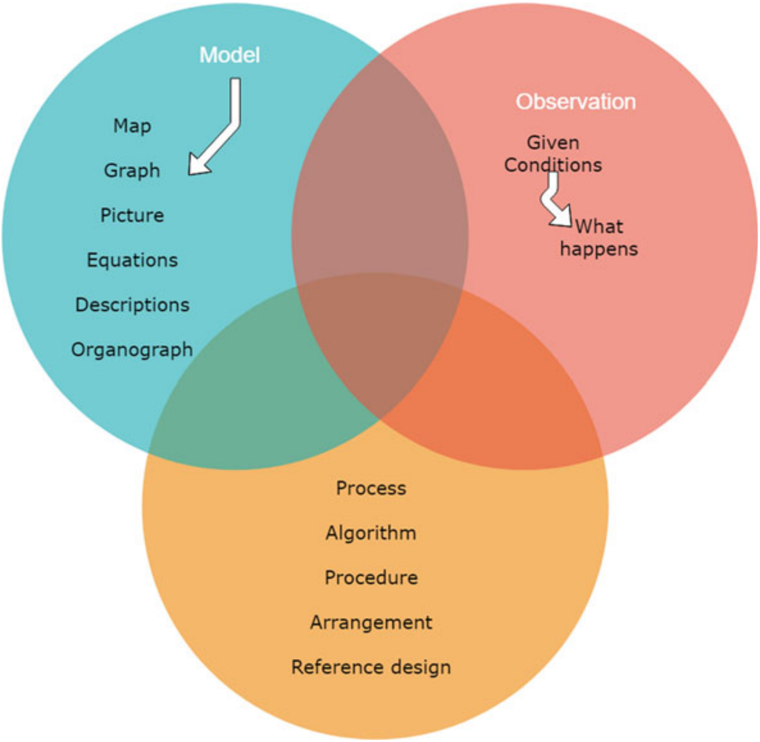

Fig. 1.2 The categories of knowledge in research

the journey can be reverse, for example, the traversal from (Problem → Topic → Area). This can happen when one is led to a problem through a connection to another problem whose top structure is different.

Engineering research is the process of developing the perspectives and seeking improvements in knowledge and skills to enable the recognition, planning, design, and execution of research in a wide range of forms relevant for engineering and technology investigations and developments. We can start off by describing some problem in the world that exists that is bugging or worrying us and that we should be addressing. It could be that there is something we would like to do or accomplish but currently can not because we lack the knowledge to do so. It could be that there is something that already works, but we do not know why and we would like to understand it better. It could be that we want to do something to see what will happen.

1.1 Objectives of Engineering Research

The objective of engineering research is to solve new and important problems, and since the conclusion at the end of one's research outcome has to be new, but when one starts, the conclusion is unknown. So, the start itself is tricky, one may say. The answer is, based on "circumstantial evidence", intuition, and imagination, one guesses what may be a possible conclusion. A guess gives a target to work toward, and after initial attempts, it may turn out that the guess is incorrect. But, the work may suggest new worthy avenues or targets which may be based on some modifications of the initial target, or may need new techniques, or one may obtain negative results which may render the initial target or some other targets as not realizable, or may lead to fortunate discoveries while looking for something else (serendipity). Research objectives can sometimes be convoluted and difficult to follow.

Knowing where and how to find different types of information helps one solve engineering problems, in both academic and professional career. Lack of investigation into engineering guidelines, standards, and best practices result in failures with severe repercussions. As an engineer, the ability to conduct thorough and accurate research while clearly communicating the results is extremely important in decision-making.

The main aim of the research is to apply scientific approaches to seek answers to open questions, and although each research study is particularly suited for a certain approach, in general, the following are different types of research studies: exploratory or formulative, descriptive, diagnostic, and hypothesis-testing.

The objectives of engineering research should be to develop new theoretical or applied knowledge and not necessarily limited to obtaining abilities to obtain the desired result. The objectives should be framed such that in the event of not being able to achieve the desired result that is being sought, one can fall back to understanding why it is not possible, because that is also a contribution toward ongoing research in solving that problem. Of course, someone else might come along and actually propose a different approach where the desired objective is indeed possible to be achieved.

1.2 Motivation in Engineering Research

The possible motives may be the result of one or more of the following desires:

(i) Studies have shown that intrinsic motivations like interest, challenge, learning, meaning, purpose, are linked to strong creative performance;
(ii) Extrinsic motivating factors like rewards for good work include money, fame, awards, praise, and status are very strong motivators, but may block creativity. For example: Research outcome may enable obtaining a patent which is a good way to become rich and famous.

(iii) Influences from others like competition, collaboration, commitment, and encouragement are also motivating factors in research. For example: my friends are all doing research and so should I, or, a person that I dislike is doing well and I want to do better.
(iv) Personal motivation in solving unsolved problems, intellectual joy, service to community, and respectability are all driving factors.

The following factors would be a mix of extrinsic and intrinsic aspects: (i) Wanting to do better than what has been achieved in the world, (ii) improve the state of the art in technology, (iii) Contribute to the improvement of society, (iv) Fulfillment of the historical legacy in the immediate sociocultural context.

Several other factors like government directives, funding opportunities in certain areas, and terms of employment, can motivate people to get involved in engineering research.

1.3 Types of Engineering Research

The different types of research are

(i) Descriptive versus Analytical: Descriptive research includes comparative and correlational methods, and fact-finding inquiries, to effectively describe the present state of art. The researcher holds no control over the variables; rather only reports as it is. Descriptive research also includes attempts to determine causes even though the variables cannot be controlled. On the contrary, in analytical research, already available facts for analysis and critical evaluation are utilized. Some research studies can be both descriptive and analytical [3].
(ii) Applied versus Fundamental: Research can either be applied research or fundamental (basic or pure) research. Applied research seeks to solve an immediate problem facing the organization, whereas fundamental research is concerned with generalizations and formulation of a theory. Research concerning natural phenomena or relating to pure mathematics are examples of fundamental research. Research to identify social or economic trends, or those that find out whether certain communications will be read and understood are examples of applied research. The primary objective of applied research is to determine a solution for compelling problems in actual practice, while basic research is aimed at seeking information which could have a broad base of applications in the medium to long term.
(iii) Quantitative versus Qualitative: Quantitative research uses statistical observations of a sufficiently large number of representative cases to draw any conclusions, while qualitative researchers rely on a few nonrepresentative cases or verbal narrative in behavioral studies such as clustering effect in intersections in Transportation engineering to make a proposition.

1.4 Finding and Solving a Worthwhile Problem

A researcher may start out with the research problems stated by the Supervisor or posed by others that are yet to be solved. Alternately, it may involve rethinking of a basic theory, or need to be formulated or put together from the information provided in a group of papers suggested by the Supervisor. Research scholars are faced with the task of finding an appropriate problem on which to begin their research. Skills needed to accomplish such a task at the outset, while taking care of possible implications are critically important but often not taught [4]. Once the problem is vaguely identified, the process of literature survey and technical reading, as described in the next chapter, would take place for more certainty of the worthiness of the intended problem.

However, an initial spark is ideally required before the process of literature survey may duly begin. Sometimes, an oral presentation by somebody which is followed by asking questions or introspection provides this perspective which reading papers do not. At other times, a development in another subject may have produced a tool or a result which has direct implications to the researcher's subject and may lead to problem identification.

A worthwhile research problem would have one or more attributes. It could be nonintuitive/counterintuitive even to someone who knows the area, something that the research community had been expecting for sometime, a major simplification of a central part of the theory, a new result which would start off a new subject or an area, provides a new method or improves upon known methods of doing something which has practical applications, or a result which stops further work in an area. The researcher has to be convinced that the problem is worthwhile before beginning to tackle it because best efforts come when the work is worth doing, and the problem and/or solution has a better chance of being accepted by the research community. Not all problems that one solves will be great, and sometimes major advancements are made through solutions to small problems dealt with effectively.

Some problems are universally considered hard and open, and have deep implications and connections to different concepts. The reality is that most researchers in their lifetime do not get into such problems. However, hard problems get solved only because people tackle them. The question a researcher has to grapple with whether the time investment is worth it given that the likely outcome is negative, and so it is a difficult personal decision to make. At the same time, even in the case of failure to solve the intended hard problem, there may be partial/side results that serve the immediate need of producing some results for the dissertation.

George Pólya (1887–1985) suggested a 4-step procedure for mathematical problem-solving [5], which is relevant to engineering researchers as well. Recent work such as [6, 7] suggest the relevance of these recommendations. The recommended steps to solve a research problem are

(i) Understand the problem, restate it as if its your own, visualize the problem by drawing figures, and determine if something more is needed.
(ii) One must start somewhere and systematically explore possible strategies to solve the problem or a simpler version of it while looking for patterns.

(iii) Execute the plan to see if it works, and if it does not then start over with another approach. Having delved into the problem and returned to it multiple times, one might have a flash of insight or a new idea to solve the problem.
(iv) Looking back and reflecting helps in understanding and assimilating the strategy, and is a sort of investment into the future.

In the subsequent chapters of this book, we present other different aspects of research which together form different parts of research methodologies and are important for a successful engineering research career.

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Chapter 2
Literature Review and Technical Reading

The primary goal of literature review is to know the use of content/ideas/approaches in the literature to correctly identify the problem that is vaguely known beforehand, to advocate a specific approach adopted to understanding the problem, and to access the choice of methods used. It also helps the researcher understand clearly that the research to be undertaken would contribute something new and innovative. The quality of such review can be determined by evaluating if it includes appropriate breadth and depth of the area under study, clarity, rigor, consistency, effective analysis.

2.1 New and Existing Knowledge

New knowledge in research can only be interpreted within the context of what is already known, and cannot exist without the foundation of existing knowledge. In this chapter, we are going to look at how that foundation of knowledge needs to be constructed so that our new knowledge is supported by it. The new knowledge can have vastly different interpretations depending on what the researcher's background, and one's perception of that new knowledge can change from indifference to excitement (or vice versa), depending on what else one knows. The significance can normally be argued from the point of view that there is indeed an existing problem and that it is known by looking at what already exists in the field. The existing knowledge is needed to make the case that there is a problem and that it is important.

One can infer that the knowledge that is sought to be produced does not yet exist by describing what other knowledge already exists and by pointing out that this part is missing so that what we have is original. To do this, one again needs the existing knowledge: the context, the significance, the originality, and the tools. Where does this existing knowledge come from? Normally, one finds this knowledge by reading and surveying the literature in the field that was established long ago and also about

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the more recent knowledge which is in fact always changing. With this foundation in place, the new knowledge that one will make will be much more difficult to challenge than without that strong foundation in place which is ensured with lots of references to the literature.

Often, but not always, the textbooks contain the older established knowledge and the research papers the newer work. Reading the textbooks on one's topic provide the established knowledge and the background to be able to read the newer work usually recorded in the research papers. Very often, reading a textbook is not too difficult for it is written as a teaching instrument, and the author of the textbook normally starts from the basics and take the reader, through everything that one needs to be able to understand that topic. This is not at all the case with a research paper where the goal is normally to present a small piece of new knowledge, and that new knowledge will not have stood the test of time in the same way as the knowledge in a textbook would have. The research paper is written for other researchers out on the edge of knowledge and it assumes that the reader already knows a lot in that field. A researcher may find oneself continually going back to other sources to try and interpret what is going on in a particular research paper. It can be difficult to find the right work to read, but the objective with all this reading and learning is to be able to get the knowledge that one needs to build the foundation.

The review process must explain how a research item builds on another one [1]. This is because useful research should elucidate how and why certain technical development took place, so that it is easy for the reader to comprehend why the present talk is being undertaken, and a good literature survey would provide a convincing under to that question. An effective review of literature ensures a firm foundation for advancing knowledge, facilitates theoretical growth, eliminates as areas that might be of interest, and opens new avenues of possible work. An efficient literature review is centered around concepts and not authors [2].

Generally, a good literature survey is the first expectation of a supervisor from the research student, and when done well can create a good impression that the state of art in the chosen field is well understood. Simple rules for writing an effective literature review are important for a research scholar, are provided [3, 4]. A good literature review would not draw hasty conclusions and look into the individual references to determine the underlying causes/assumptions/mechanisms in each of them so as to synthesize the available information in a much more meaningful way. A literature review should be able to summarize as to what is already known from the state of the art, detail the key concepts and the main factors or parameters and the underlying relationships between those, describe any complementary existing approaches, enumerate the inconsistencies or shortcomings in the published work, identify the reported results that are inconclusive or contradictory, and provide a compulsive reason to do further work in the field.

A good literature survey is typically a two-step process as enumerated below:

(i) Identify the major topics or subtopics or concepts relevant to the subject under consideration.

(ii) Place the citation of the relevant source (article/patent/website/data, etc.) in the correct category of the concept/topic/subtopic (with the help of a ✓, for example).

It could be that as one is reading and comes across something that one considers to be very important for one's work, a core principle or a description of something that just sounds really good, and one is excited to have found it. Naturally, one highlights that section or underlines it, or put an asterisk in the margin, so that one could come back to it later. Effectively, one is saying that it is important and hence the marking so as not to forget it.

After having marked or highlighted the section, it is suggested that the paper be put away or the book be closed. Then one should write about the highlighted part without copying it. As one writes about why one thinks that part is important and what it contains, one is automatically changing it and making it fit into one's foundation in the way that makes sense. There are shaping and crafting of that piece of knowledge to fit where one needs it to be. To build the knowledge foundation, one needs to be reading and learning continually. But that is not enough, one also needs to be writing about what one has read.

A comprehensive literature survey should methodically analyze and synthesize quality archived work, provide a firm foundation to a topic of interest and the choice of suitable research methodologies, and demonstrate that the proposed work would make a novel contribution to the overall field of research.

2.2 Analysis and Synthesis of Prior Art

After collecting the sources, usually articles, intended to be used in the literature review, the researcher is ready to break down each article and identify the useful content in it, and then synthesize the collection of articles (integrate them and identify the conclusions that can be made from the articles as a group) [5]. A literature survey grid of N topics and M sources is shown below to help crystallize the information in different categories.

A researcher should analyze the relevant information ascertained in Table 2.1 by undertaking the following steps:

(i) Understanding the hypothesis,
(ii) Understanding the models and the experimental conditions used,
(iii) Making connections,
(iv) Comparing and contrasting the various information, and
(v) Finding out the strong points and the loopholes.

It is always good to be suspicious of the claims made in the sources that have been thoroughly reviewed, especially in the case of tall claims. If one is amenable to easily accept whatever is available in the literature, one may find it difficult to go

Table 2.1 The literature survey grid

	Source 1	Source 2	…	Source M
Topic 1		✓		
Topic 2	✓			✓
⋮				
⋮				
Topic N	✓	✓		

beyond it in one's own work and may also fail to carefully analyze with a suspicious bent of mind one's own results subsequently.

The goal of literature survey is to bring out something new to work on through the identification of unsolved issues, determine the problems in the existing models or experimental designs, and present a novel idea and recommendations.

No matter where one gets the available information, one needs to critically evaluate each resource that the researcher wishes to cite. This methodology analyzes available materials to determine suitability for the intended research. Relying on refereed articles published in scholarly journals or granted patents can save the researcher a lot of time. Here are a few criteria that could help the researcher in the evaluation of the information under study:

- Authority: What are the author's credentials and affiliation? Who publishes the information?
- Accuracy: Based on what one already knows about the topic or from reading other sources, does the information seem credible? Does the author cite other sources in a reference list or bibliography, to support the information presented?
- Scope: Is the source at an appropriate comprehension or research level?

There are other criteria to consider as well, such as currency, objectivity, and purpose. It is important to ensure that the search question is neither too narrow nor too broad.

2.3 Bibliographic Databases

"Bibliographic databases" refer to "abstracting and indexing services" useful for collecting citation-related information and possibly abstracts of research articles from scholarly literature and making them available through search. Performing simultaneous searches through such large databases may allow researchers to overtly rely on any one database and be limited by the intrinsic shortcoming of any one of them for quality research [6]. A researcher should be able to quickly identify the databases that are of use in the idea or problem that one wishes to explore. In this section, we present some details about a few of the popular bibliographic databases most sought after by engineering researchers, but do not attempt to provide exhaustive details.

2.3.1 Web of Science

Web of Science (formerly known as ISI or Thomson Reuters) includes multiple databases, as well as specialized tools. It is a good search tool for scholarly materials requiring institutional license and allows the researcher to search in a particular topic of interest, which can be made by selection in fields that are available in drop down menu such as title, topic, author, address, etc. The tool also allows sorting by number of citations (highest to lowest), publication date.[1]

Put quotes around phrases, add more keywords, or use the "Refine Results" panel on the left to narrow down the search by keyword, phrases in quotation marks, type of material such as peer-reviewed journal articles, date, language, and more. Expanding the search results is possible by looking for alternate word endings, breaking the search concepts down, thinking of alternate search terms (including scientific names if applicable) and connecting them with OR, and using the database's features for finding additional references. "Cited reference search" option enables a researcher to trace articles which have cited a formerly published paper. Using this element, it is possible to find how a familiar idea has been applied, improved, or extended subsequently.

A structured search like this that enables narrowing and refining what one is looking for is effective to ensure that the results throw up relevant sources and time spent in studying those is likely to be well utilized. Based on the researcher's need the search result can be broadened or narrowed down using the built-in fields provided in this website. When clicked on any of the search results, this website provides the title of the paper, authors, the type of journal, volume, issue number and year of publication, abstract, keywords, etc., so that the researcher has enough information to decide if it is worthwhile to acquire the full version of the paper.

2.3.2 Google and Google Scholar

Google is a great place to start one's search when one is starting out on a topic. It can be helpful in finding freely available information, such as reports from governments, organizations, companies, and so on. However, there are limitations:

[1] https://clarivate.com/products/web-of-science/.

(i) It's a "black box" of information. It searches everything on the Internet, with no quality control—one does not know where results are coming from.
(ii) There are limited search functionality and refinement options.

What about Google Scholar? Google Scholar limits one's search to scholarly literature. However, there are limitations:

1. Some of the results are not actually scholarly. An article may look scholarly at first glance, but is not a good source upon further inspection.
2. It is not comprehensive. Some publishers do not make their content available to Google Scholar.
3. There is limited search functionality and refinement options.

There are search operators that can be used to help narrow down the results. These help one find more relevant and useful sources of information. Operators can be combined within searches. Here are some basic ones that one can use:

(i) OR—Broadens search by capturing synonyms or variant spellings of a concept. Example: Synchronous OR asynchronous will find results that have either term present.
(ii) Brackets/Parentheses ( )—Gather OR'd synonyms of a concept together, while combining them with another concept. Example: RAM (synchronous OR asynchronous).
(iii) Quotation marks " "—Narrow the search by finding words together as a phrase, instead of separately. Example: RAM (synchronous OR asynchronous) "Texas Instruments".
(iv) Site—limits the search to results from a specific domain or website. This operator is helpful when searching specific websites such as the BC government, which is Example: RAM (synchronous OR asynchronous) "Texas Instruments" site: http://ieeexplore.ieee.org.
(v) Filetype—limits the search to results with a specific file extension one could look for pdf's, PowerPoint presentations, Excel spreadsheets, and so on. Example: RAM (synchronous OR asynchronous) "Texas Instruments" site: http://ieeexplore.ieee.org, filetype: pdf.

The Search Tools button at the top of the Google results gives you a variety of other options, such as limiting the results by date. There are other operators and tools that one can use in Google and Google Scholar. Google is but one search tool a researcher can use—it is not the only one!

It can be hard to sift through all the results in Google or Google Scholar, especially if the intent is to find scholarly resources from a specific subject area. To find the best resources on a topic, one should search in academic databases, in addition to Google. Databases provide access to journal articles and conference proceedings, as well as other scholarly resources. One gets more relevant and focused results, because they have better quality control and search functionality. One should choose a database based on subject area, date coverage, and publication type. Interfaces vary between databases, but the search techniques remain essentially the same.

2.4 Effective Search: The Way Forward

A scholarly publication is one wherein the published outcome is authored by researchers in a specific field of skill. Such work cites all source contents used and is generally peer reviewed for accuracy and validity before publication. Essentially, the audience for such works is fellow experts and students in the field. The content is typically more complex and advanced than those found in general magazines.

While most of the engineering researchers need to refer articles that appear in scholarly journals, books or other peer-reviewed sources, there is also a substantially useful content in more popular publications. These are informal in approach and aim to reach a large number of readers including both the experts in the filed and also amateurs, but the content focuses on news and trends in the field. Research outcomes are not typically first disseminated here but are usually meant for general reading.

A researcher should use all search tools for comprehensive search. No one place or one source exists that will provide all the information one needs; one will likely need to look in all the places that would be described in this chapter and in others not mentioned.

A researcher must consider what type of information is needed, and where it could be found. Not all information is available online. Some information is only available in print. It can take time for scholarly and peer-reviewed information to be published. One might not be able to find scholarly information about something currently being reported in the news. The information may not be available, or studies on a topic of interest to the researcher have not occurred. In such a case, the researcher should look for similar studies that would be applicable to the specific topic; look for broad information (general process, technology, etc.), as well as information that addresses the specific context of the researcher's report.

Searching is an iterative process:

- Experiment with different keywords and operators;
- Evaluate and assess results, use filters;
- Modify the search as needed; and
- When relevant articles are found, look at their citations and references.

After the search is complete, the researcher needs to engage in critical and thorough reading, making observation of the salient points in those sources, and summarize the findings. A detailed comparison and contrast of the findings is also required to be done. This entire process may be needed to be done multiple times. The conclusion of the entire process of literature survey includes a summary of the relevant and important work done, and also the identification of the missing links and the challenges in the open problems in the area under study. One must note that the literature survey is a continuous and cyclical process that may involve the researcher going back and forth till the end of the research project.

Not many people begin research work in their graduate program with an already acquired skill to efficiently parse math-heavy articles quickly, but those who eventually succeed in an engineering research career quickly develop that skill from reading a lot of papers, seeking help in understanding confusing parts, and getting through relevant coursework to build up the required skills and intuition.

It is very important to not lose sight of the purpose of an extensive search or literature survey, for it is possible to spend a very significant amount of one's time doing so and actually falsely think that one is working hard. Nothing will come of it unless one is an active reader and spends sufficient time to develop one's own ideas build on what one has read. It is not as if literature survey ends and then research begins, for new literature keeps appearing, and as one's understanding of the problem grows, one finds new connections and related/evolving problems which may need more search. It is mandatory for a Ph.D. scholar to write a synopsis of the topic and submit it to the doctoral committee for approval. During this stage, the scholar needs to undertake an extensive literature survey connected with the problem. For this purpose, the archived journals and published or unpublished bibliographies are the first place to check out. One source leads to another.

2.5 Introduction to Technical Reading

It is now imperative for any active researcher to keep oneself abreast with research outcomes in their field of interest. Finding the right work to read can be difficult. The literature where knowledge is archived is very fragmented and there are bits and pieces all over the place. Very rarely will one find everything that one wants close together in one place. However, it is obvious that the number of papers relevant to a particular researcher is very few, compared to the actual number of research papers available from peer-reviewed technical sources. It is also important to know where to read from; relying on refereed journals and books published by reputed publishers is always better than relying on easily available random articles off the web. While reading an engineering research paper, the goal is to understand the technical contributions that the authors are making.

Given the abundance of journal articles, it is useful to adopt a quick, purposeful, and useful way of reading these manuscripts [7]. It is not the same as reading a newspaper. It may require rereading the paper multiple times and one might expect to spend many hours reading the paper. A simple, efficient, and logical approach is described in this section for identifying articles and reading them suitably for effective research.

Amount of time to be spent will get ascertained after an initial skimming through the paper to decide whether it is worth careful reading. There will also be papers where it is not worth reading all the details in the first instance. It is quite possible that the details are of limited value, or simply one does not feel competent to understand the information yet.

Start out the skimming process by reading the title and keywords (these are anyways, probably what caught the initial attention in the first place). If on reading these, it does not sufficiently seem to be interesting; it is better to stop reading and look for something else to read. One should then read the abstract to get an overview of the paper in minimum time. Again, if it does not seem sufficiently important to the field of study, one should stop reading further. If the abstract is of interest, one should skip most of the paper and go straight to the conclusions to find if the paper is relevant to the intended purpose, and if so, then one should read the figures, tables, and the captions therein, because these would not take much time but would provide a broad enough idea as to what was done in the paper.

If the paper has continued to be of interest so far, then one is now ready to delve into the Introduction section to know the background information about the work and also to ascertain why the authors did that particular study and in what ways the paper furthers the state of the art. The next sections to read are the Results and Discussion sections which is really the heart of the paper. One should really read further sections like the Experimental Setup/Modeling, etc., only if one is really interested and wishes to understand exactly what was done to better understand the meaning of the data and its interpretation.

As one works through the literature in this way, one should consider not only the knowledge that is written down but also the reputation of the people who made that knowledge. A researcher will always need to be searching for the relevant literature and keeping up to date with it. If one is busy with a small project, the advisor might just give a single important paper to read. But with a larger one, you will be searching for one's own literature to read. For this one will need a strategy as there is just too much work out there to read everything.

2.6 Conceptualizing Research

The characteristics of a research objective are that it must have new knowledge at the center, and that it must be accepted by the community of other researchers and recognized as significant. But how do we actually conceptualize the research? Besides being original and significant, a good research problem should also be solvable or achievable. This requirement already asks us to think about the method and the tools that could be used to obtain that new knowledge. Now, the significance and the originality and all the theory that we read and tools and methods that we need to take on a problem, all of these normally come from the existing recorded literature and knowledge in the field.

Coming up with a good research objective, conceptualizing the research that meets all of these requirements is a tough thing to do. It means that one must already be aware of what is in the literature. That is, by the time one actually has a good research objective, one is probably already an expert at the edge of knowledge else it is difficult to say with confidence that one has a good research objective. If one is doing research at the Ph.D. level or higher, then conceptualizing the research is probably something that one needs to do oneself. This is a very tough step because one needs to know all that literature in the field.

So, when working at the Ph.D. level, one needs to be prepared to become that expert, one needs to be continually reading the literature so as to bring together the three parts: (i) significant problem, (ii) the knowledge that will address it, and (iii) a possible way to make that new knowledge. How these three aspects would come together will be different for every person doing research and it will be different in every field, but the only way to be that expert is by immersing oneself in the literature and knowing about what already exists in the field.

However, if one is working on a research project that is of a smaller scope than a Ph.D., let us say a master's thesis, then conceptualizing the research is possibly too tough to do, and one does not have the time that it takes to become that expert at the edge of knowledge. In this case, the researcher needs the help of someone else, typically the supervisor who may already be an expert and an active researcher in that field, and may advise on what a good research objective might be. An established researcher in any field should be able to immediately point to the landmark literature that one should read first. Otherwise one would need to spend a lot of time reading the literature to discover.

As engineers, we like to build things, and that's good, but the objective of research is to make knowledge. If one's research is about building something, one ought to take a step back and ask if new knowledge is being formulated. Even if what one is building is new and has never been built before, if it is something that any experienced and competent engineer could have come up with, one runs the risk of one's work being labeled obvious and rejected as research.

2.7 Critical and Creative Reading

Reading a research paper is a critical process. The reader should not be under the assumption that reported results or arguments are correct. Rather, being suspicious and asking appropriate questions is in fact a good thing. Have the authors attempted to solve the right problem? Are there simpler solutions that have not been considered? What are the limitations (both stated and ignored) of the solution and are there any missing links? Are the assumptions that were made reasonable? Is there a logical flow to the paper or is there a flaw in the reasoning? These need to be ascertained apart from the relevance and the importance of the work, by careful reading.

Use of judgemental approach and boldness to make judgments is needed while reading. Flexibility to discard previous erroneous judgments is also critical. Additionally, it is important to ascertain whether the data presented in the paper is right data to substantiate the argument that was made in the paper and whether the data was gathered and interpreted in a correct manner. It is also important to decipher whether some other dataset would have been more compelling.

Critical reading is relatively easy. It is relatively easier to critically read to find the mistakes than to read it so as to find the good ideas in the paper. Anyone who has been a regular reviewer of journal articles would agree to such a statement. Reading creatively is harder, and requires a positive approach in search. In creative reading, the idea is to actively look for other applications, interesting generalizations, or extended work which the authors might have missed? Are there plausible modifications that may throw up important practical challenges? One might be able to decipher properly if one would like to start researching an extended part of this work, and what should be the immediate next aspect to focus upon.

2.8 Taking Notes While Reading

A researcher reads to write and writes well only if the reading skills are good. The bridge between reading and actually writing a paper is the act of taking notes during and shortly after the process of reading. There is a well-known saying that the faintest writing is better than the best memory, and it applies to researchers who need to read and build on that knowledge to write building on the notes taken. Many researchers take notes on the margins of their copies of papers or even digitally on an article aggregator tool. In each research paper, there are a lot of things that one might like to highlight for later use such as definitions, explanations, and concepts. If there are questions of criticisms, these need to be written down so as to avoid being forgotten later on. Such efforts pay significantly when one has to go back and reread the same content after a long time.

On completing a thorough reading, a good technical reading should end with a summary of the paper in a few sentences describing the contributions. But to elucidate the technical merit, the paper needs to be looked at from comparative perspective with respect to existing works in that specific area. A thorough reading should bring out whether there are new ideas in the paper, or if existing ideas were implemented through experiments or in a new application, or if different existing ideas were brought together under a novel framework. Obviously, the type of contribution a paper is actually making can be determined better by having read other papers in the area.

2.9 Reading Mathematics and Algorithms

Mathematics is often the foundation of new advances, for evolution and development of engineering research and practice. An engineering researcher generally cannot avoid mathematical derivations or proofs as part of research work. In fact, these are the heart of any technical paper. Therefore, one should avoid skimming them. By meticulous reading of the proofs or algorithms, after having identified the relevance of the paper, one can develop sound understanding about the problem that the authors have attempted to solve.

Nonetheless, one might skim a technical section if it seems like an explanation of something already known, or if it is too advanced for the research at the present moment and needs additional reading to be understandable, or if it seems to specialized and unlikely to be needed in the course of the research program in which case one can get back to it later on. Implementation of an intricate algorithm in programming languages such as C, C++ or Java is prone to errors. And even if the researcher is confident about the paper in hand, and thinks that the algorithm will work, there is a fair chance that it will not work at all. So one may wish to code it quickly to check if it actually works.

2.10 Reading a Datasheet

Researchers in different fields of engineering will need to read certain types of documents. For example, mechanical and civil engineers would need to read drawings related to mechanical parts and buildings. Researchers in the field of electronics need to read datasheets. On occasions, researchers in other fields may also need to incorporate a certain electronic part in which case careful reading of the datasheet is imperative. The same principles like initial skimming of the datasheet are required to ascertain whether further careful reading is needed.

Datasheets are instruction manuals for electronic components, which (hopefully) details what a component does and how one may use it. Datasheets enable a researcher (or a working professional) to design a circuit or debug any given circuit with that component. The first page of the datasheet usually summarizes a part's function and features, basic specifications, and usually provides a functional block diagram with the internal functions of the part.

A pinout provides the physical location of a part's pins, with special mark for pin 1 so that the part can be correctly plugged into the circuit. Some parts also provide graphs showing performance versus various criteria (supply voltage, temperature, etc.), and safe region for reliable operation which should be carefully read and noted by the researcher. One should be also in the lookout for truth tables which describe what sort of inputs provide what types of outputs, and also timing diagrams which lay out how and at what speed data is sent and received from the part. Datasheets usually end with accurate dimensions of the packages a part is available in. This is useful for printed circuit board (PCB) layout.

When working with a new part, or when deciding which part to use in the research work, it is recommended to carefully read that part's datasheet to come up with a bit of shortcut that may potentially save many hours later on.

As already stated, an engineering researcher will have documents to read which are specific to the branch of engineering in which one is researching in. However, the objective of the authors herein has been to use datasheets as an example to state the need to pay attention to the art of reading such documents. Technical published papers or books are not the only contents that a researcher has to master reading!

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Chapter 3
Attributions and Citations: Giving Credit Wherever Due

In this chapter, we highlight the importance of expanding attributions and acknowledgments to roles and responsibilities beyond primary authors of journal articles or principal investigators of grant proposal documents. This would be applicable especially to scientific research projects that involved diverse skill sets and expertise.

Academic writing, by definition, must follow certain rules and conventions. Among the most important of these are the rules and conventions about citing, referencing, attributing, and acknowledging the works of others. That means giving proper credit wherever due. Citing is the practice of quoting from, referring to other authors' works and ideas in the text of our work in such a way that the context is clear to the reader. Referencing is the listing of the full publication details of a published work that is cited so as to give background information to the readers.

Acknowledgment in research publications indicates contributions to scientific work. However, acknowledgment, attributions, and citations differ in the manner of their application. Acknowledgment is arguably more personal, singular, and simply an expression of appreciations and contribution. In this chapter, we address these issues in detail apart from the legal challenges when attributions and citations are not adequately done.

3.1 Citations: Functions and Attributes

Citations (references) credit others for their work, while allowing the readers to trace the source publication if needed. Any portion of someone else's work or ideas in papers, patents, or presentations must be used in any new document only by clearly citing the source. This applies to all forms of written sources in the form of texts, images, sounds, etc. and failure to do may be considered plagiarism which will be described in detail in subsequent chapters of this book. One should avoid distress and embarrassment by learning exactly what to cite. Depending on the exact type

D. Deb et al., *Engineering Research Methodology*, Intelligent Systems Reference Library 153, https://doi.org/10.1007/978-981-13-2947-0_3

of material, the researcher may need to give due credit to the creator of the original source.

The growth of knowledge in any field of study, especially in technological fields, is primarily incremental and a researcher invariably and naturally builds upon prior information. There are well-established means of preventing and spreading knowledge through publication of patents, papers (conference paper and the peer-reviewed journal paper), or articles, and also through textbooks and classrooms. While it is true that a research needs to leverage the prior art in the area of research interest so as to make further development, at the same time it is important to ensure that credit for that existing knowledge is suitably acknowledged.

When a bibliography of previously published patents or papers is placed in the new works of a researcher, a connection is established between the new and previous work. As per relevance to context, the researcher provides due credit through the use of a citation. Citations help the readers to verify the quality and importance of the new work and justification of the findings. It is a way to tell readers that certain material in the researcher's present work has come from another source and as an ethical responsibility, appropriate credit has been given to the original author or writer. Materials that can be cited include journal papers, conference proceeding, books, theses, newspaper articles, websites, or other online resources and personal communication. Preferably, citations should be given at the end of a sentence or the end of a paragraph as can be seen even in this particular paragraph. Citation must contain enough details so that readers can easily find the referenced material [1].[1]

A researcher needs to cite each source twice: (i) in-text citation, in the text of the article exactly where the source is quoted or paraphrased, and (ii) a second time in the references, typically at the end of the chapter or a book or at the end of a research article. Most citation styles have the same or similar elements, but differ on the order of elements and layout. Unless otherwise specifically required by a particular journal or a book, one may choose any style of one's choice as long as one is consistent. The citation elements differ and so what is to be recorded can differ from one source to another. It is also important to mention the date the source was published and sometimes also the particular date it was accessed by the researcher if it is related to web content.

LaTeX, a document preparation system often used by engineering researchers to automatically format documents that comply with standard formatting needs, is very effective to track and update citations. LaTeX has a steep learning curve and will be repeatedly used in this book to address different issues pertaining to technical writing which is intimately linked with research for engineers.

There are three main functions of citation:

(i) Verification function: Authors have a scope for finding intentional or unintentional distortion of research or misleading statements. Citation offers the readers

[1] For instance, the fact that citations should supply enough details for readers to find the referenced material is not an original proposition of the author of this book. Therefore, a suitable source such as the reference in [1] has been cited with all available publication details.

a chance to ascertain if the original source is justified or not, and if that assertion is properly described in the present work [2].

(ii) Acknowledgment function: Researchers primarily receive credit for their work through citations. Citations play crucial role in promotion of individual researchers and their continued employment. Many reputed organizations and institutes provide research funding based on the reputations of the researchers. Citations help all researchers to enhance their reputation and provide detailed background of the research work.

(iii) Documentation function: Citations are also used to document scientific concepts and historical progress of any particular technology over the years [3].

Citations are the currency that authors would wish to accumulate and the technical community gives them credit for these contributions. When other authors make citations, they honor those who initiated the ideas. Authors demonstrate their comprehension skills by identifying, estimating, and incorporating other's research work and then create and express their own ideas precisely while acknowledging ownership of ideas through citation [4].

Authors should cite sources to indicate significance of the work to the reader. Relevant citations help authors develop an easily understandable argument and prevent the need to navigate through work irrelevant to the reader's interest areas. Failure to cite appropriately infringes on the rights of the researcher who did the original work.

There are certain cases when references do not fulfill the actual goal of citations and acknowledgments, and thus do not benefit the reader.

1. Spurious citations: In certain cases, when citation is not required or an appropriate one is not found, if the author nevertheless goes ahead with including one anyways, it would be considered as a spurious citation. These sorts of citations do not add any value to the reader in terms of properly understanding the paper. Such actions result in loss of time of the reader or reviewer in looking for the cited paper that is otherwise not relevant. Just as due credit should be given to a paper through citation, inappropriate credit must be avoided so that the credibility of a research work or of the journal or conference proceedings where that paper is published is not lost through this sort of carelessness [1].
2. Biased citations: When authors cite the work of their friends or colleagues despite there being no significant connection between the two works, or when they do not cite work of genuine significance because they do not wish to give credit in the form of citation to certain individuals, then such actions can be classified as biased citations. Neglect of citations to prior work whose conclusions or data contradict the current work is also biased.
3. Self-citations: There is nothing wrong in citing one's prior work if the citation is really relevant. Self-citation of prior papers is natural because the latest paper is often a part of a larger research project which is ongoing. Sometimes, it is also advantageous for the reader because citations of all the related works of the same author are given in one paper and this may reduce the effort of the reader in trying to find the full versions of those papers. However, it is helpful and ethical only if all the papers are really relevant to the present work [5].

However, there can also be negative impact on the journal as well as individual researchers due to inappropriate and irrelevant self-citations. Self-citations in such cases may be either spurious or biased or even both. Editors of journals who ignore such types of citations and allow by negligence or otherwise, to be included in published materials end up directly or indirectly altering the impact factor of those publications [6].

4. Coercive citations: Despite shortcomings, impact factors remain a primary method of quantification of research, as described later in detail in Chap. 10. One side effect is that it creates an incentive for editors to indulge in coercion to add citations to the editor's journal. Even if not explicitly stated, the implied message is that the author could either add citations or risk rejection [7]. Such demands consequently diminish the reputation of the journal.

From the above discussions, it is clear that the author(s) must maintain a balance between too few and too many citations. At the same time, author(s) must give credit whenever due even if it is their own work.

3.2 Impact of Title and Keywords on Citations

The citation rate of any research paper depends on various factors including significance and availability of the journal, publication types, research area, and importance of the published research work. Other factors like length of the title, type of the title, and selected keywords also impact the citation count [8].

Title is the most important attribute of any research paper. It is the main indication of the research area or subject and is used by researcher as a source of information during literature survey. Title plays important role in marketing and makes research papers traceable. A good title is informative, represents a paper effectively to readers, and gains their attention. Some titles are informative but do not capture attention of readers, some titles are attractive but not informative or related to the readers' research area [9]. The download count and citation of a research paper might be influenced by title. There are three different aspects which provide a particular behavior to the title: (i) types of the title, (ii) length of the title, and (iii) presence of specific markers [10].

Stremersch et al. [11] analyzed title characteristics of the papers published during 1990–2002 in the area of research and studied relationship between title characteristics and citation, which concluded that title length positively affects the number of citations. In another study, Sagi and Yechiam [12] found that highly amusing titles have fewer citations and pleasant titles have no significant relation with citations. In yet another study, Jacques and Sebire [8] analyzed different papers' titles and their citations hit for 25 most-cited and 25 least-cited research and review papers of a particular genre of journals, and found a strong association between title lengths and citation rates, with highly cited articles having more than twice as many words in the title compared with lower cited papers. Jamali and Nikzad [13] analyzed several open access papers and found that articles with question-type titles are downloaded more but poorly cited compared to the descriptive or declarative titles. Declarative titles are downloaded and cited less than descriptive titles but difference is not much [13]. As per analysis of Habibzadeh and Yadollahie [14], longer titles are strongly associated with higher citation rates. Longer titles mainly include the study methodology and/or results in more detail, and so attracts more attention and citations [14].

In general, titles containing a question mark, colon, and reference to a specific geographical region are associated with lower citation rates, also result-describing titles usually get citations than method-describing titles. Additionally, review articles and original articles usually receive more citations than short communication articles. At least two keywords in the title can increase the chance of finding and reading the article as well as get more citations.

Keywords represent essential information as well as main content of the article, which are relevant to the area of research. Search engines, journal, digital libraries, and indexing services use keywords for categorization of the research topic and to direct the work to the relevant audience. Keywords are important to ensure that readers are aware about research articles and their content [15]. If maximum number of allowable keywords are used, then the chance of the article being found increases and so does the probability of citation count of the article. Usage of new keywords should be minimal as such keywords may not be well known to the research community and so may lead to low visibility of the article.

3.3 Knowledge Flow Through Citation

Knowledge flows through verbal communications, books, documents, video, audio, and images, which plays a powerful role in research community in promoting the formulation of new knowledge. In engineering research, knowledge flow is primarily in the form of books, thesis, articles, patents, and reports. Citing a source is important for transmission of knowledge from previous work to an innovation [16]. Production of knowledge can be related to the citation network. Knowledge flow happens between co-authors during research collaboration, among other researchers through their paper citation network, and also between institutions, departments, research fields or topics, and elements of research [17]. Figure 3.1 shows the relationship between citations, knowledge flow, and elements such as researchers, papers, journal publications or conferences, and institutions. If paper A is cited by paper B, then knowledge flows through citation networks across institutions.

The complex interdisciplinary nature of research encourages scholars to cooperate with each other to grab more advantages through collaboration, thereby improving quality of the research. Sooryamoorthy [18] examined the citation impact of the South African publications among different collaboration types, discipline and sectors, and observed that co-authored publications had more citations than single author paper and there was a positive co-relation between number of authors and the number of citations [18]. Figure 3.2 shows a relationship between co-authorship and different

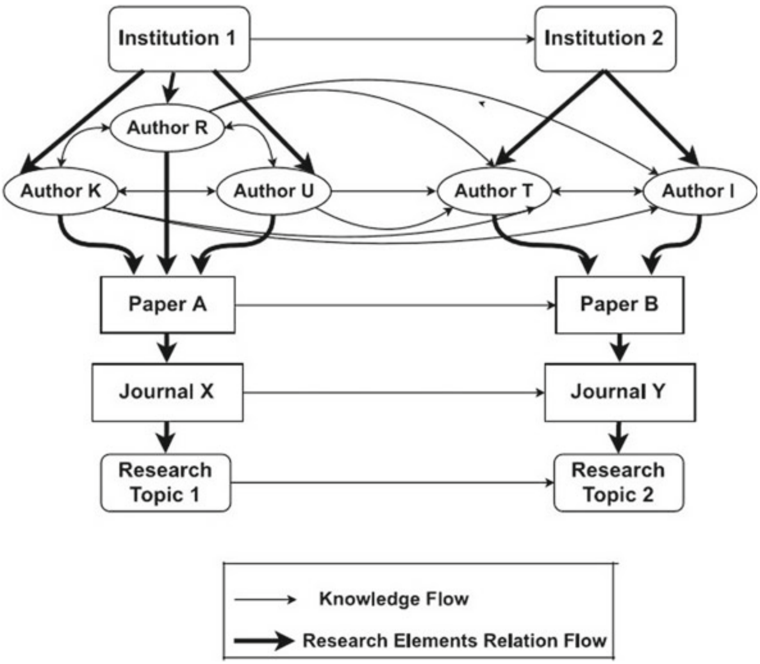

Fig. 3.1 Citation-based knowledge flow [17]

types of citations. Three articles (X, Y, and Z) and five references (X1, X2, X3, Y1, and Y2) of article X and Y, respectively, are considered. A, B, and C are authors of article X, and D, E, F, G, and also A are authors of article Y. Article Z has two authors H and E. References X1, X2, X3, Y1, and Y2 have authors (A, P), (H, R), (D), (Q, B, F), and (R), respectively.

Based on co-authorship citation network, references X1 and Y1 are considered self-citation, reference X3 is a level-1 co-author citation because author of article Y is direct collaborator of author A, reference X2 is a level-1 co-author network because author A is collaborator of E who collaborated with H. We conclude that papers which frequently cite collaborators will also often cite collaborators of collaborators. Collaborations certainly impact citation counts.

3.3.1 Citing Datasets

The nature of engineering research has evolved rapidly and now relies heavily on data to justify claims and provide experimental evidences [20] and so data citations must fetch proper credit to the creator of the dataset as citations of other objects like research articles. Data citations should have provisions to give credit and legal

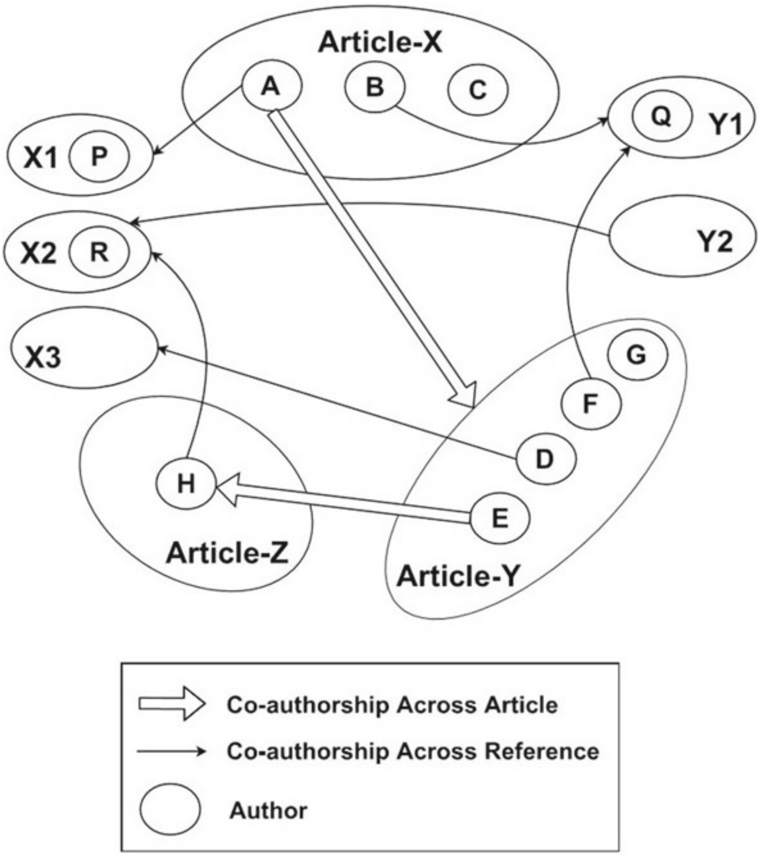

Fig. 3.2 Co-authorship network [19]

attribution to all contributors, enable identification and access, while recognizing that a specific style may not apply to all data [21].

Ascertaining the ownership of data can be a complicated issue especially with large datasets, and issues of funding can also make it a difficult matter. A researcher should obtain necessary permission for using data from a particular source. Citations related to datasets should include enough information so that a reader could find the same dataset again in the future, even if the link provided no longer works. It is proper to include a mixture of general and specific information to enable a reader to be certain that the search result is the same dataset that was sought.

Examples:

1. Historical Data, Sotavento (Wind Farm), Corunna, Spain (July 2016): [Accessed: 4 Oct, 2016] Retrieved from http://www.sotaventogalicia.com/en/real-time-data/historical
2. Deb, D (2016). [Personnel survey]. Unpublished raw data.

3.3.2 *Styles for Citations*

Citation styles differ primarily in the order, and syntax of information about references, depending on difference in priorities attributed to concision, readability, dates, authors, and publications. Some of the most common styles for citation (as well as other aspects of technical writing) used by engineers are as follows:

1. ASCE style (American Society of Civil Engineers)[2]

   (a) Reference list: This part is to be placed in the bibliography or references at the end of the article or report. A template with example for the same is given below:

Template for books:
Author Surname, Author Initial. (Year Published). Title. Publisher, City, Pages Used.

Example:
Wearstler, K., and Bogart, J. (2004). Modern glamour. Regan Books, NY.

Template for websites:
Author Credentials / Company Name (Year Published). 'Title'. http://Website URL (Oct. 10, 2013).

Example:
Blade cleaning services (2015): http://www.bladecleaning.com/problematica (29 Oct, 2016).

Template for journal publications:
Author Surname, Author Initial. (Year Published). 'Title'. Publication Title, Volume number(Issue number), Pages Used.

Example:
Johnston, L. (2014). "How an Inconvenient Truth Expanded The Climate Change Dialogue abd Reignited An Ethical Purpose in The United States". 1–160.

[2] http://library.canterbury.ac.nz/services/ref/asce.shtml.

(b) In-text citation for journals or books: The following part is to be placed right after the reference to the source of the citation assignment:

> Template
> (Author Surname/Website URL Year Published)
>
> Examples:
> i. Citation is a very important part of technical writing. (Deb 2016)
> ii. Engineers create devices to monitor mountains so that nearby inhabitants can be warned of impending eruptions. (Teachengineering.org 2014)

2. IEEE style (Institute of Electrical and Electronics Engineers)[3] IEEE style is standard for all IEEE journals and magazines, and is frequently used for papers and articles in the fields of electrical engineering and computer science. The IEEE style requires endnotes and that references be cited numerically in the text.
   Those submitting to an IEEE publication should see guidelines for the specific journal or magazine and may also refer to the complete IEEE editorial style manual. Some examples of IEEE styles of citations for different types of sources are enumerated below:

> Chapter in an edited book
> [1] A. Rezi and M. Allam, "Techniques in array processing by means of transformations," in Control and Dynamic Systems, Vol. 69, Multidimensional Systems, C. T. Leondes, Ed. San Diego: Academic Press, 1995, pp. 133–180.

3. ASME style (The Association of Mechanical Engineers)[4]

3.4 Acknowledgments and Attributions

Acknowledgment section is a place to provide a brief appreciation of the contribution of someone or an organization or funding body to the present work. If no particular guideline is available for the intended publication, then it can be introduced at the end of the text or as a footnote. Acknowledgment is a common practice to recognize persons or agencies for being responsible in some form or other for completion of a publishable research outcome. Acknowledgment displays a relationship among people, agencies, institutions, and research. In some case, certain individuals may help in the research work but may not deserve to be included as authors. As a sign of gratitude, such contributions should be acknowledged. Classification of acknowledgment into six different categories like moral, financial, editorial, institutional or technical, and conceptual support.

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[3] http://www.ieee.org/documents/style_manual.pdf.

[4] https://www.asme.org/shop/proceedings/conference-publications/references.

Acknowledgments and attributions are also very important in the publications of journal or conference papers. Giving proper credit wherever it is due is very important and even if the contribution is minor, it should not be neglected. A researcher should always recognize the proprietary interest of others. Whenever possible, author shall give name of persons who may be responsible, even if nominally, for designs, inventions, writings, or other accomplishments. Given the importance of work published, authorship is also important. The reward triangle theory shows a relationship between citations, acknowledgment, and authorship.

In engineering research, acknowledgments are meant for participating technicians, students, funding agency, grant number, institution, or anyone who provide scientific inputs, shared unpublished results, provided equipment, or participated in discussions.

3.4.1 What Should Be Acknowledged?

Every author should know that what should/should not be acknowledged. Author should acknowledge quotation, ideas, facts, paraphrasing, funding organization, oral discussion or support, laboratory, and computer work.

(i) Quotation: In technical writing such as in the field of engineering, quotes are used very rarely. Quotations are of two types:

  (a) Direct quotations are used when author use actual words or sentences in the same order as the original one. Author should use quotation marks for the words or sentences with proper acknowledgment.
  (b) Indirect quotation summarizes or paraphrases the actual quote. In such cases, it is important to acknowledge with proper name and date.

(ii) Authors should acknowledge people who give appropriate contribution in their research work. Non-research work contributions are not generally acknowledged in a scientific paper but it may be in a thesis. Persons must be acknowledged by authors, who gave a scientific or technical guidance, take part in some discussions, or shared information to author. Authors should acknowledge assistants, students, or technicians, who helped experimentally and theoretically during the research work.

(iii) If the researcher received grant from a funding agency and if those funds were used in the work reported in the publication, then such support should always be acknowledged by providing full details of the funding program and grant number in the acknowledgment section.
The authors should also gratefully acknowledge use of the services and facilities of any center or organization with which they are not formally affiliated to [22].
An example of acknowledgment of grant received is as follows:

Acknowledgments:
This research work was funded in part by the Extra Mural Research Funding 2014–17 (Individual Centric) of the Department of Science and Technology (DST), Govt. of India.

If there are any concerns that the provision of the information provided in acknowledgment may compromise the anonymity dependent on the peer review policy of a particular journal or conference proceedings, the author(s) may withhold the acknowledgment information until the submission of the final accepted manuscript. Many technical journals explicitly discourage authors to thank the reviewers in their article submissions. This could be construed as favoritism or an attempt to encourage reviewers to accept their manuscript for reasons other than scientific merit.

(iv) Acknowledging that results have been presented elsewhere: If the results were presented as an abstract in a journal, then there should be a suitable citation. If the results were presented as part of scientific meeting, symposium, or other gathering, then some relevant information should be provided. At the very least, the name of the gathering and year should be cited. Other helpful items include the location of the gathering (city and state or country) and the full date of the occasion.

By acknowledging all help received in one's research work, the author(s) demonstrate integrity as a researcher, which in turn encourages continued collaboration from those who helped out in different ways. One may also appropriately bolster one's colleagues' careers, as being credited in an acknowledgment section is emerging as one of many ways a researcher's professional impact is evaluated.

Acknowledgment is no longer simply a means of expressing gratitude. Funding agencies these days often require that their grant be acknowledged and explicitly state the exact information to be provided if the research work leads to a publication. The grantee is responsible for assuring that an acknowledgment of support is made in any publication (including websites) of any direct or indirect outcomes from the funded project. The format of required information is often explicitly stated in the terms and conditions of grants provided. Acknowledgments are also appropriate in technical presentations. Failure to acknowledge funding may result in the discontinuation of current funding and/or ineligibility to receive future funding for a certain number of years or indefinitely.

Unless the information can be considered "common knowledge,"[5] proper attribution of an idea, algorithm, computational methodology, or experimental design is required even if a journal operates with double-blind review.[6]

[5]Defined by the Oxford Dictionaries as "something known by most people."

[6]Both reviewer and author identities are concealed from the reviewers, and vice versa, during the review process.

3.4.2 Acknowledgments in Books/Dissertations

A page of acknowledgments is usually included at the beginning of a thesis/dissertation immediately following the table of contents. These acknowledgments are longer than the one or two sentence statements in journal papers or articles in conference proceedings. These detailed acknowledgments enable the researcher to thank all those who have contributed in completion of the research work. Careful thought needs to be given concerning those whose inputs are to be acknowledged and in what order. Generally, one should express appreciation in a concise manner and avoid emotive language. The following are often acknowledged in these types of acknowledgments: main supervisor, second supervisor, peers in the lab, other academic staff in the department, technical or support staff in the department, colleagues from other departments, other institutions, or organizations, former students, family, and friends.

Sample Acknowledgement in Thesis:
I wish to express my sincere appreciation to my supervisor Prof. Gang Tao for the useful comments, remarks and encouragement throughout this thesis work. Furthermore, I wish to express my thanks to Prof. Jacob Hammer for introducing me to the topic and for the support along the way. Also, I like to thank my peers in the Adaptive Control Lab such as Yu Liu and Shanshan Li, who have shared their precious time during many lively technical discussions. I would like to thank my family members who have supported me throughout this journey in many different ways.

3.4.3 Dedication or Acknowledgments?

Dedication is almost never used in a journal paper, an article in a conference proceedings, or a patent, and it is used exclusively in larger documents like books, thesis, or dissertations. While acknowledgments are reserved for those who helped out with the book in some way or another (editing, moral support, etc), a dedication is to whomever the author would like it to be dedicated to, whether it is the author's mother, the best friend, the pet dog, or Almighty God. And yes, it is possible to dedicate something to someone while also mentioning them in the acknowledgments. For example, one may dedicate a book to one's spouse, but acknowledge them for being the moral support and putting up with when one got very stressed.

The acknowledgments in technical books can be sometimes as brief as the ones in journal articles. The acknowledgment section of a technical report may be a paragraph that is longer than a journal paper but shorter than dissertations. Generally, the length of the acknowledgment may have some correlation with the length of the document.

Summary

Citation is a specific form of attribution, but attribution itself can be done in many different ways. For engineers, citation is very useful to their careers due to the prevailing publish or perish environment. Proper citation and reference:

- Gives credit and respect to the original author(s).
- Allows readers to find the original source(s).
- Strengthens the credibility of your report. If a researcher does not cite the sources, it is plagiarism.

Plagiarism is using another person's ideas without giving credit or citation and is an intellectual theft. Plagiarism comes in varying degrees, and there are serious consequences for a researcher if caught plagiarizing. All academic and industrial research organizations have integrity and misconduct policies. Even past one's time at a research organization, evidence of plagiarism can affect the integrity and credibility and can also retrospectively make an earned degree null and void.

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Chapter 4
Building Intellectual Property Rights

One of the distinctive features of this book on Research methodology is the inclusion of a Chapter on Intellectual Property Rights. However, a researcher needs to not only know how to effectively and ethically conduct research, but also must be aware of the rights that the intellectual property developed during the process of research work entails. The researcher is expected to develop the mindset of an inventor and a basic understanding of the patent laws helps in this regard.

Intellectual Property (IP) is the terminology attributed to intangible assets having commercial value, and arising from human intelligence, creativity, and imagination, but typically lacking physical form. The major types of IP are

1. Trademarks: A trademark is a sign that suitably differentiates the owner's goods or services from those of others.
2. Patents: A patent is a legal record that bestows the holder the exclusive right over an invention as per the claims, in a limited geographical domain and for a limited duration by thwarting possible interested parties from any form of manufacture, use or sale of the product or outcome of the invention. In theory, the applicant (or inventor) can draft a patent application but given the technical and procedural complexity, in practice, patent lawyers and researchers collaboratively write such applications.
3. Industrial Designs: An industrial design protection is related to certain specific ornamental shapes associated with products whose duplication the owner may wish to thwart.
4. Copyright: Copyright is the right bestowed on the owner or creator in relation to publication, and distribution of a piece of writing, music, picture or related works. Copyright also applies to technical contents such as software, datasheets, and related documents.

Copyrights generally do not need registration with a government body. The rest of the Intellectual Property Rights must be sanctioned by, and registered with, a government office for recognition and enforcement.

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4.1 Codes and Standards

Engineers often need to locate standards in the course of their work. Standards are published specifications, criteria, and guidelines for the performance or composition of a product or process. Standards often supplement the design process by guiding the engineer, saving significant design time. They increase quality, reliability, and interoperability. Standards are created by a variety of organizations and may be voluntary or legally mandated. For example, Institute of Electrical and Electronics Engineers Standards are a set of global standards in a range of industries related to different fields of electrical engineering, and the National Building Code of India (NBC) is a set of national standards providing norms for regulating building construction.

4.2 Patents: Subject and Importance

A patent is an exclusive right of exclusion of others, barring the licensee, to manufacture, use, sell or import an invention into a region where the patent has been granted, for a period of twenty years from the filing date. The patent must generally be technical in nature and be meant for an invention that works, or as it is sometimes said, "reduced to practice." The invention can be a product, a composition, a method, a process, or an improvement of any/all of these. Patents contain solutions to technical problems, reveal the current state-of-the-art, and provide vital information for decision making on new research projects and business opportunities. In most countries, failure to file prior to making any public disclosures results in denial of the patent application. Most applications nowadays are reviewed by a government-employed examiner who attempts to determine if the claimed invention sufficiently advances the prior art. A granted patent is presumed valid until a successful challenge, and can be invalidated by the existence of a prior art discovery or for other reasons.

Prior art relates to preexisting content found in public documents like patents, publications, or technical reports. A prior art search involves an organized review of content in such documents, and includes patentability searches done by an inventor (or representing lawyer) before filing; invalidity searches in litigation; and patent examination searches done by an examiner to determine to make a decision on the application. Such searches are conducted by lawyers or researchers using public databases of issued patents, and exhaustive databases.[1]

Prior art search is not a requirement of a patent application. However, performing a prior art patentability search helps broaden claim coverage. Prior art searches may help find references so as to assess patentability. Many patent agents only do a brief and inexpensive searches since the clients often do not wish to pay for a detailed search. It helps if the inventor has a good idea about the novelty in the present work

[1]The U.S. Patent and Trademark Office (USPTO) patent database contain more than 9 million patents, and 3 Million published applications. It is updated weekly.

based on the literature in the field. Search results are critical in deciding patent filing. If a search reveals references that anticipates some of the claims, one may attempt to "avoid the prior art" by redrafting the claims, and if that is not worthwhile, the intention to file should be revisited. However, the mere existence of a reference does not warrant abandonment of the application. The search techniques explained in Sect. 2.3 is applicable to patent searches as well.

Patent laws in certain countries do not allow protection of inventions on genetic organisms or gene sequences, and computer software programs. Patents are valuable assets. One may start out with a first-to-market advantage but soon the competitors can learn how to successfully build and market that product. Through this process, at least one competitor may eventually be able to launch a cheaper version of that product. Unless one holds intellectual property rights (IPRs), the revenues will eventually shrink with an increase in the number of manufacturers. If the company holds IPR, it is easy to enforce foreclosure of others from manufacturing or using that product to build a different product, or the company can reap licensing revenues.

Many research organizations use their patent portfolios as a tool to attract government and venture capitalists to help start companies. A strong Patent portfolio can be used as a negotiating tool with competitors to engage in cross-licensing each other's patents. Sometimes, companies may continue to simply hold lucrative patents only to defend their control over existing product portfolio by thwarting competitors from replicating key features of the patents. Many patent owners with the wherewithal to manufacture their own products, ensure that their patent portfolio forces competitors who cannot design around the patents, to exit the market.

Patents contain descriptive and useful technical information (including drawings or diagrams) that may not be found elsewhere. Patents assist in both design and academic research, and can be easily located with its application, publication, or patent number. Sometimes, patent numbers can be found on products, packaging, or within documentation. One can also search by inventor or applicant.

4.2.1 Requirements for Patentability

The requirements of patentability may be categorized as novelty, utility, and nonobviousness.

1. **Novelty** is a critical requirement which is central to the patent system. In most countries, no public disclosure should have taken place before filing takes place. That is why researchers should be very careful that they do not make any presentation or communicate any manuscript containing the contents of the patent to any journal before the patent filed and published. In order for a single reference (a technical paper or an earlier patent) to anticipate an invention, all of the limitations must be in it. The examiner is not supposed to combine multiple sources to argue anticipation. However, several references may be combined to show obviousness and so non-patentability.

2. **Utility/Industrial Application**: A proposed invention must be able to perform the specified functions and achieve certain beneficial results. A critical requirement for a patent to be granted, is that the invention should do what is claimed in the patent, such that the society benefits before granting an exclusive right to anyone. However, the invention need not be superior to existing products. In some countries, the invention must be legal, moral, and in line with public policy.
3. **Nonobviousness/Inventive Step**: Obviousness or "inventive step" requires that the invention cannot be put together from different pieces of known information by a person with average skill in the art, thereby ensuring that a patent is granted only for significant improvement over the prior art. An invention may be obvious despite not being exactly disclosed in prior art. If the prior art discloses most of the intended claims, the obvious conclusion could be that the claims are "obvious" over that reference, especially if other references can combine with the first one to disclose the entire claimed invention.

If a prima facie case of obviousness is established, it then becomes incumbent upon the applicant to explain with arguments and/or evidence to invalidate the case. Inappropriate application of the nonobviousness standard may lead to either low incentives to innovate or permit patenting trivial technological advance [1].

4.2.2 Application Preparation and Filing

A patent application is a contract between the applicant and the patent office eventually resulting in a granted patent. The draft of a patent application, called in India patent system as the Form 2 (Provisional or Complete Specification) is vastly different from writing a research paper despite both mandatorily containing novel technical content. The patent is evaluated over the years by patent examiners, judges, and prospective licensees, and therefore must be drafted with such audiences in mind.

A patent application consists of the Background section, Summary, Detailed Description with Drawings, Claims, and Abstract. It is imperative to file patents in a timely manner. A third party might file an application at any time and prior art might become available that wouldn't have gone against the applicant's application if the filing had been done without delay.

It is unlikely that a patent lawyer will have sufficient content to unambiguously understand the invention without a "live" meeting with the inventor. Similarly, the inventor cannot possibly understand the legal implications of the claims, in the absence of such a meeting. Ideally, the two parties sign the nondisclosure agreement and then the agent reviews the disclosure materials and notes any questions or need for additional disclosures. During the meeting, the agent tries to fully understand the invention, establishes that no additional disclosure is needed, and understands the commercially critical aspects of the invention. In many cases, multiple meetings between the patent agent and the inventors may be needed to ensure everything communicated is well understood and incorporated.

Researchers basically think in terms of research outcomes and not about inventions or patent claims. However, a patent filing actually happens only when the inventors can explain the patentability aspects to the patent agent. Often inventors intend the inventions to serve a very specific purpose and have not fully ascertained what other areas it could be applied to. However, the inventor needs to strive to provide the patent agent with the clearest understanding of the invention possible so that the patent can have the broadest allowable claims. It is also imperative to have good design drawings espousing the invention. In fact, the examiner is expected to spend the second most amount of time evaluating the drawings, after the claims section.

Constructing a Patent strategy is much akin to bracing oneself for a battle. An ill-thought plan, a series of wrong moves, some mindless decisions and Boom! It is important to craft a well-planned patent strategy for your organization or even for your own self. Among copyrights, patents and trademark, patents are the most important intangible assets, and so it is necessary to craft a well-planned "patent strategy". A patent strategy could be defined as establishing a plan of action in order to use the patents granted, for generating revenue by licensing or selling the patent rights; and protecting the products/process from being used by competitors by having a broad range of patent protection.

The formation of a successful patent strategy requires considering three different phases during the whole life cycle of a patent—patent filing, litigation and maintenance. If planned strategically, every phase can lead to generating an overall winning patent strategy.

4.2.3 Patents and Commercialization in Academia

It is important for academic researchers to note that patenting an idea does not preclude publications. There are many well-known papers which have associated patents. However, once a manuscript gets published it becomes part of prior art and thus obtaining a patent for the same is not possible.

Most patents do not make money, but can serve the academic interests of young researchers and can be a stepping stone to bigger things. Often a concern raised by editors of reputed journals is that the submission does not contain novelty. If a researcher focuses on first patenting the idea, then it is natural that the idea would have to get crystallized and contain novelty and so when the findings are then submitted as a journal manuscript the idea of novelty would not need to be separately taken care of. However, a few patents do make a lot of money and many of those have come from the academia as well.

It is important for the researcher, starting from early on in career, to focus on possible industrial application of the research work. One important aspect of ensuring that the engineering research work being performed has industrial applications, is to understand what entails intellectual property rights and the process of patent filing. It is also important because the usual route of publishing research findings through conference and journal publications which a researcher is very familiar with, would render the patent filing null and void. A published paper becomes prior art and thus cannot be patented. An idea of design when patented can still be published in a journal later on and so the researcher should be aware and be able to make a decision if the work that has been performed in patentable or not.

Research universities need to be flexible in partnering with Industry and Government bodies to more effectively transfer into society the new ideas emerging from university research and to address current and future global challenges. Apart from Industries and Research organizations who have a vested interest to protect their intellectual property rights, there is now growing demand on academia to actively involve in the initiatives such as "Make in India".[2]

Basic research can spur innovation and therefore inflow of funds for this purpose needs to continue, but with close interactions with industry long-term problems should be taken up. University missions are now also actively seeking commercialization of university research outcomes, active consultancy and knowledge dissemination to solve industry-relevant problems. However, traditional career advancement parameters like journal publications should cease to be an overwhelming barometer for performance in academia if such initiatives have to succeed [2].

Most colleges and universities require faculties or graduate student researchers to execute formal agreements which grant the university the rights to all the discoveries made using its laboratories, equipment, or other such resources. In some cases, when an invention is commercially successful, the school pays some portion of the revenues to the inventors.

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[2]Detailed description about expectations of Govt. of India from different sectors has been provided in http://www.makeinindia.com/home.

Chapter 5
Ethics in Engineering Research

Ethics generally refers to a set of rules distinguishing acceptable and unacceptable conduct, distinguishing right from wrong, or wise aphorisms like the sayings of Chanakya.[1] Most people learn such norms in their formative years [1], but moral development continues through different stages of growth. Although everyone recognizes some common ethical norms, but there is difference in interpretation and application. Ethical principles can be used for evaluation, proposition or interpretation of laws [2]. Although ethics are not laws, but laws often follow ethics because ethics are our shared values.

International norms for the ethical conduct of research have been there since the adoption of the Nuremberg Code in 1947 [3]. According to Whitbeck [4], the issues related to research credit dates back to the establishment of the British Royal Society (BRS) in the seventeenth century to refine the methods and practices of modern science [4]. This event altered the timing and credit issues on the release of research results since BRS gave priority to whoever first submitted findings for publication, rather than trying to find out who had first discovered.

Whitbeck [4] raised two simple but significant questions to address the tricky issue of authorship in research: (1) who should be included as an author and (2) the appropriate order of listing of authors. In an increasingly interconnected world, the issue of coauthorship is very relevant to all researchers. There are issues around individuals who may be deeply involved during the conduct of the research work, but may not contribute in the drafting phase. Additionally, certain universities now put restrictions on coauthorship to prevent malpractices which will be described later in this chapter.

[1]Chanakya was a fourth-century Indian teacher, philosopher, and royal advisor, who authored the political treatise, Arthashastra. He is regarded as a pioneer in politics, ethics, and economics.

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Government bodies, and universities worldwide have adopted certain codes for research ethics. Research ethics and the responsible conduct of research are often erroneously used interchangeably. Research ethics examines the appropriate application of research outcomes, while responsible conduct of research deals with the way the work is undertaken. In this chapter, let us take a look at specific challenges posed by the application of ethics in engineering research.

5.1 Ethics in Engineering Research Practice

Technological developments raise a whole range of ethical concerns such as privacy issues and data related to surveillance systems, and so engineering researchers need to make ethical decisions and are answerable for the repercussions borne out of their research as outcomes. The reason that ethics matter in data used in engineering research is usually because there is impact on humans. Certain practices may be acceptable to certain people in certain situations, and the reasons for unacceptability may be perfectly valid. We have unprecedented access to data today, and unprecedented options for analysis of these data and consequences in engineering research related to such data. Are there things that are possible to do with this data, that we agree we should not do? Engineering ethics gives us the rule book; tells us, how to decide what is okay to do and what is not.

Engineering research is not work in isolation to the technological development taking place. Researchers make many choices that matter from an ethical perspective and influence the effects of technology in many different ways:

(i) By setting the ethically right requirements at the very outset, engineering researchers can ultimately influence the effects of the developed technology.
(ii) Influence may also be applied by researchers through design (a process that translates the requirements into a blueprint to fulfill those requirements). During the design process, decision is to be made about the priority in importance of the requirements taking ethical aspects into consideration.
(iii) Thirdly, engineering researchers have to choose between different alternatives fulfilling similar functions.

Research outcomes often have unintended and undesirable side effects. It is a vital ethical responsibility of researchers to ensure that hazards/risks associated with the technologies that they develop, are minimized and alternative safer mechanisms are considered. If possible, the designs should be made inherently safe such that they avoid dangers, or come with safety factors, and multiple independent safety barriers, or if possible a supervisory mechanism to take control if the primary process fails.

5.2 Types of Research Misconduct

Engineering research should be conducted to improve the state-of-the-art of technologies. Research integrity encompasses dealing fairly with others, honesty about the methods and results, replicating the results wherever possible so as to avoid errors, protecting the welfare of research subjects, ensuring laboratory safety, and so forth. In order to prevent mistakes, peer reviews should take place before the research output is published.

There may be different types of research misconduct as described in research articles like [5] and [6], which can be summarized as follows:

(i) Fabrication (Illegitimate creation of data): Fabrication is the act of conjuring data or experiments with a belief of knowledge about what the conclusion of the analysis or experiments would be, but cannot wait for the results possibly due to timeline pressures from supervisor or customers.

(ii) Falsification (Inappropriate alteration of data): Falsification is the misrepresentation or misinterpretation, or illegitimate alteration of data or experiments, even if partly, to support a desired hypothesis even when the actual data received from experiments suggest otherwise.

Falsification and fabrication of data and results, hamper engineering research, cause false empirical data to percolate in the literature, wreck trustworthiness of individuals involved, incur additional costs, impede research progress, and cause actual and avoidable delays in technical advancement. Misleading data can also crop up due to poor design of experiments or incorrect measurement practices.

> Fabrication and falsification of data in published content can hurt honest researchers getting their work published because what they can churn out may short fall of what is already published through misconduct till the misconduct is established and subsequently retracted.

The image of engineering researchers as objective truth seekers is often jeopardized by the discovery of data related frauds. Such misconduct can be thwarted by researchers by always trying to reproduce the results independently whenever they are interested to do further work in a published material which is likely to be part of their literature survey.

(iii) Plagiarism (Taking other's work sans attribution): Plagiarism takes place when someone uses or reuses the work (including portions) of others (text, data, tables, figures, illustrations or concepts) as if it were his/her own without explicit acknowledgement. Verbatim copying or reusing one's own published work is termed as self-plagiarism and is also an unacceptable practice in scientific literature. The increasing availability of scientific content on the internet seems to encourage plagiarism in certain cases, but also enables detection of such practices through automated software packages.[2]

[2] A commonly used tool among researchers is iTheticate: http://www.ithenticate.com/.

How are supervisors, reviewers or editors alerted to plagiarism?

(i) Original author comes to know and informs everyone concerned.
(ii) Sometimes a reviewer finds out about it during the review process.
(iii) Or, readers who come across the article or book, while doing research.

Although there are many free tools and also paid tools available that one can procure institutional license of, one cannot conclusively identify plagiarism, but can only get a similarity score which is a metric that provides a score of the amount of similarity between already published content and the unpublished content under scrutiny.

However, a low similarity score does not guarantee that the document is plagiarism free. It takes a human eye to ascertain whether the content has been plagiarized or not. It is important to see the individual scores of the sources, not just the overall similarity index. Setting a standard of a maximum allowable similarity index is inadequate usage of the tool. Patchwork plagiarism is more difficult to evaluate.

There are simple and ethical ways to avoid a high similarity count on an about to be submitted manuscript. Sometimes, certain published content is perfect for one's research paper, perhaps in making a connection or fortifying the argument presented. The published material is available for the purpose of being used fairly. One is not expected to churn out research outcomes in thin air.

However, whatever is relevant can be reported by paraphrasing in one's own words, that is, without verbatim copy. One can also summarize the relevant content and naturally, the summary invariably would use one's own words. In all these cases, citing the original source is important. However, merely because one has cited a source, it does not mean that one can copy sentences (or paragraphs) of the original content verbatim. A researcher should practise writing in such a way that the reader can recognize the difference between the ideas or results of the authors and those that are from other sources. Such a practice enables one to judge whether one is disproportionately using or relying on content from existing literature.

(iv) Other Aspects of Research Misconduct: Serious deviations from accepted conduct could be construed as research misconduct. When there is both deception and damage, a fraud is deemed to have taken place. Sooner or later ethical violations get exposed. Simultaneous submission of the same article to two different journals also violates publication policies. Another issue is that when mistakes are found in an article or any published content, they are generally not reported for public access unless a researcher is driven enough to build on that mistake and provide a correct version of the same which is not always the primary objective of the researcher.

5.3 Ethical Issues Related to Authorship

Academic authorship involves communicating scholarly work, establishing priority for their discoveries, and building peer-reputation, and comes with intrinsic burden of acceptance of the responsibility for the contents of the work. It is the primary basis of evaluation for employment, promotion, and other honors.

There are several important research conduct and ethics related issues connected to authorship of research papers as described by Newman and Jones [7], and are summarized herewith in the context of engineering research.

Credit for research contributions is attributed in three major ways in research publications: by authorship (of the intended publication), citation (of previously published or formally presented work), and through a written acknowledgment (of some inputs to the present research). Authorship establishes both accountability and gives due credit. A person is expected to be listed as an author only when associated as a significant contributor in research design, data interpretation, or writing of the paper.

Including "guest" or "gift" (coauthorship bestowed on someone with little or no contribution to the work) authors dilutes the contribution of those who actually did the work, inappropriately inflates credentials of the listed authors [8], and is ethically a red flag highlighting research misconduct [9]. Sometimes, the primary author dubiously bestows coauthorship on a junior faculty or a student to boost their chances of employment or promotion, which can be termed as Career-boost authorship [10].

There is also an unfortunate malpractice of coauthorship that can be described as "Career-preservation authorship" wherein a head of the department, a dean, a provost, or other administrators are added as Coauthors because of quid pro quo arrangement wherein the principal author benefits from a "good relation" with the superiors and the administrator benefits from authorship without doing the required work for it [11].

Sometimes, an actual contributor abstains from the list of authors due to non-disclosed conflict of interest within the organization [10]. Such coauthorships can be termed as ghost coauthorship. Full disclosure of all those involved in the research is important so that evaluation can happen both on the basis of findings, and also whether there was influence from the conflicts. In another type of questionable authorship, some researchers list one another as coauthors as a reciprocal gesture with no real collaboration except minimal reading and editing, without truly reviewing the work threadbare.

Some authors, in trying to acquire a sole-authored work, despite relying on significant contribution to the research work from others, recognize that effort only by an acknowledgment, thereby misrepresenting the contributions of the listed authors. The unrecognized "author" is as a consequence, unavailable to readers for elaboration.

All listed authors have the full obligation of all contents of a research article, and so naturally, they should also be made aware of a journal submission by the corresponding author. It is imperative that their consent is sought with respect to the content and that they be agreeable to the submission. In case of misconduct like inappropriate authorship, while the perpetrator is easier to find, the degree of appropriate accountability of the coauthors is not always obvious. Being able to quantify the contributions so as to appropriately recognize and ascertain the degree of associated accountability of each coauthor, is appealing.

Double submission is an important ethical issue related to authorship, which involves submission of a paper to two forums simultaneously. The motivation is to increase publication possibility and possibly decrease time to publication. Reputed journals want to publish original papers, i.e., papers which have not appeared elsewhere, and strongly discourage double submission.

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Chapter 6
Technical Writing and Publishing

As engineering researchers, we need to write things down. New knowledge is something that can be written down and can be read by someone else. Writing communicates thoughts and ideas and, of course, new knowledge. A researcher is seen by the community primarily through writing. A researcher would want people to engage with the output of the work, new knowledge, and they do that through what has been written. Writing is not only about communicating ideas, writing is also part of the creative discovery process. Writing is not something that should take place at the end when everything else is done. It is an integral part of the research process.

In research, there are probably going to be many aspects that need to be taken into account and normally the problems that one needs to deal with are complex. Writing is a tool that assists in problem solving. By writing, we mean all the forms of written work such as equations, drawings, graphs and, of course, what we are going to concentrate on here, writing with words.

Technical writing is connected to a variety of documents related to various aspects of engineering, and can be grouped into four major categories:

1. Reports and communications: Most engineering technical writing involves preparation of various "reports" which are an important aspect of product development, technological advancement and dissemination of technical information, and often includes engineering drawings. Reports help to communicate technical viability of designs to the management as also the customers.
2. Technical papers, articles, and books for purposes of education, teaching, and information sharing: Books on technical topics need unique attributes, are generally authored by academics (or professionals) in their area of experience and knowledge, and are meant for a wider audience compared to technical reports. Papers and thesis (typically one per degree) are other reports put together by researchers. It is quite likely that an engineer would write papers throughout one's career.

D. Deb et al., *Engineering Research Methodology*, Intelligent Systems Reference Library 153, https://doi.org/10.1007/978-981-13-2947-0_6

3. Patents: Lawyers usually draft Patent, but the outcome hinges on a lot of writing and searching on the part of the inventors and so in this book, the focus would be on the inventor's part of the patent application.
4. Operational manuals, instructions, or procedures: This sort of writing is not addressed in this book and is usually written by a technical expert with possible inputs from a legal expert.

Technical writing is integral to research methodology because whatever is not communicated in writing may be deemed to be not communicated at all. This chapter aims to provide easy to follow guidelines to engineering students and working engineers on writing effective reports and technical papers. Technical communication is an integral part of every researcher's work and so this chapter aims to provide a concise guide to eliminate writing challenges and addresses technical paper writing in particular with the help of technical writing tool LaTeX. Efficiency in communication of technical information is a result of organized and structured following of research methodologies.

6.1 Free Writing and Mining for Ideas

Very often, when a researcher needs to write something substantial, one sits in front of the PC with a blank screen or an empty piece of paper and it just looks intimidating. After writing a few sentences, the write-up just looks wrong and is either erased, or it is not clear what to write next, or one rearranges the words to make it sound better. And then starts the next sentence, and so on, and the progress is slow and painful. Why is this process seemingly so difficult?

When writing like this, two separate processes are taking place. The first is the creative part, the part that is trying to say something, and the second is the critical part, the part that tells that what has just written does not sound quite right. These two processes are in conflict with each other, the creative one and the critical one. The bad news is that the critical part of the mind normally always wins. It is much easier to criticize than to create. But the research process is about creating, trying to create new knowledge. And writing is part of that discovery process. It is a vital part of the process and so that creative (the problem solving) part should not be allowed to be shut down by the critical mind.

The authors suggest a technique called free writing. This is writing that the researcher does for oneself, and it is now meant to be shown to anyone. This is generative writing where one is being creative and is discovering what is in the mind and combining the thoughts to create new ideas. The actual act of writing helps to crystallize these ideas and brings them to life. This free writing process is about writing the thoughts down as they are flowing and one does not evaluate or criticize or do anything to stop that process.

The thoughts are very nonlinear and they are all over the place and trying to streamline them in the head normally does not work so well. One should just let the thoughts pour out. Later on one will evaluate them. Because nobody else will see this, it gives the researcher the freedom to not have to be critical. So, one can shut down the critical part of the mind and let the new ideas take shape. Write down what is in the head without evaluating. The evaluating through the critical part of the mind will have its chance later on.

Since this is continuous writing and one is not stopping to edit or to consider what has been written, naturally a lot of words get generated in this way. After a gap of several hours or a few days, but not much longer than that, one should get back to what has been written. Even though the write-up may sound terrible and all over the place, it is not a cause for despair. The task now is to start to unravel what has been captured, and mine for real ideas and possible breakthroughs from within what has been written. Now is the time to apply the critical mind and assess what is good and what is not. If something is really no good, delete it or draw a line through it, if it is good then keep it and note the main idea. If there is repetition in a big block of text, then group all the text of the same theme together. If there is just a small part of an idea but it looks promising, note that down for further investigation. In this way, unscramble and sift through the text and extract what is good.

One may ponder, what if everything that was written during the free write stage is all meaningless? Even if one is trying to write on a not so familiar topic, one will find that questions arise during the free write. These questions point the way to things that one might need to find out more about, normally through reading more on the subject. Even if there are only questions arising, those questions are probably the right questions. So, the free write process is still giving success. If needed, this process of free writing can be repeated the next day with substantially different outcomes with other thoughts and ideas and questions coming out. One needs to have some sort of indexing arrangement to keep track of all of these free writing, for it is by nature jumbled and all over the place. This body of text, the raw thoughts are to be mined to find the good thoughts and ideas and questions. Next, one can begin drafting all these content that was meant for oneself, into something meaningful that can be read by others.

6.2 Attributes and Reasons of Technical Writing

In the free writing and the mining phases, the writing was exclusively for oneself. Now, comes the part of the writing process where one starts to take the reader into consideration. The reader is important because they are the ones who one essentially wants to communicate the message, the big ideas to. One would like the reader to be convinced by what is written and to accept the message that one is trying to get across.

An important aspect of technical writing is that one needs to understand the message that one wants to get across, and needs to understand the reader. Finding the core message through the free writing and mining process is normally not too hard, but it needs to be followed up by putting oneself in the shoes of the reader and ask oneself if the reader will be convinced with the message and the reasons associated with the message. There probably needs to be some supporting work that helps the reader to come to the conclusion that the researcher wants them to. Most of this supporting work will already be present in the output of the free write process.

If the supporting material directly supports the message, one should keep it, but if it does not really support the message (despite being relevant), one needs to be cautious about including it for it may dilute the core message for the reader. So, one needs to analyze every section and every part to see if the entire part of the writing is contributing to the actual message. At each stage, one needs to ask what the reader will think. If something that is written is likely to raise a question in the reader's mind, then one needs to preemptively answer that soon enough.

Technical writing especially in Engineering deals with a structured and formal writing on a specific topic with the objective of sharing useful information or technical knowledge concisely while citing contributions of others. The purpose of technical papers, for example, is to clearly explain what was done, why was it done, and/or report the results of a research work, and should typically end with recommendations on what should be done next. There should be substance in every statement in a technical paper and each claim should be substantiated by data and factual information and not opinion.

First person pronouns make engineering research work less authoritative and are discouraged, while writing in the third person is an accepted style in reputed engineering journals and books. A technical paper should state the message in the fewest words. Background information should be provided if and only if the targeted readers of the article actually would need it.

Style is the way a technical paper is written, while the format is the order and actual layout of the paper. A suitable style for writing engineering research outcomes is objectively and accurately presenting data, facts, results, and theories. The format for such writing is a structured one that includes a basic organized sequence like (i) Introduction, which describes why the particular research work was undertaken, (ii) Procedure, which describes the steps undertaken, (iii) Results, which detail what happened, (iv) Discussion, which infers the significance of the results, (v) Conclusions, which summarize what was learned from the work, (vi) Recommendations or Future Work, which suggest possible work that can be undertaken subsequently, and finally (vii) References, which detail as per the style of the particular journal, and the citations which formed the basis of the technical background information in the form of books and papers for this work.

A major attribute of technical writing is that it should enable archival of valuable and pertinent information. Technical papers should cite information sources and recognize contributing persons or entities including funding agencies. Engineering research papers that are verbose, poorly organized, cluttered, or contain low-quality illustrations, lack essential writing attributes.

Albeit often understated in engineering, effective writing skills are contributing factors for a successful career. However, the most common reason for writing is that it is an expected part of the program in the case of a student and also a required attribute of the tenure for a faculty. Many organizations related to engineering use effective publications in archived journals as a performance metric. In some cases, the number of papers written and the frequency of publications as compared to peers are the performance indices used. Such issues are dealt with in detail in the final two chapters of this book.

Writing effective grant proposals can be useful in funding projects, procuring capital equipment, or reaping financial benefits. If there is no written proposal, there is no funding. In industrial research organizations, the primary reason for writing report is that the management wants it. Even if it is not mandated, writing the report helps one organize one's work and deliverables using a systematic analysis of data, and review of related facts.

Writing is the best way to know if a technical study is actually complete because in case of situations like inadequate data, it would become apparent that a decision is not yet possible. Sometimes the first draft of a technical paper shows that only a part of the work is over and on other occasions, it may provide a hitherto unidentified direction of work.

A paper is a well-organized description of state of the art and new findings in a particular topic. Several useful guidelines for engineers on constructing publishable papers are enumerated [1]. Technical writing entails organizing some existing and new findings into a lucid whole that provides value addition to the author and the potential readers. Technical writing also indicates the end of a project and can reassure the supervisor that the goals of the project have been met. For an engineering researcher, an approved project grant received by the supervisor typically indicates the start of a project, and a technical paper or a report ultimately indicates the end of the project.

Engineers often spend considerable time evaluating a new approach, or a new mechanism, and sometimes funding reductions stop the work. In such situations, if a technical report on the work already done, is not documented and archived, the work may get unnecessarily repeated or may be lost forever. Another obvious reason for documentation is that verbal communication is prone to misinterpretation or alteration. Good writing skills are also contributing factors in writing standard methods and help in minimalist designs but can be acquired with little diligence and have a beneficial effect on careers and the lack of it can cause significant damages. People who have demonstrated writing skills get hired, retained in jobs, and grow faster in research career as they are considered more valuable than nonwriters in times of attrition in industry.

Journals and conference papers should be written for wide circulation and usefulness to the readers, and provide original and significant results. Additionally, only well-organized, and concise papers with complete and clearly made statements elucidating how the research outcomes further the state of the art are likely to meet these requirements and be published.

6.3 Patent or Technical Paper?—The Choice

Some companies encourage publication, while others discourage the same in journals so as to categorically ensure leak of proprietary content. However, all established organizations have a robust review policy on publication requests of the employees. The review of manuscripts for possible publication should include the writer's immediate supervisor, and the legal department to ensure maintenance of intellectual property. However, it is still possible that company secrets could get divulged in the oral presentation of a paper, and so many companies are ambivalent about publications and rightfully so. There may be many other reasons specific to individual organizations which may dissuade a researcher my choosing to go ahead with a journal paper submission, and so an alternative like patent is required to be explored. However, as will be clear shortly, the inability to publish is not the only reason to file a patent!

A research paper is just that, a publication. It does not give you any rights, except bragging rights. A research paper may or may not be presenting an invention or something new. For example, it can be a tutorial paper or a case study analysis, etc. It may or may not be applicable to anything considered "useful".

A patent is supposed to represent something novel, useful, and nonobvious. A patent also bestows the right to stop someone from making a product that infringes upon the patent claims. Unlike a research article, the drafting of the patent is usually done by a lawyer through active involvement of the inventor but is not usually done directly by the inventor. Patents are accorded the highest importance by organizations who know their value because after all, intellectual property is the often the most valuable asset. There are many companies actively seeking to and copy a product, and under such circumstances, if one researcher has a compelling idea (and product), the only practical way to protect it, in most cases, is through a patent.

A technical paper (a document in an archival journal), or a patent presents different levels of detail, and the effectiveness in the two forms in describing the status of the project, the conclusions, and recommendations, is different. An invention is patentable only on satisfying three main aspects:

- It must be new: One can check if something is new through a search of previous patents via the various patent databases.
- It must be demonstratively useful: the process or mechanism must work and produce a sort of desirable outcome.
- It is not obvious: Finally, a proposed invention must be nonobvious, producing a unique outcome not predictable from known experiences.

When an engineering researcher finally gets a device to work as intended or obtains some encouraging results from an experimental setup, it is time to write and report these findings. But it can also be a time of conflicting thought process because the way forward may be a patent or a publication. By first publishing, presenting, and applying for funds, the inventor would get robbed of a patent because it would have been disclosed. If there is enough potential satisfying the patentability requirements, then one must first file the patent application. A filed and published patent can then be rewritten as per the style and format of an archived journal and submitted to it for consideration without any proprietary issues, but the other way round is not possible.

A researcher should deliberate on the choice of patent or journal publication. Patents or the claims made in the patents (during the process of filing) do not go through a peer review process as journal publications usually do. An additional consideration is that patent filing costs significant amounts of money.

6.4 Writing Strategies

Writing strategies require thoughtful analysis of three fundamental elements:

(i) Readership: the targeted audience. Thoughtful consideration of who the readers would be is critical to technical writing because it directly determines the level of details that is appropriate, which may otherwise negatively impact the reader. Technical writing should be such that all intended readers can understand. For instance, if an article in an electrical engineering magazine or journal is written for nonelectrical engineer readers, it would be much longer because of the need to define and explain more, and the electrical engineers among the readers who are expected to be more in number would find it boring.

(ii) Scope: the boundaries of what needs to be discussed. Every technical document has boundaries on the suitable amount of details to be included, and such boundaries have to be well defined, considering the following factors:

- Number of ideas/experiments/studies: The tasks that need to be addressed in technical papers must be identified.
- Depth of writing: In the strategy phase, one must decide on the desired depth of technical discussions. Need for depth of coverage should depend on the complexity of the subject and is intrinsically linked to the intended objectives.
- Level of detail: Concision is desirable, but enough detail should be included for an interested reader to validate the results in the paper.

(iii) Purpose and Objectives: the stated intention is defined as purpose, and the stated outcome would be referred to as the objectives of the document. Almost always, objectives are defined by the sponsor, funding agencies, or the management. Purpose usually determines strategy and is more immediate.

Good writing skills is important for a technical career and it is in one's interest to regularly and proactively perform appropriate documentation. Technical content depends on the document type and intended readers. A document should be written with careful choice of words and contain useful information about the chosen subject and be mindful of the targeted readership. While working in a research team or while coauthoring any manuscript, online technical writing tools like Overleaf[1] are useful. Such tools allow supervisors to give comments to the manuscript shared by the research scholar. There are also tools that can help complete a document quickly, but copyrighted material cannot be used. Software now exist that can scan documents for material plagiarized from other sources. There is a devastating result of being caught in plagiarism. Even a couple of copied sentences can end careers of otherwise reputed researchers.

Any written document should be supported by data to be able to seek the attention of readers. An issue in even published papers is the lack of a set of statements describing why the task was undertaken. The author must state what is being tried to achieve; the purpose and objectives should be made clear.

When describing one's own work, one should be humble and not use superlatives of praise, either explicitly or implicitly, even if one is enthusiastic. The starting paragraph ought to be one's best paragraph, and the first sentence should be the best one. If a paper starts poorly, the reader winces and is generally left uninterested to read further. Conversely, a smooth beginning gets the reader hooked who then tends to not notice occasional lapses later on.

6.5 Journal Paper: Structure and Approach

The method of presenting the information is as critical as the technical information itself, and a logical structure is important for the reader. All technical documents must contain distinct parts organized logically. A technical paper typically has the following structure:

- Beginning
  1. Title
  2. Abstract
  3. Introduction
- Body
  4. Procedure
  5. Results
  6. Discussions
- Closure
  7. Conclusions
  8. Future work
  9. References

Most technical journals furnish an author's guide containing suggested presentation techniques so as to remain consistent among different paper submissions. In some cases, papers would not even be sent to reviewers and returned back to the authors if they do not adhere to these presentation guidelines.

[1] https://www.overleaf.com/: Overleaf is an online LaTeX and Rich Text collaborative writing and publishing tool.

Technical documents are not for entertainment but should not be dull either. It can be made interesting by including new facts and demonstrated important results. An author should make every possible effort to avoid statements reflecting opinion rather than objectivity and specific remarks and not generalizations. The mechanics of document layout include a range of considerations that contribute to the accessibility and readability of the paper. These include pagination conventions (for example, centered at bottom, no number on first page), text spacing conventions, quotation marks and other punctuation conventions, guidelines for incorporating equations into the text (for example, numbered, centered, two spaces from text), capitalization conventions, typeface and style considerations, and binding guidelines, and finally "widow" and "orphan" problems.[2]

6.5.1 Title, Abstract, and Introduction

The title in a journal paper should be precise and simple, and be followed by names and affiliations of the authors, as per the journal's guidelines. The title page should include about five keywords, indicate the journal to which the manuscript is being submitted, and provide contact details of at least the corresponding author.

The abstract is the first thing in a paper that a reader will read. In many cases, searches also return the abstract along with the title. Typically, the abstract is a short paragraph (and sometimes have word limits) that is supposed to be independent, not relying upon contents in other sections and, likewise the rest of the paper do not depend on what the abstract contains. It is a place to state your contributions and explain why they are important. The first sentence should specify the purpose of the work, followed by any preferred hypothesis. Subsequently, there should be statements explaining the basis and validation of the hypothesis. The next sentences enumerate the steps performed to carry out the experiment or proof, and then the main results are reported. The abstract ends with a sentence or two, describing the significance and impact of the outcomes on the overall field of interest.

The introduction follows next, and requires a short review of the relevant literature, starting with broad areas and gradually zeroing in on the specific topic of interest. A couple of paragraphs may appropriately introduce the general area of research, with the ensuing paragraphs describing how a particular facet could be refined and further developed. The penultimate paragraph of this section describes the experimental question to be answered, and the hypothesis immediately follows. Next, the hypothesis testing method is described, and this paragraph would typically end with a description as to how to answer to the query would advance the state of the art. The final paragraph describes briefly the contents of each of the subsequent sections in the paper.

[2] Widow: The last few words of the last sentence of a paragraph ending at the start of the next page (or column), thus away from the rest of the paragraph. Orphan: A paragraph-starting line appearing by itself at the bottom of a page (or column), and so similarly like 'widow', away from the rest of the paragraph.

Writing an apt introduction is very important and requires time, patience, effort (in thinking and writing and rewriting), and experience, to get it just right and overcome the inherent challenges. Without some notation one cannot proceed; using too much notation will make the description dense at the beginning itself. One needs to define a few terms to get started; but, putting a formal and precise definition at the start will scare readers (and possibly reviewers). One should try to state the contributions as soon as possible (remember reviewers may not be patient souls); but without stating some background work, one cannot place the results in the proper context. One should be providing tabular/graphical comparison but cannot provide too much details. Conscious reading of papers written by others, and watching for both flaws and good features, can eventually make one write good abstracts and introductions.

6.5.2 Methods, Results, and Discussions

Next, is a detailed description, typically in passive voice, of the methods (or Problem statement, in a theoretical paper) in an experimental paper. Each method is to be detailed in a separate subsection with precise explanations such that readers can repeat the work if needed. Specific experimental designs are described in a separate subsection. Similarly, a theoretical or modeling description should be presented as per the needs of the paper.

Relevant algorithm descriptions also form part of this section. Explain the role played by each data structure. Divide into subroutines. Provide a matching textual description. In the presentation, aim for clarity rather than precision. Describe in plain language the nontrivial core of the algorithm. This will help the reviewer/reader appreciate the novelty of the work. Complexity of algorithms, run time, space, random bits, etc. should be described, and comparison with other algorithms may be described. Use tables and/or plots. The comparison could be theoretical or experimental. Mention the hardware and software platform used for comparison. Be fair to the algorithms you are comparing with. Results of running the algorithm (if applicable) can come in the results section of the paper which follows next.

The results section generally reports the experimental data through tables and figures (or presents a theoretical proof), but no discussion or data interpretation.[3] Introduce each group of tables and figures separately where the overall trends and points of specific interest are mentioned, indicating the placement of the tables and figures in the text of this section.

In the case of mathematical results, a main/important result in the context of the work is named as a theorem and usually provided in a subsection of the results section. Small results which lead up to a theorem are called Lemmas. Sometimes, a lemma becomes a key step in the proof of several theorems. Corollary is a direct consequence of a theorem (and sometimes also of a lemma). The theorem statement

[3] Sometimes, a single section titled results and discussions can be presented, but it is advised to do so in different paragraphs.

may be of a general import while a corollary may be of more specific interest. Sometimes, a corollary arises out of a side effect of the technique used to prove the theorem. Sometimes corollaries are used in the subsequent work. A "stand-alone" result which is perhaps not important enough to be called a theorem is called a Proposition. Such suitable nomenclatures are very important in technical papers.

Explain the motivation for the result before stating the result. If the theorem statement is complicated, then explain the different components before getting into the proof. If the theorem has interesting consequences, then mention some of them before getting into the proof. This will convince a reader that the theorem and its proof are worth reading. If possible, structure the proof into smaller results (lemmas). This helps in verifying the proof. The lemmas could come earlier or later. For long proofs, provide an overall description (intuition) of the proof strategy before getting into the details of the proof.

The discussion section is relatively easy to formulate if a simple rule is followed. The promised tasks or objectives of the penultimate paragraph of introduction section needs to be backed up with the information provided in the results section, and a detailed explanation needs to be provided for each of the objectives. Provide an overview of the work in a brief first paragraph of this section. Summarize the main outcomes and, suitably accept or reject the hypothesis. Next, identify the prominent results and contrast those with other reported outcomes. A discussion of the potential weaknesses of the interpretation may also be described.

6.5.3 Table, Figures, Acknowledgments, and Closures

The tables should be headed with a caption (for example, Table 1: Soiling Attributes), and end with a couple of sentences describing the content and impact of the tabulated data. The table should be in proper format as per the journal guidelines, with clearly presented data that is easy to interpret by the reviewer or reader. Tables are likely to be useful in reporting the results, in precisely presenting the background information in the Introduction, or while describing the different aspects or parameters involved in the methods. In review papers, it is not uncommon to have page long tables with details from many papers. Clarity in images and plots is important. The plots should be large, with legends (if any), axis labels and captions in appropriate font. Legends should be either in caption if not in the plot itself. The caption should present the significant result or interpretation from the figure. Each table and figure should be referred to in the text.

Acknowledging the inputs in any shape or form that have enabled completion of the present work is important. All the funding institutions should be explicitly stated as per the guidelines provided by the funding source.

A casual reader will often move to the conclusion right after the abstract. A well-written conclusion section should also state the limitations of the work and possible ways of overcoming them; state possible open problems; future work which is in progress. Some people think that a conclusion should not be a restatement of the abstract. Without a well-written conclusion, the ending of the paper may seem abrupt.

Many editors these days return the submitted manuscript straightway if all the references are not referred in the rest of the paper. The selection of references must be meticulously done and consist of relevant papers in the field, especially recent ones. Citation of previously published work of one's own research group (or supervisor's) should be judiciously done. The mandated reference format of individual journals should be used to avoid delays in the manuscript review process. Creating citations and reference lists without errors and as per a Journal's referencing style is often very important for a paper to be even be considered for review. There are online tools like "Cite This for Me"[4], which identifies the content in the references section simply from the DOI (Digital Object Identifier) link.

6.6 Language Skills, Writing Style, and Editing

This section elaborates on some of the most important technical document attributes that pertain to proper use of language. The overuse of complex words or jargon can profusely obscure meaning and should be avoided. Proper technical writing requires sentences that are neither too short (presents a choppy type of writing) nor too long (difficult to read). Concision is also important in technical writing because readers wish to be informed in the fewest words possible.

Punctuation and grammar are the basic language rules, and disregarding these rules leads to poor readability or misinterpretation. Spelling or punctuation errors can destroy an otherwise perfect technical document and the reviewers may question the credibility of the work. Punctuation can also be very important in terms of context and can change the meaning of a sentence. An author should never allow a misspelled word in a finished document and the best way to do so is to fix an error immediately when found.

Proofreading by a trusted peer is the best way to catch and correct grammar errors. There are many software for judicious spelling and grammar check. The author should be mindful that these software packages do not always recognize certain technical words and the context therein and may wrongly interpret the intended sentence. Ultimately, a good technical document must have good content that is presented in an easy-to-read format without technical or grammatical errors.

Writing style encompasses the mannerisms reflected in the consistent and unconscious choice of words, sentence formations, and the alignment of ideas and thoughts to create a document that meets its stated goals. The author needs to endeavor to develop a style in technical writing that keeps the work objective and impersonal. The writing should keep the reader uppermost in mind, and make the reader look forward to what comes next.

[4]http://www.citethisforme.com/: Creates citations, reference lists, and bibliographies automatically using the APA, IEEE, Chicago, etc.

When it comes to tenses of verbs, either use present tense in the entire paper, or write sequentially. The sequential approach is more appropriate for lengthy papers. Do not overdo the use of colons. While the colon in “Define it as follows:” is fine, the one in “We have: formula” should be omitted since the formula just completes the sentence. The first alphabet after a colon should be capitalized only if the phrase following the colon is a full sentence, but not if it is a sentence fragment. While too many commas interfere with the smooth sentence flow, too few can make a sentence difficult to read.

Technical words are certainly to be expected in technical documents but there can be an overdose and the whole endeavor may miss its mark if the reader is unfamiliar with many of the words. Slang abounds in the daily interactions but does not read well in technical writing. Euphemisms (words or phrases used in place of what really needs to be said) are used to make things sound better but needs extra length, and should be avoided in most cases. Uncommon words, long or complex words should all be avoided in a technical document. Most superlatives (best, greatest, superior, fastest, and so forth) are meaningless or misleading words and make unsubstantiated claims about the results of a research work because one can only report comparatively superior functioning of one product (or method) over another. Such words and others which cannot be backed with facts lower the credibility of the document.

Construction of good sentences in technical writing involves word choice that are concise and substantive, and includes valid facts and data. Avoiding these unsound habits of sentence construction can improve technical writing:

- Starting with dependent clause, and long sentences with many clauses which contain a significant physical barrier between the subject and verb, are best avoided because such sentences may potentially confuse the reader.
- Incoherent sentences usually result from omitting a word or when two sentences are inadvertently merged.
- Same-sounding word and wrong usage: The root cause of such errors is overreliance on only computer spelling checking applications.

Idioms, slangs, and errors in grammar or punctuation must be avoided. The best and obvious way to avoid topographical errors ending up in a published manuscript is to adopt a simple policy of correcting the error as soon as it is noticed.

Researchers need to pay special attention to paragraph construction. This is especially true for engineers who are not used to reading long verbose texts. Identifying logical breaks to form paragraphs in the shortest length possible to complete a thorough discussion makes it easier to read. A paragraph break indicates that a new idea or information is about to be introduced. Related sentences when grouped together should provide a single complete thought. A rule of thumb for paragraph length is that there should be no more than three and at least one paragraph break in each page (or screen view). A paragraph should have some relation to the one before and the one following it.

While writing about contributions of the authors, avoid starting successive sentences with “Our”; also and avoid repeated use of the word “our”. Notice and avoid stylistic cliches. An example of a cliche would be starting the abstract with “In this paper ...". Be careful in the use of punctuation. No space before a punctuation symbol and a space after it.

Avoid repetition of words in the same or in nearby sentences, especially words like "this" or "also" in consecutive sentences. Unusual or polysyllabic utterances tend to stick in a reader's mind longer than other words, and so good style keeps "sticky" words spaced apart. The structure of the sentence and the choice of words should be such that monotony is avoided. Consistent notation should be used for the same variable or attribute throughout the document.

Technical writing is about communicating a technical idea, a message to the reader. The drafting process is all about arranging the material in such a way that it leads the reader to the conclusion that we would like them to make. The last stage of this writing process is the editing stage. This happens after one has all the material in the right place and said it in the right way to convince the reader. Next, there is a need to make it look good. This might seem obvious again, but this stage is very often overlooked.

The research community will want to see the form of the writing in a way that they will accept. Often, if the work contains language and formatting errors, it will be rejected out of hand and the message, the new knowledge, will not be seen by the reader. This means that before the written work goes out, one must analyze it very carefully to ensure that every detail is near perfect. Everything from the font sizes and headings to the grammar and the spelling, the readability of the labels on graphs and figures, the links and references to the figures and other literature need to be correct.

If this is not done the reader will certainly see this and they will conclude that since the author was sloppy with the care of the final document, then probably the details of the actual research were sloppily done as well. Such an impression, the author certainly wants to avoid. During this copy editing stage, the researcher might want to show the work to someone else, someone who was not involved in the preparation of it, to read through it and find those errors. If English is not the researcher's first language, help of someone with the copy editing to get the language right might be needed. And even if English is the first language and one is quite convinced that one can do a good job of writing it, asking for feedback from a language expert is always a good idea. The bottom line here is that one should not send out work to the final reviewers of a journal or the examiners of a Ph.D. that is not very well copy edited and where all the details have been crafted to near perfection.

6.7 Rules of Mathematical Writing

Be careful to avoid starting successive sentences with the same word or the same set of words. Starting sentences with "The" is very tempting. Starting sentences with "Thus," "Consequently," "Therefore," or "So," can become a habit in mathematical writing.

Knuth et al. [2] have presented several guidelines for mathematical writing [2]. Instead of providing a lot of details about writing sentences involving mathematical symbols, we summarize some of those rules that are useful for engineering researchers using some examples:

1. Symbols in different formulae must be separated by words:

$$\text{Avoid: Consider } m_a, a < b.$$

$$\text{Follow: Consider } m_a, \text{ where } a < b.$$

2. Symbol should not be used to start a sentence:

$$\text{Avoid: } \frac{m(s)}{n(s)} \text{ has } r \text{ zeroes, and } q \text{ poles.}$$

$$\text{Follow: The transfer function } \frac{m(s)}{n(s)} \text{ has } r \text{ zeroes, and } q \text{ poles.}$$

3. For example, do not say "U_m for $0 \leq m \leq r$" in one case and "U_n for $0 \leq n \leq r$" in another instance of the same paper or thesis.
4. Extraneous brackets are distracting. For example, in the phrase "let i be $(a_m - a_n) - p$," the parentheses is unnecessary.
5. Do not allow formulae to get long enough to not format well or get confusing. For example, "$l = k + (a_m - a_n - p)s$" should be $l = k + ds$, where $d = a_m - a_n - p$, if there is going to be a lot of formula manipulation in which $a_m - a_n - p$ can be used as a unit.
6. Do not write "$m < n$ and $d_n < d_m$", rather ensure that m and n appear in the same relative position.

6.8 Publish Articles to Get Cited, or Perish

Research methodology should include the ways and means of appropriate publications, because what is not published is as good as not done. Culmination of technical writing for most researchers in academia is in submission to an appropriate outlet like a peer-reviewed journal. Especially for engineering research students pursuing a Ph.D., there is little or no value for publishing in conference proceedings, although there is much value in attending a conference and presenting the paper in the form of networking. The publication process is as follows: (i) Submission to an appropriate outlet, (ii) Review reports and editorial decision, (iii) Submit revised version, or Submit to another journal.

The submission process ideally begins with self-evaluation. The significance of the work should be evaluated in terms of the current interest of the research community in the problem and how prospective reviewers would view it, the quantum of impact on the existing theory, and the practical implications of the new findings. The originality (novelty) of the work should be ascertained in terms of usage of new tools or combination of known methods. The completeness of paper should also be ensured in terms of consideration of the consequences of the results, incorporation of all the necessary details, and/or addition of appropriate implementation details. Technical correctness and sufficient details to verify correctness should also be looked at.

The choice as to where to get the paper published is another important consideration. Specific journal-related factors like time to publication and/or decision and circulation among the relevant community are important attributes to consider. Dissemination may be easy today but it is still hard to make the "experts" notice the work to receive a stamp of quality. Papers in a "top" journal are more likely to be taken seriously and enhance the curriculum vitae of the researcher.

Some researchers or supervisors have a publishing strategy which involves first publishing a conference version and then follow it up with a journal version. The advantage of this sort of publishing methodology is that it ensures timeliness of the results and gives the authors more time to prepare the final version. The downsides are that many journals have started to ask for "significantly" more material than a conference version; and so failure to publish the final version leaves only the conference version available to the readers, and on the curriculum vitae of the researcher.

Every journal with a good circulation typically mentions the "Aims and scope of the journal" in the website. This information should be read thoroughly apart from the "Instructions to authors" to ascertain the suitability and expectations of the journal for the present work. If the present paper builds on (or reference) papers published earlier in the same journal, then it is a good reason to consider the journal for submission.

A researcher should note that the idea is to submit a final manuscript, not a first draft. If one is still finding typos or adding results, improving the writing, then the paper is not yet ready for submission. A poorly prepared paper is almost certain to be rejected. Each rejection after the review process "costs" the authors about three to four months on an average. Each submission to a new journal brings in potentially new set of reviewers, and so it is imperative to be diligent and submit a paper without obvious errors of any kind, in the first place. It is a good idea to share the final draft with a colleague for proofreading and seek helpful comments. If the reviewer detects a casual attitude, then this creates a negative bias. Errors discovered after submission have to be reported which slows down the process.

One of the places where research outcomes are recorded in is in subject-specific journals. These are publications dedicated to recording and archiving new knowledge in a specific area. These journals are often read by other researchers, also at the forefront of knowledge production in that area. Researchers would like to get their work published in these journals because they would naturally want those other researchers to be aware of their work. Researchers want their work to have an impact and they want to be recognized as the ones who contributed that new knowledge.

Once the paper is submitted to such a journal, the editorial assistants of the journal perform an initial check against formal technical criteria (structure of submission, adherence to Guide for Authors, and language usage). Usually, the manuscript needs to be accompanied by a cover letter which in some cases must explicitly state that the authors have complied with the journal's ethical requirements.[5] Once the editorial assistants find the manuscript in order, it is sent to the editor-in-chief who assigns it to an appropriate associate editor. Some journals allow direct submission to an associate editor.

In some cases, the editor-in-chief and/or the associate editor may reject a paper without further review. The editor appoints reviewers who he or she considers to be experts in the field of that journal. The referring by anonymous reviewers allows free (unrestrained) expression of opinion. In some cases (Double), blind review is adopted wherein the identity of the author(s) is also hidden from the reviewer wherein the motivation is the level "playing ground" for all authors. In such case, the authors should make sure that there is no obvious references and/or acknowledgements. These expert reviewers compile a report of the research and motivate either that it should be accepted or rejected or that it looks promising but needs more work. The reports from one or more reviewers are collected by the associate editor and forwarded to the editor-in-chief who takes the final decision.

The final decision of the editor-in-chief may be (i) Accept; (ii) Accept after minor revision; (iii) Submit after major revision; (iv) Reject, or (v) sometimes, encouraged to submit after substantially more work. The editor-in-chief may add comments in addition to what was received from the reviewers. If the decision is not what the authors expected, there is no need to be too upset and react personally. This peer review process is very rigorous and the better the reputation of the journal the more difficult it is to get the work published in it. However, a researcher would like to have the work appear in these prestigious journals because it gives the work greater exposure.

Let us say that a submitted journal paper has made it through the review and there has been a success. This is of course, great, but one actually wants more than just that. For the work to make an impact, it needs to be seen by more than just the reviewers. Of course, the reviewers are the first hurdle and one needs to keep them in mind when constructing the writing, all the time asking if the content will meet the expectations of the reviewers. However, there is also a broader audience, the general research community who are free to engage with the paper or toss it aside if they do not like it. These are the actual folk who will one day build on this work, use it and cite it in their own work [3]. A researcher would want these readers to be impressed and to be captivated.

What makes the readers want to engage with the writing? The research outcome ought to be presented in the form of a cohesive story to the audience (the readers) to make them really want to read the work. The opening of the story is the background and context of the work, then the challenge (the research problem) is identified,

[5] https://www.springer.com/in/partners/society-zone-issues/springer-s-guide-publishing-ethics-for-journals/15064.

followed by the action (the way one went about the research, the methods used, the data collected, and the analysis), and finally the resolution as to how the research outcome has changed the state of the art.

Doing good research and meeting the expectations of the field is important aspect in order to get cited, but not really enough. That is just the action part of the story. One also needs to focus on the change that has come about because of all that action. The part that makes the work attractive is the change part, how the world is different because of the new knowledge. The title of the paper is probably the most important part of the paper in terms of getting someone to read the work and should contain the change that is discussed in the paper, and as far as possible it should contain the problem as well and the new knowledge with appropriate choice of keywords.

The same holds true for abstract and the conclusions, but to a lesser degree. All these increase the impact of the article and help to get it cited. Networking with fellow researchers and making the manuscripts easily accessible through social media for instance, also go a long way in helping quality papers get cited, especially in areas where multiple competing methods are available in literature. Some researchers think that citing their own paper is not ethical. It is not the case. Most researchers build on their own work. So, subsequent works should appropriately cite the previous work. If one simply abandons the work and expects others to pick up on it, it mostly does not work this way, unless the work is really groundbreaking. So, a fair amount of self-citations exist and for good reason.

In the next chapter, we present details about how to develop arguments and how to know when a contribution has been made, and ways and means of dealing with criticisms including dealing with paper rejections.

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Chapter 7
Contributions, Arguments, and Dealing with Criticisms

Effectiveness in research output is based on several aspects like developing skills to be able to convey good reasons to believe and accept the conclusions made, deal with the criticisms that may come one's way from the supervisor, the reviewers or the examiners, and the ability to use the peer review process to one's advantage to do research that has an impact and contributes to one's field of study.

7.1 Arguments in Research

Argument is a core tool that researchers use to develop new knowledge and convince others that what has been done is good and acceptable. The definition of argument is that it is a process of giving reasons to believe a claim. This process is important not only for communicating research in the form of journal papers, but it is also fundamental to the actual research design process. We consider the basics of argument in a pragmatic way that is useful for research. For researchers, argument is about reason to believe a claim. There is always a possibility of asking why a particular statement should be accepted, and before such a statement is challenged a good researcher preempts the objection and provides adequate reasons. Every reason given can be considered to be a statement that can be challenged again. Formally this process has no end, but the conclusion might be a claim of new knowledge which does not need further asking for justification.

One might be more ready to accept the claims of a paper based only on the reputation of the journal where it was published. This is also the case when the author of the paper that one is reading is an established expert because we accept them as an authority although there is no guarantee that what they are saying is indeed correct. Sometimes we also accept something because it fits in well with what we already know about the field as supported by references.

D. Deb et al., *Engineering Research Methodology*, Intelligent Systems Reference Library 153, https://doi.org/10.1007/978-981-13-2947-0_7

> There are two sources of claims that we accept without seeking justification, something that: (i) comes from an authoritative source, (ii) fits in with what we already know or call common knowledge.

However, we often cannot rely on these sources alone. Often, when claiming new knowledge these will not be good enough and the new knowledge will need to be defended much more rigorously to the community of other researchers so that they accept it, and this leads to the need for a good argument which has two aspects: (i) the evidence, and (ii) how that evidence is arranged. If there is a concept in the claim it must appear in the evidence, and no concept in the evidence may stand by itself. These two rules help a researcher formulate arguments that are robust and not open to attack.

The argument process is about giving someone reasons to believe a claim or a conclusion, and a good argument is able to convince someone of something, and withstand scrutiny. The new knowledge developed by a researcher will be continually challenged and needs to be responded with a strong argument not only in convincing someone else, but probably even more in actually designing the process of knowledge formulation. When planning the research work, one should not plan it from an action perspective but rather from an argument perspective.

There are two types of arguments that exist. The one has a conclusion that can be considered proven (deductive argument) and can only be attacked by attacking the evidence statements, and the other has a conclusion that can only be considered strong (inductive argument). Most of the arguments in research will be of this inductive form which can only be strong, and it gains strength through the addition of evidence.

The argument supporting new knowledge can fail on many counts and need to be guarded against, but probably the most common ways it can fail are: (i) an insufficient foundation when attacked fails, and then everything that was built upon it fail as well, (ii) good evidence that is irrelevant, and (iii) not matching the scope of the claims to the scope of the evidence; the claim might need to be smaller because the evidence at hand is limited.

7.2 Research Contributions

What is contribution to knowledge? As a researcher develops new knowledge, something that was not there before, naturally the researcher wants that added to the existing knowledge. When does it get added? When does the work become part of the body of knowledge in the field? This normally happens when others say so. If a researcher has a new piece of information, something that is finished researching with, does this get added to the existing knowledge automatically? Is it automatically a contribution or could a situation arise that the new knowledge is not a contribution? In the case of research in generation, it is the community of people who are actively involved in the field that would make the call whether it is a contribution to that particular field or not.

When it comes to one's own research, one might want to think of the community in the field as the customers because they are the ones who would decide if the output of the research is indeed a contribution. It might be that the new knowledge is good and everything was done correctly, the evidence is in place, and the conclusions are well argued, but the community does not consider it to be a contribution. In that case, it is not a contribution and the objective of making a contribution to knowledge is not achieved. This is one of the biggest risks in research, and a tough situation to be in and a researcher would naturally want to avoid it. How to be certain that one's new knowledge will be accepted as a contribution? How can one go about trying to minimize this risk?

7.2.1 Peer Review Process

This much sought after acceptance by the community often starts with a process called peer review, where a few selected experts in the field will review the new knowledge, comment on it, and make a judgement call whether to accept or reject the work. We have dealt with different aspects of technical writing in the last chapter, precisely because to seek peer review that knowledge developed through research has to be first written down. The knowledge in the written documents that are peer reviewed can be used by readers who can then build upon it and this is how the field of research progresses. A researcher would naturally like that the new knowledge, that is, the outcome of research, makes an impact in the field.

Therefore, this approval, this acceptance during the expert peer reviewer process is of the utmost importance. One encounters the peer review process in two different places: first, when one submits an article for publication in the open literature; and second when you submit a thesis or a dissertation or a research report for examination. In both of these cases, the process of peer review is somewhat similar although the outcome is focused differently. For the journal submission, the final outcome is the article appearing in the publication. For the examination, the outcome is an individual getting a qualification. In both cases the researcher needs to be meeting the standards and expectations of these peer reviewers because they are the actual ones who decide that the new knowledge is good or not. Therefore, one needs to understand what these peer reviewers are all about and what their expectations are.

The decision of the reviewers will also be seen by other researchers in the field. If the reviewers accept an article, then everyone who reads that journal will see that article when it is published. So, the reviewers are also asking the question of whether or not other researchers in the field will want to see this work. Will other researchers in the field value it? Additionally, in a certain journal, one may find that there is a great emphasis placed on detailed mathematical rigor, but in another journal, one may find that results are sought to be backed up by rigorous experimental evidence. It is these subtleties that shape the culture of what goes on in that research community.

Reviewers in different research communities look for different types of conveying the information and different types of details based upon the type of journal. Basically, the reviewers apply the values and expectations of the research community that they are in to assess what the author has done. So, it is vitally important to understand and get to know one's research community.

Similarly, in the case of thesis examination, the examiner will need to give good reasons for the decision on the submitted thesis, and those reasons could be challenged. However, a researcher would rather avoid having to challenge the reasons the examiner gives for an unsuccessful outcome, then to carefully meet the specific implicit expectations of the research community of which both the researcher and the examiner are part of.

There are other forms of peer review as well, sometimes a bit less rigorous like when we present our work to others in a weekly research group meeting or at a conference or even just writing a progress report. In these cases some of our work, probably not the final product, is shown to others and they might form an opinion about it. Those looking at our work, in such cases, might not necessarily be the leading world experts in the field, but they are probably competent researchers and are able to understand what we are doing. This sort of feedback might not be in the same form as the formal peer review process and probably not as rigorous, but it is still an indication of what others in the field think about our work.

7.2.2 Dealing with Criticisms from Reviewers

Most researchers have been criticized at some time or other. Being able to accept criticism assertively is one of the most important tasks in a successful research career. To accept criticism maturely, one needs to be able to receive feedback about one's research work in the form of analysis, observation or interpretation from other people.

Criticism can be invaluable to a researcher and can make one think about, reflect upon as to how the research can be improved, enhanced, and made more robust. The opportunity to receive constructive criticism in research is something that we should be grateful for. That is not to say that criticism is always good to hear. Sometimes it may make one feel somewhat deflated. Nevertheless, it is something one has to take on board and these can make the research projects better subsequently. It takes a kind of attitude shift to see that criticism is something that propels one's research work forward.

Sometimes, when we present our work, even in the context of a research group meeting, we are a bit nervous and worried if it will be well received. Nobody likes to present their work and to be told they are no good. This is true even in a friendly environment of, let us say, the fellow researches in the research laboratory. We are looking for that acknowledgement that what we are doing is good, and if we do not get that acknowledgement then we sometimes tend to become a bit disappointed and perhaps even despondent.

In the formal review process, when we submit something to a journal and the reviewers do not like it, the reviewers can tend to be very harsh and critical. This is good because it means that the standards of the research community are high and our work has not yet met those standards. However, when we show our work to others we are exposing a part of ourselves, of who and what we are, and it can be very intimidating if the feedback that we get is negative and it can sometimes give our confidence a bit of a knock.

The authors would suggest that a researcher approaches peer review in the same way as one would any experiment or data gathering exercise. And by peer review, we mean all forms of review, from a journal submission to a presentation of provisional work in a research group setting, to an informal chat with another researcher. When a researcher is busy with an experiment, in any form, whether in the laboratory or doing experiments, perhaps doing simulations, or running a survey, the focus is on getting data so that one can learn something. The researcher sets up the experiment in a certain way so that the results are useful and it probably contributes to the research in some way. Now, very often, and even normally, the outcome of an experiment is not quite what was expected, at least not initially. Perhaps the researcher is monitoring the reaction temperature of a modified chemical process and observes that it is rising where in fact, the modification was expected to cause the temperature to fall. This is not unusual and it normally indicates that one needs to go back and ask the question: why this might be the case? Obviously, when the results of the experiment are not quite what was expected, one does not consider it to be an attack on oneself as a person. It is part of the discovery process, and one uses that outcome to advance. The peer review process should be taken in a similar way.

Just as an unexpected temperature measurement during the experiment is not an attack on the researcher as a person, the data one gets back from the peer reviewers (and in this case the data is what they think of the work), is not a personal attack, and this data can be used to advance in the right direction. By depersonalizing the process, by considering the feedback to be about the new knowledge and not about the researcher, can be very helpful. One can even go a step further and just like one would do in the laboratory, one can actively target the kind of feedback, in other words, the data which one is looking for. For example, if one is worried about whether or not the research problem is significant enough, at your next presentation or discussion one can focus everything on the issue of if what one is doing is important, and see what everyone thinks.

A researcher should make use of every possible opportunity to get feedback on the work that one is doing, and present it in as many forums and places as possible. And design the presentation of the work, whether it is a journal submission or a slide presentation, so that you get good data back from that process. This feedback is just as important as the feedback that one gets from running conventional experiments.

If one is doing a small bit of incremental work that fits in nicely with that of others around then it is normally quite easy to convince the peers that it is good new knowledge, and there is nothing wrong with doing incremental work. Most research work is incremental and it advances knowledge one small step at a time. However, if it is very different from what currently exists then it might be difficult to convince the reviewers and may take "inordinate" time to get published. Breaking with convention and making disruptive, game-changing knowledge is a good thing to do, but such a researcher should be prepared to have a tough time of getting it accepted.

There is another type of research that also breaks with convention and which can also be difficult to get accepted and that is, interdisciplinary research. This is where two different fields can be combined to generate something new. There might not be that many researchers with this combined expertise or that community might be very small. In this case, one should look carefully at where the actual new knowledge might lie and which is the primary field. In such a situation, it is important to include some form of tutorial of the contents from the secondary field for the target audience of the primary field, to get them up to speed. One may not be able to completely avoid being criticized in such a scenario because it is hard to predict what the reviewers are actually looking for, but targeting the community of the primary field with some details in the form of tutorial of the secondary field, is probably the best way forward.

7.3 Revising Peer-reviewed Papers

Very often, a researcher is quite convinced that the research outcome is correct and good, but the important issue is do the experts in the field, the peer reviewers agree with that view. When one submits one's research work in an engineering journal, one can expect to receive harsh criticism. In fact, as per latest data a research article typically goes through two and in some cases even three rounds of stringent reviews. Sometimes one faces arrogant or ignorant reviewers, while on other occasions, the work is actually replete with errors.

Even when a reviewer is seemingly biased, investing one's energy to meticulously respond to the objections raised, can turn out to be very productive. The knowledge and confidence gained through this process would allow subsequent addressing of similar criticisms swiftly. Very often, however, everything is not perfect. May be the arguments and results are correct, but it is possible to present them better and the reviewers' comments are enablers in that direction. Generally, the reviewing process significantly enhances the quality of the work by allowing the authors to incorporate inputs from experts in the field.

The following are suggestions on dealing with harsh reviews:

- If one rarely publishes, the likelihood of being able to deal with criticism is naturally lesser. One should realize that harsh criticism does not necessarily indicate impending pain.
- Repeated inferior work naturally affects one's reputation, but everyone gets it wrong occasionally. Most reviewers are least bothered about the author of the paper they just reviewed, and so there is no use ruminating over a harsh criticisms from a reviewer.
- A suggested approach is to take it one comment at a time and not allow oneself to be demoralized by the pages of criticisms. Do not look at all the different possible flaws identified by the reviewer as one message: break it into components and address each comment individually. Tackling recommendations sequentially

allows one to be able to check off one comment at a time before proceeding to the next, so as to not be overwhelmed.

- An author should go through the comments of reviewers and the editor, and make suitable changes. After all those modifications are meticulously done, one should print out the whole article and read through it, fixing up expressions and making it more congruent for the reader.

Calcagno et al. have found that papers with multiple round of reviews eventually tend to get more citations than those that are accepted faster [1]. It is important to be patient during the review process. A thoroughly done "response to reviewers" is a vital segment of engineering research publication, and is a compendium to the manuscript each time a revised version is submitted. The following guidelines would help the authors formulate their response:

(i) Response should start with a summary of modifications since the last revision (or original manuscript), stating new results, data and analysis done against the most significant criticisms of the reviewers. Typically, in engineering journals, the response sheet may have plots and tables to explain the answers given in response to reviewers' comments, but these may not necessarily appear in the revised version of the paper. Criticisms raised by more than one reviewer may also be addressed at the start of the response document. The complete set of reviewer queries should then be arranged with the responses interleaved.

(ii) The onus on providing clarity lies with the authors. If a reviewer misunderstands or does not clearly understand, the fault at least partly lies with the authors but what is certain is that in such a case the losers are the authors and not the reviewers at all. A rude critique from the reviewer does not warrant a rude reply from authors since the main goal is not to win an argument but to publish the paper. Even when the reviewer has requested a change that is seemingly unwarranted, it is generally advisable to revise so as to convey that due importance was given to the views of reviewer.

(iii) If possible, the authors should refer to specific line numbers of the (revised) manuscript where the suggested changes were applied to address the concerns of reviewers.

(iv) The response sheet should be self-contained such that the likelihood of reviewer again reading the full paper to find new flaws, is reduced.

(v) Response should be given to all the points raised by the reviewers, ensuring not to miss multiple points raised under the same bullet point or numbering, by answering only one of the points raised.

(vi) Review comments, responses to them, and changes that have been made to the manuscript should be discriminated using typeface, color, and indenting. It is imperative to be explicit about what changed in the revised manuscript relative to the previous version and attribute the change to the valuable suggestion/comment of the reviewer.

(vii) Begin responding to each query with a direct answer. Background information can follow for clarifications, but never at the start of response.

(viii) Even when the authors believe that the reviewer has requested an analysis that is based upon flawed understanding, it is always advisable to do as asked, provide the results in response document, and then state succinctly why these results do not appear in the revised manuscript. It is a bad idea to give an impression of reluctance to address the concerns of the reviewers.

7.4 Criticism from Research Advisors

Criticism can be demoralizing after one has worked tirelessly for months only to have a manuscript returned with red ink from the supervisor's comments. However, one should not get too discouraged, while also realizing the need for feedback with intricate details. It is great to have advisors who would criticize while also guiding and supporting their research students. Some advisors are more direct than rest and tell it straight; others are conservative in their comments. To be critical in a constructive way is the task of a research advisor. With no critical feedback from the advisor, researcher might not succeed in his work.

In order to receive feedback, one needs to write up and present one's ideas to the advisor. Even for pre-publishable papers, writing carefully and clearly maximizes the chances of getting useful comments. Seeking the advisor's help in finding suitable forums, a researcher should present research work at conferences, other research labs, at other university forums whenever possible. Many fields have informal workshops that are ideal for presenting work in progress.

If the advisor has something negative to say, the researcher should not disregard the comments even if he no longer has a high opinion of the advisor. Instead of shutting down, staying objective and genuinely open to hearing (without interruption) helps in an engineering research career as in any other situation where criticism is received.

Using active listening techniques throughout the conversation like paraphrasing what one is hearing in one's own words and making eye contact to show that one is actively engaged, is imperative in deciphering the criticism clearly [2]. Taking negative feedback well is a rare skill that needs practice, humility, and a sizable dose of self-awareness [3]. However, the ability to learn from advisor's criticism fuels creativity in research and helps the free flow of valuable communication.

While trying to get a foothold in research, the experience can be mentally traumatizing. While insults are unacceptable, it is important to discern attack of the work from a personal lash out at the student. Attacking a student's work on whom the advisor is investing much of his time, is a common occurrence in academia. Even the best researchers fail more often than they succeed.

> A key attribute to remember is that, in general, the criticism or "attack" from a supervisor or examination committee member is not personal and has long term benefits in evolving oneself into a matured researcher.

The researcher should be able to understand that the advisor is not expected to be easily impressed with the "good" academic record and/or the student's hard work. Successful academics invariably tend not to be impressed by academic records and hard work, since it is considered to be par for the course. Best thing for the young researcher is to resolve the differences of views early on by seeking regular feedback. It is in the best interest of the student to try to ascertain what his strengths are and what he should work on. This can be easily done through regular dialog with the advisor. If one is unsure of the progress or capabilities to accomplish the set milestones, one can always seek reassurance from the advisor.

7.5 Criticism from Research Lab Managers

As researchers advance up the career ladder especially in the industry, they are called on to apply management skills that were not part of their training as a research engineer. For some, the transition is easy and natural, but for others it is fraught with problems that can hinder productivity. Receiving criticism from the manager or supervisor in a research lab that is naturally driven by productivity and tight deadlines is an acquired skill.

Before getting too upset at the boss, one should try to understand the intentions. Is boss upset with the researcher's performance and trying to help fix it, albeit in an unhealthy way? May be it is an exceptionally stressful situation and so the boss is prone to saying things which are not fully meant to be inferred as said. If so, the researcher can keep this in mind as he/she frames the response and can breathe easier. However, if the boss seems to be only criticizing to make one feel bad about oneself, that is a completely different situation, and at that point, one may want to consider finding a new job.

Those with good research credentials can easily find a suitable job elsewhere if the current workplace is no longer conducive to conduct innovative work. In this sense, the situation for an engineering researcher in an industrial research position is distinctly different from a researcher working toward a graduate degree in an academic program. The threshold for tolerating a difficult boss should obviously be much higher when there is a price to pay like starting a new thesis topic under a new advisor. Additionally, the supervisor in the industry is also expected to be more subtle about the criticism, whereas the advisor in academia may sometimes tend to be patriarchal or matriarchal.

If the boss is criticizing the researcher for something that is beyond one's control or refusing to enter into a dialog, the researcher should consider giving his/her own criticism if the work environment is otherwise professional barring the supervisor. However, such criticism can be provided only once one has successfully entered a calm, distanced state. Tell the boss that his/her criticism was unwarranted or unhelpful, but suggest alternative strategies he/she can use in the future to make the criticism better.

Without loss of generality, the more objective, calm, and logical one is in this situation, the better the final results of such difficult situations will be. All attempt should be made to ensure that criticism is not taken personally but should be a catalyst for improved future behavior in order to gain the maximum advantage from the feedback [4]. In any case, it is always a personal decision that one should be able to live with. Sometimes, taking some time before a drastic step is worthwhile as it may often be that the cause for misunderstanding sometimes is removed on its own.

7.6 Distilling the Feedback

The following are some ways one can distill the useful information and use them to one's benefit:

(i) Detach the criticism from associated ambiance: It is normal to be defensive when insulted, but one should dispassionately look at what's being said and see if there are clues for personal growth embedded in the vitriol.
(ii) Filter out the actionable and repeatable items from the subjective opinions, keeping what is applicable to the work and filtering out the rest.
(iii) Write down those useful parts. Doing this removes the heightened emotion and lets one step back from the criticism, and separate the advice from how one felt on getting it, so that it gets acted upon.
(iv) Specific and actionable tips should be turned into measurable goals. If the complaint is that the researcher is taciturn during the discussions, one should systematically work toward developing into a voluble river of technical ideas and information.
(v) Despite doing all these, one may still get depressed when someone points out areas of improvement. Attitude is vital, and if one does not push oneself to be positive about the criticism one gets, it is natural to be depressed. One should always see criticism as an opportunity to get better and possibly surpass even the critic.

The key to transition from student to academic or a researcher in any industry, is acquiring the skill to channelize criticism to improve scholarship. That means assimilating whatever helps and averting that which misses the point.

7.7 When Things Still Do not Work Out!

Some problems are not always solvable. Skills and strategies in dealing with one's ego and the advisor's criticism, are not unlimitedly effective in all circumstances. It is almost certain that a researcher will not be able to change a professor's attitude. The advisor would have been managing the research lab in a certain way, and has by now a non-flexible way of doing things. To start with, the affected student may discuss the issues with other students of the advisor.

It may be worthwhile to speak to one of the members of research progress committee about the concerns. Sometimes, with proper mentoring, the student may even identify that the fault does not lie with the advisor. At other times, such seeking out may bring about useful advice from a committee member, both in terms of direction and in terms of actual research work.

As a last resort, one can switch labs whenever one wants. It should really be the last resort and the decision be made dispassionately. It will set one back a few years, but that may be a necessary cost as a last resort. Always keep that in mind; no one is bound to anyone by any means. On the other hand, sticking it out may be worthwhile, and this is a personality type one will likely come across again in academia (and elsewhere). It is definitely worth getting to know how to deal with a really difficult supervisor.

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Chapter 8
Research Management, Planning and Collaboration

Performing an activity satisfactorily requires a certain amount of time, and in general many activities are needed to be performed. Management of the available time of a researcher is important for effective and efficient execution of one or more tasks, and inadvertently affects the time of collaborators, managers or supervisors as well. Managing time well ensures that one can get the most of what is set out for in any given day.

There is always a lot of things to do beyond one's main tasks, and time always seems to be running out. At the same time, it is equally critical to devote enough time to unwind and rejuvenate, so as to be refreshed enough to deliver a satisfying research performance on a consistent basis to the academic community or to one's organization.

8.1 Prioritize and Say No to Procrastination

People feel that the time of researchers is very flexible, for they can, in many cases, chalk out their own schedules, and so time management skills are not a critical attribute for them. On the contrary, possibility of flexibility actually requires that researchers be good time managers. Research, invariably, needs long hours, for the results might be unexpected and unpredictable, and some procedures may take longer than expected. Therefore, reasonable estimates of time required for each activity must be done, and careful time management of all the expected activities is required so as to reserve time for unforeseen circumstances. This is the only possible way to recover from minor disruptions in certain activities which is inevitable.

In many cases, engineering researchers have many additional responsibilities like conducting or assisting, and studying for courses, field data collection, laboratory assistantship, tutoring, invigilation, departmental works, exam grading, etc. A researcher needs to be skillful in managing time and deadlines so that there is

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no omission or underperformance on any of these important tasks, lower research quality, depression, etc.

Research schedule should be appropriately chalked out to fit all the expected tasks into the time available to complete those tasks. Requests for extension may not help, and often may damage the career either by increasing the time to achieve the goals or being one's competency and work ethic into question. However, time spent on leisure or talking to people, including networking with other researchers, who may be unrelated to the present work being undertaken, is not a waste and helps maintain one's physical and mental health, and ultimately may aid in the research output. Time management is essentially the organization of time such that the desired goals are most effectively met.

We often postpone taking up tasks, even when they seem to warrant attention, possibly because the task is not well defined. It could also be that one is unaware as to how to get it rolling. Once started, though, there will be a better chance of meeting the objectives, and if progress is slow one can get help. If one starts early, there will be the opportunity for quality improvement and refinements. If one completes the critical tasks first, one will find that it is possible to do the other ones in a relaxed manner, and also avoid being under time pressure to complete difficult tasks which may take more time than expected.

A research student is recommended to begin exploring his research problem while coursework is still going on, thereby allowing enrollment in relevant and advanced courses which are in line with the research problem in the works. Starting early will also enhance chances of securing published papers while still in the academic program, and subsequently helps one secure a major advantage over peers in job search or career growth.

Being more organized helps instill self-confidence, reduces stress and enhances satisfaction in a researcher. As a result, one is able to engage in productive research and find a faster pace in career growth, apart from improved health and interpersonal relations. On the contrary, poor time management is often the result of procrastination. The more one procrastinates, the more is the built up pressure, thereby adversely impacting performance. Poor time management may potentially bring about negative impact on relationship with the supervisor and/or with research committee members.

There are certain research problems that are expected to run similar pathways. It may be worthwhile in such situations to ascertain from others how it was done earlier, and avoid reinventing the wheel. It is worthwhile to backward engineer the thesis work a little bit by looking at the expected deliverable, and then turn it into smaller tasks that would build on each other toward the ultimate goal.

It is vital to complete documents when the work is done or when action is needed; proposals for funding must obviously meet any submission deadlines. Procrastination may cause similar work to be published by someone else. It has been seen that many times when two people came up with the same invention, the person who was actually second to make the discovery got the patent or was published first, and received all the laurels. Another reason for timeliness is the possible loss of data or missing finer details if writing is delayed.

To meet deadlines, one must prevent distractions, and so a researcher should have a dedicated workspace as far as possible. Sometimes one may need a space with access to resources like a library. At the same time, one should not let one's research work be upset by the absence of a dedicated and distraction-free location.

8.1.1 Nonlinear Planning

Research planning is important because irrespective of what research one is actually busy with, one will probably have a limit to the amount of time that one can spend on it. In a formal qualification, the rules of the institution might dictate a time limit, or one may only have funding for a certain period, or one might just want to get on with the next thing.

Experienced researchers opine that research always seems to take longer than anticipated. Let us try and understand why this is and let us see if we can get a strategy in place to try and prevent the research from taking an excessively long time. As part of the knowledge production process, one will be doing a great many things. There is literature that must be read, background to be learnt, get evidence via lab work or in the field, analyzing results and developing models, and writing down the work and presenting it to the community.

There are many twists and turns and dead ends and there are moments of despair and there are moments of enlightenment. And sometimes progress is fast and sometimes it is slow. It is very nonlinear with a great deal of inherent uncertainty. For example, what happens when the outcome of the lab experiments points to a problem with one's theory? There may have been a flaw in one's reasoning and one needs to go back and change things and test it again. One was certainly not planning to introduce that flaw, but now it has thrown the timeline out completely.

One may need to go back and revisit a section that was supposed to have been finished a long time ago, or suddenly there appears a new paper in the literature that proves what one was trying to do is impossible which throws everything into disarray as well. These types of difficulties are almost to be expected.

8.1.2 Planning for the Objective, Adapting with Feedback

Let us take a look at our actual objective and see if we can make sense of planning to achieve it. Time by itself does not drive the research process. If the time allocated to a certain activity has come to an end, it does not mean that that activity has been completed and is finished. For example, if the time allocated to lab experiments has run out, but the researcher discovers inconsistencies in the measurements, there is a need to go back and redo them.

> Time is certainly a resource, a very precious resource, and one should optimize that resource, but it does not drive the process.

Research is an attempt to make contribution to knowledge and that comes from two things, the actual new knowledge and its value to the community. Therefore, rather than using a linear time-based approach we could represent what we are doing on a two-dimensional plane. On the horizontal axis, we have the new knowledge that we are making. It extends from a small scope (a minor observation) near the origin and gets larger (a generalized theory or model) as we move to the right. On the vertical axis is the significance of the work, its contribution to the community. This extends from weak significance all the way up to earth-shattering significance. On this two-dimensional plane, we could map the research activity. When we start out we are at the origin.

As we progress, we make new knowledge and that increases in scope and significance. Ideally, we would like to be up at the top right, where we have a large scope and large significance. With the research process, as we progress we will move around this plane and we can drive our work in the right direction. We move to the right by increasing the scope of the new knowledge and we move up by testing the knowledge against the community to see if it is significant.

How can we judge where we are on this plane on a regular basis, so that we do indeed know that we are progressing toward our final objective? Let us say that we have done a lot of new work, made the new knowledge and sent it out for review or examination and we have received the feedback. In that case, we could indeed place our work on that research plane. However, with this approach it takes much too long to get the required feedback. What we would like to do is to see ourselves moving incrementally, week by week or month by month toward our goal. We would like to track our discoveries and their significance continually, so that we can adapt to changes as we progress and learn.

The discoveries are coming from our writing and the significance is coming from the feedback of the community. The knowledge production process certainly starts with a problem, which gives rise to the requirement for new knowledge. Then we do a whole lot of actions, the actual research work, and then we end up with our conclusion, our new knowledge.

> The new knowledge is only made during the writing process, and so one should be writing continuously and not only at the end, so as to enable using the learning and discovering to guide the knowledge production process as it unfolds. This is how the flaws get found and where we see the different directions that might need to be taken.

We would like to enable the feedback process as much as possible so that we can know sooner rather than later if there is a problem with the work. Then we can make an adjustment to what we are doing in good time. A problem we sometimes have as researchers is that we are quite happy with the progress as long as we do not write anything down or as long as we do not show it to anyone. But without writing it down and showing it to others we actually do not know where we are on that two-dimensional research plane and we actually do no know what the new knowledge really looks like and what its significance is. So one needs to be writing and showing the work to others continuously throughout the time that one is busy with research, so that one can get the feedback process working.

Regular feedback enables us to chart our position and our progress on the two-imensional research plane. So how do we go about doing this? Every week, or perhaps every two weeks, one should completely write a paper, dissertation or thesis. The knowledge be completely formulated, even though it may be of very limited scope due to the limited time, but should be written such that it is completely understood by those looking at it. The scope can grow with time. However, every week, the work can receive feedback. Every few weeks one can update to a newer version of the research paper, thesis or dissertation. The scope of the work gets slightly bigger, parts are added that make it more significant.

There might be a long experiment to run and process data that takes a long time before one gets the results. However, the longer one waits before having a working draft, even if it is of very limited scope, the bigger the risk becomes. What would happen if after running a long experiment, one discovers that there is something wrong and one needs to go back and repeat something? That puts one back a great deal and that means that the time taken would get extended. Sometimes this approach is called exploratory research. One can do a quick experiment or some simple work to see if there is anything meaningful in the direction that one is thinking of moving in. Getting feedback quite fast and gives one the guidance on whether one should continue in that direction or not.

One can take this idea of exploratory research to the limit as far as one's work allows. After all, research is all about exploring. First, one should ascertain the minimum viable argument that one can define? And shed any parts of the big argument that are not vital. One may now be weakening the argument greatly and limiting the size of the claim tremendously, but that is fine as one gets a small core piece of knowledge to start with. Once one has written it down and formulated it properly from start to finish, one can show it to someone else, and then start to expand that argument and strengthen it, build it out and increase the size of the claims. The whole idea behind this approach is that one always has the new knowledge ready to show the community and get the vital feedback about whether it is good or not.

> This incremental approach ensures that one always knows where one is on the research plane of knowledge scope and significance, and one has the ability to adapt quickly as one learns and discovers more.

One is only developing a small piece of knowledge and testing it to see if it is good, then as one progress, one can increase its size and significance as one gains confidence. However, the writing is done in a completely well-argued form. The knowledge exists only when it has been written down.

8.2 Set and Achieve Milestones

Establishing goals and objectives is the first step of effective research. Goals are statements that focus on ends rather than means and define what are the future expected outcomes and provide direction. Objectives are clear, specific, measurable, and deadline-driven statements of action which when done, enables one to achieve the goals. Deadlines may be often set by oneself or be imposed by external conditions like funding scenarios, customer requirements, supervisor's suggestion, or university's mandates.

Research tasks are not done in at a stretch. A researcher can set milestones that pass on the way to completing the entire task. If one is disorganized, one may lose the will and momentum to complete it. But if one organizes the effort and sets milestones one can monitor one's progress with respect to those targets, and build momentum as one passes them. To do lists (in written form) can serve as milestones and free up one's mind from the burden of remembering tasks, and rather one can focus on completing the tasks.

Each broad research task can usually be divided into sub-tasks, and in most cases, there are inherent delays between sub-tasks. In such situations, it is important to explore flexibility and try to interleave the sub-tasks of different planned tasks. Multitasking may be an efficient usage of the researcher's time as per the comfort level, but every researcher should evaluate how much multitasking is too much. In certain tasks, it may simply be too complicated to do them in any other fashion apart from sequentially.

Checkpoints must be part of any time plan to accomplish any task, and there must be time points to stop, ponder, revise time-estimates if needed, and evaluate the inevitable slips till that point. Tasks may not play out as was expected in the first place and therefore it is necessary to have review sessions with peers and advisor/manager, as often as feasible.

During the review, the team can adjust a researcher's time plan and incorporate self-correction mechanisms based on the challenges faced in handling the assigned tasks, or adopt completely new plans. Even if a researcher is not in a position to get on to an assigned task straightaway, there is still the need for review while the discussion is still fresh, and to do so effectively each review session should involve taking notes. Without notes, forgetting the details is normal and the ability to have good research outcome will become more challenging.

8.3 Effort Management in Research

Effort management deals with appropriate utilization of time and resources to accomplish planned tasks. Performing any activity requires a certain amount of effort, and naturally performing research work also does. The type and extent of effort depend on the nature of the activity, and effort is not synonymous with time. However, understanding issues related to effort is crucial to proper time management.

Effort depends on energy: Physical and intellectual. Physical energy is important is research and has arisen as part of general social awareness. Intellectual energy includes energy spent in observation, reading and absorption, writing and speaking, programming, experimenting, and tedious calculations.

Intellectual energy gets drained out in varying degrees based on research task and the researcher, but can be replenished in different ways by different persons. During time management in research, a healthy mix of high-energy and low-energy tasks is useful. Nature of energy requirement and consumption is complex. However, in certain cases, different high-energy tasks can be done one after another. Understanding and improving one's capability for different kinds of energy helps in improving effective energy utilization.

8.4 Goals and Objectives of Dissertation

A Ph.D. student should be adept at ensuring broad division of the available time into nonacademic and academic. The nonacademic component grows with time and unsatisfactory management of this component adversely affects academic works. The academic component should be significant. More academic time typically implies better or more research, but that relationship is not always linear. The academic tasks may include reading and learning, meeting and discussions, thinking, writing, programming, experimenting, teaching and giving presentation, and also reviewing.

The goal of a research student is to become an accepted and productive member of the research community. By the time one is finished with one's dissertation, people in the field should be citing that work, and know one by the papers and talks. Such a researcher should be getting invitations to review other people's papers. One should by then know the literature and be able to write and teach well. Of course, other researchers should want to hire one based on one's proven ability of research contribution.

The dissertation is the culmination of organized research work that is based on building an academic background through course work and directed reading, identifying and solving a few problems, writing and publishing a few papers, submitting papers to journals and/or conferences, making presentations, and finally using all those material to write a thesis and finally defending that thesis. The Ph.D. requirements are not just arbitrary rules. The dissertation demonstrates that one will be able to carry out a sustained program of work on one's own, once the Ph.D. is over.

The coursework ensures that one is not so narrow that one is left stranded when the field changes. So do not treat the Ph.D. as a silly game that is to be won. Treat it as an important mission that is to be accomplished. It is true that at some point, one will have to figure out how to finish in a reasonable time according to the rules.

Every Ph.D. student has to have a supervisor whether one likes it or not, and so the management of this relationship is very important. The supervisor supervises your research work and helps one move through the unknown terrain of research world. The goals and objectives of working with a particular supervisor towards the dissertation may be similar academic interests, strong publication record, or good post-Ph.D. placement possibility using the supervisor's network in industry and academia. Actual choice can be based on a combination of these attributes.

At the same time, the supervisor also has expectations from the student such as commitment and motivation, enthusiasm, basic understanding, willingness and ability to learn new things, and openness to strongly consider advises and suggestions of the supervisor. In order to meet the objectives of the dissertation, a healthy collaborative research partnership, often a long-lasting relationship of several decades, between the student and the supervisor is paramount.

Any research project can be extended indefinitely, and so in collaboration with the advisor, one has to figure out how one can package some coherent subset into a dissertation that stands on its own. But this is just a larger version of the same exercise one has to do in order to publish any paper: what goes in, and what is left for future work? The dissertation does have to be a "substantial and original contribution to human knowledge," and it should advance the state of art.

It is wise to think ahead about how one will be able to fulfill the formal requirements in *n* number of years. But one cannot and should not spend that time on something—a significant fraction of one's adult life—unless one believes it is a genuinely good use of that time: that one's work is helping the world and that it is helping one to grow and prepare for the next phase.

8.5 Research Collaboration

Understanding what is collaboration and with whom and when to collaborate, are important in a successful research career, especially in applied field like engineering. For instance, it is not always possible to have all the necessary equipment in one's laboratory, or in research laboratory of one's supervisor or organization, and so collaboration can be effective in completing the task at hand. Collaboration involves jointly participating in a project and contributing to its possible completion. Make a positive contribution in terms of ideas and also in terms of working out details to keep the research project moving ahead. Every collaboration is also a "friendly" competition and one should enjoy and use it to focus and improve.

Engineering research requires diverse skill sets and strengths, and these skills and capabilities usually develop over a period of time. Under such circumstances, an innovative idea for research collaboration can provide motivation. One may start one's research career with certain strengths, but can manage to generate research outputs under the guidance of other researchers equipped with other related expertise.

Collaboration provides distinct advantages such as division of work and the share of expertise. It is widely accepted across engineering disciplines that research collaboration with senior researchers is hugely advantageous to the career of novice researchers, and provides them with opportunities to learn.

Research collaboration almost naturally happens or becomes imperative when one attempts to participate in interdisciplinary research. The skills of different persons complement each other. For instance, theoretical study, experimental design and analysis, and elegant writing are important tasks that need diverse skills of research methodology that are rarely the forte of the same individual. Collaboration also avoids the requirement of one person having to read up everything to proceed. Collaboration may help overcome deadlock. The project may be stuck and somebody may help it move forward.

The downsides of collaboration are that one may tend to develop a habit of looking for people who can provide solutions rather than look for the solutions. Various skills related to research are only acquired through trial-and-error and practice, and too much collaboration can make one a manager rather than a researcher. Some studies have used quantitative research methods to identify the fields where the benefits of collaboration dominate the inherent drawbacks, disciplines where collaborating is not worth the pain, interestingly engineering fields like computer engineering which is in an intermediate situation, wherein some nominal collaboration seems beneficial [1].

Reference

1. Franceschet, M., & Costantini, A. (2010). The effect of scholar collaboration on impact and quality of academic papers. *Journal Of Informetrics*, *4*(4), 540–553.

Chapter 9
Communicating Research Work: Presentation Skills

Engineering researchers are tasked with solving increasingly complex and interdisciplinary problems requiring succinct communication and presentation skills. Presenting research at an academic or professional meeting can be intimidating, but can also be a rewarding experience that gives a deeper understanding of one's own research while developing communication skills. Having experts question about the research undertaken might seem scary, but with proper preparation and resources, one can be earning compliments.

The best presentations are those that tell a story: What is the question being asked and why is it important? Why was the particular methodological approach chosen and how was it successful? Most importantly, what discoveries were made and how has the discipline been advanced through this study? Even if the project was not as successful it was initially hoped, a good presentation can still convince the listeners that it was an important question and that something new was learned along the way. Best presentations are those that conclude with a clear path forward. Research is an ongoing process that does not end with the present work. New questions developed are the seeds for research in the future.

9.1 Oral Presentations

While the idea of presenting to an audience may seem daunting, an oral presentation allows research to be described in a concise, controlled manner. Oral presentations can reach a wider audience and receive fewer questions with little to no interruptions.

Given the need for practice at one's own pace to be able to master presentation skills, the authors recommend freely available educational tools like Virtual-i Presenter.[1] which is a video and PowerPoint presentation recording software that allows

[1] http://www.virtual-i-presenter.info/.

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for evaluation by experts and improvement. Here are a few aspects to keep in mind when giving an oral presentation:

- Get to presentation room early and test the technology.
- Keep it simple. Ditch the complex animations, large blocks of text, and complicated graphics.
- Do not just read the contents. The slides should only be a guide for your presentation, and as a way to illustrate your research to your audience.
- Pay attention to nonverbal skills. Audience may be excited about the talk only if the presenter is. Make eye contact, move around, and vary the voice for emphasis.

It is not a good idea to show an outline of the presentation unless the presentation is at least half an hour long, and always be sure to discuss the meaning of the results presented. Reinforcement of the key points in the concluding slide is a must.

Visual elements are critical components in effective oral presentation, especially for engineers. The importance of imagery and how it relates to branding, memory recall, and awareness cannot be underestimated. Using one relevant image can have quite an impact.

As in the research work, during presentation one has to structure the ideas, facts, and data into a logical convincing story using a narrative structure. We are not suggesting fabricating a catching tale, but the ideas, facts, data, and results have to be structured into an interesting story to be told during the presentation. Depending on the "design" skills of the speaker and audience's taste, slides can potentially create different emotions from a slight annoyance to physical sickness, but the worst part is that instead of improving the presentation such slides confuse the audience, distract them, and finally oblige the speaker to explain them rather than being as self-explanatory as possible. A suggested distribution of time for a research presentation is shown in Fig. 9.1.

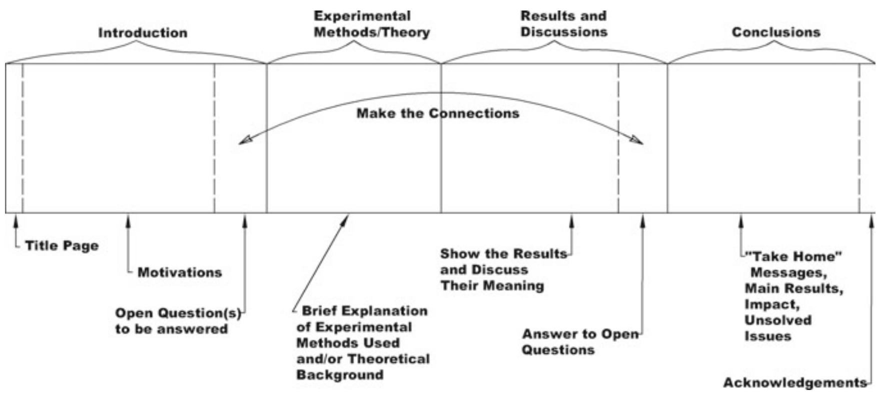

Fig. 9.1 A suggested flow of presentation (in timescale)

9.1.1 Language Choices

The language choices in a technical presentation are dictated by the prior knowledge of the audience. A presentation made to general public naturally uses a significantly different language than a presentation given to colleagues or supervisor.

The employment of analogies, examples, and stories can often be the difference between a good presentation and a great one. Examples and stories help technical information to "come alive" for an audience and most engineering presentations benefit from it. Analogies are powerful speech strategies which anchor a complex technical idea to something that an audience already understands, thereby providing a deeper form of learning and higher amount of retention. While introducing a new term, one must clearly define it to ensure that your audience is on the same page with the presenter. An excellent language strategy that helps engage the audience in the presentation is to preempt where they would have questions about the material. One can verbally acknowledge this to the audience, "So you might be wondering at this point …" This makes the audience feel as though the presenter is relating this talk to their needs and the result will be that they will be more likely to stay engaged.

9.1.2 Delivery

The voice and body language can enhance the messaging in a technical presentation even though content is obviously the most important part. Energy and enthusiasm are definitely key attributes for effective delivery. A presenter should identify few aspects of one's research that one is enthusiastic about and let that come through in the presentation in a seamless fashion. Although it is crucial that the delivery be natural, practicing a lot while incorporating strategies like vocal emphasis or effective movement can help one develop a natural and effective style so that one need not be resigned to just trying to survive the presentations instead of trying to thrive within them. Putting in the time and preparing thoroughly can provide the confidence on the content, and all that remains in to convey the understanding to the audience while allowing one's passion to come out.

A few areas of delivery are especially critical for researchers:

(i) The speed of the presenter's speech should be such that there is enough time for the audience to keep up with the material while processing the usually dense information conveyed, and if required the content should be reduced.
(ii) Pauses are an important delivery tool that allows the audience to absorb the content delivered and emphasize it, while also allowing the presenter to organize thoughts on subsequent content.
(iii) Make specific and sustained eye contact with individual members and be sure to not spend too much time talking to the slides. Again, practice will help to be more comfortable with making eye contact with the audience. Eye contact

also provides feedback as one can ascertain if the audience looks confused and perhaps needs more explanation.

(iv) A researcher is expected to speak to the audience from one's knowledge of the material and not relying on notes which has a negative impact on the presenter's credibility.

9.2 Poster Presentations

A poster presentation is a way of communicating one's research outcomes and understanding of a topic in a short and concise format. One needs to analyze and evaluate information, synthesize ideas, and creatively demonstrate understanding or the findings of your research.

Poster presentations are more personal, interactive, and a well-designed poster that can serve as a permanent record of research accomplishments. However, one needs to plan for the time it takes to compose the text and figures, print the poster well in advance in case of printer errors, and be prepared to discuss the research in depth (and repeatedly) one on one.

Once one has decided what to include, one needs to plan how to present it so as to capture and hold the attention of the viewer. Layout is the first thing to decide: where to place the information and how to divide the space and the placement of headings and graphics, as well as how much space to assign to different elements, are all important considerations. It is important to leave some white space on the poster blank without which it may appear crowded and overwhelming. Spaces are also needed around images and text so as not to detract and overshadow each other. Posters are meant to be a visual presentation and so should use a mix of images, tables, plots, and flowcharts to convey the research outcomes with minimal text. Some additional guidelines in preparing a poster depicting research outcomes are as follows:

(i) Make sure the poster can be read from a distance. A font size over 24 pt is recommended for body text, with titles and headings even larger. Body text should be clearly readable from 5 ft away, and the title from 50 ft away.

(ii) Break up the content into clearly defined sections (introduction, results, discussion, etc.), but keep a logical flow. A reader should not have to jump around the poster to understand the project.

(iii) Poster should be professional and visually appealing. One does not need to be an artist to make a great looking poster, but adding clear and simple pictures, tables, and graphs is a great way to summarize data and to visualize the research.

(iv) Give people a reason to stop at the poster.

(v) Posters should be designed for a general audience, not experts in the field. If the audience wants to know more, they can ask!

In most cases, a researcher is expected to display the poster in a poster presentation session, stand beside the poster, and answer questions from a few viewers at a time in limited time. It is important that the presentation complements the contents on the poster, engages the viewers, and responds to the queries succinctly.

9.3 Presentation Preparation Guidelines

Do not try to sum up the entire research project in one night. For poster presentations, at least a week is needed to compose, review, and print the poster. One needs preparation to answer questions and explain the research to an average person. For oral presentations, one needs to make sure that the slides load properly with all the equations and in the intended fonts. Presentation should be rehearsed several times. Presenting in front of one's research colleagues can help make sure that the data is right, while someone who is not familiar with the research can help identify if it is understandable to a general audience.

As a general guideline, the aim should be to have the slides 95% finished 3 days prior to the talk. A few days should be available to rehearse the talk and change little details in the slides. Writing the ideas down, even those that may seem silly in the beginning, helps generate clear thoughts, formulates ideas into the right logical order, and focuses on the impending job. Often clinching lines get conjured at unexpected times, and so one should be ready to write at any time.

Turn complex tables into simple graphs, condense each slide or section into basic bullet points, and leave complicated jargon and methods for questions. Remember, the poster or slides should not explain every nuance of the research work undertaken. Make sure the audience knows why the work is important. Whether it be developing a new method, testing a novel hypothesis, or answering a long-standing question, the "why" is crucial to fully justifying the need for research in that problem.

An advisable sequence in which the slides may be prepared is described herewith. To start with, prepare the conclusions first with a maximum of three take-home messages, and another three tasks for future research. Next, identify the results to be shown in the form of images if possible. Subsequently, create the slides with methods that the audience need to hear (and see) to decipher how those results were arrived at. Then, create the introduction slides depending on what is known about the audience.

These slides should motivate the audience to hear, describe the necessity of the research, and explain the choice of methods to be described shortly but duly prepared already. Finally, the title slide is to be created. This slide provides the first impression of the presenter and is often underestimated in importance. The presenter is expected to spend the longest time on this slide, and so a lasting impression should be made here.

If everything is written in the slides and nothing extra is added in the speech, why is the talk being given anyway? Bullet points (in phrases) and not more than five in number per slide are easier to read than full paragraphs or sentences. It is best to avoid repetitions: If there is a comparison of two experiments, do not give details for both. Describe the first one elaborately, and while explaining the second one, focus on the disparities with the first one. Otherwise, people may be bored and stop paying attention. Data should not be too detailed and only that section of data should be used which emphasizes the story. Avoid using abbreviations and spend roughly the same amount of time on each slide.

Knowing the background of audience positively impacts the quality and structure of the talk. Amount of introduction needed, details about the technique, and the problem should be catered to the level of understanding of the audience. If attendees are from diverse backgrounds, a basic description of the field of research and importance of research in that field needs to be discussed. However, if most of the audience consists of researchers in the field, one can go straight to the novelty of research topic. Considering the questions which might be raised helps one understand the mindset of the audience and visualize the presentation from that perspective. The presenter should keep in mind that if there is nothing that the audience can relate to, they may not take interest in that presentation.

Chapter 10
Bibliometrics and Research Quality

In any research community the word "Journal" refers to record of a serious, scholarly publication of the findings which are most often peer-reviewed. Journals, nowadays, exist in print and in online (Web-based) formats. These voluminous scientific records called "Journals" are mostly used by research scholars (Ph.D. students)/postgraduate students and nowadays even by undergraduate students in engineering with a sole view to get his/her findings validated by experts in that field of research and consequently share it with the scientific community through publications in a relevant Journal.

At this stage, an individual and management of an academic/research organization faces questions like

- Where should one publish his/her valuable research work?
- Whether degree (Ph.D.) would be evaluated based on quality of publications?
- How can one define quality of publications?
- Do we have any absolute measuring scale for those publications?

There may be many such questions. In order to effectively study the impact of research output in general, let us understand a term called bibliometrics which covers a range of quantitative measures to assess the research impact, which complement the qualitative impact indicators such as research grant obtained, patents granted, and peer review.

The non-exhaustive lists of commonly used bibliometric measures are as follows: (i) Citation counts: the number of times a research output appears in bibliography of other articles and books; (ii) h-index: supposed to measure a researcher's productivity and impact, and is the number of papers (h) published by someone that are cited a minimum of h times; (iii) Journal Impact Factor: depends on the average count of citations per paper appearing in that journal in the preceding 2 years; (iv) CiteScore: the average number of citations in a year by all items published in preceding 3 years in that journal; (v) SCImago Journal Rank: values citations from more "prestigious"

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journals more; and (vi) Source Normalized Impact per Paper (SNIP): quantifies contextual impact of citations based on the total citations in a subject field. In this chapter, the authors try to project few vital concepts related to measurement of quality of publications and some critics associated with it.

These bibliometric measures are of course debatable and the following questions may be justifiably raised:

(i) Is counting citations a good method of measuring "scientific worth"?
(ii) Is it fair to compare individuals across areas based on number of citations?
(iii) Should the size of the relevant "scientific community" be taken into account?
(iv) Is any sort of "ad-hoc" citation measure better than subjectivity?

10.1 Impact Factors: Definition and Usage

Journal impact factor is from Journal Citation Report (JCR), a product of earlier Thomson I.S.I (Institute for Scientific Information), now Clarivate Analytics.[1] The JCR uses quantitative tools to rank, evaluate, categorize, and compare journals. The impact factor is one such tool that measures the frequency of citation of the "average article" in a journal in a specific time period. The impact factor of a journal for a particular year k is expressed as $I(k)$, and is given by

$$I(k) = \frac{k\text{th year citations to articles published in } (k-1)\text{th and } (k-2)\text{th year}}{\text{Number of 'citable' articles published in } (k-1)\text{th and} (k-2)\text{th year}},$$

where "Citable items" refer to articles, reviews, proceedings, or notes, not editorials or letters to the editor.

A major downside of IF is that self-citations are also counted in its calculation. Journal impact factors provide

(i) libraries and researchers with a tool to manage library journal collections, and is also useful as a quantitative evidence for editors and publishers for journal positioning vis-a-vis the competitions.
(ii) an approximation of the prestige of journals as compared to others.

JCR from Clarivate Analytics does not singularly rely on the impact factor, in assessing a journal. The impact factor is to be used only after proper estimation of all the phenomena that possibly affect citation rates. In case of academic promotions or applications, it is sometimes inappropriate to use the impact factor of the published papers of a candidate as the sole or over encompassing criteria for selection. Impact factors are significantly different in case of review articles or method articles, and varies across disciplines. As of today in academics, it is the only quantitative

[1] https://clarivate.com/essays/impact-factor/.

evaluation tool for quality of journals, and so it needs to be used appropriately. Due considerations should be given to factors like amount of review, editorial board, proper categorization of the journal and relevant topic considered in a particular journal category, and variations across disciplines.

10.2 Impact Factors: Downsides and Way Ahead

Few arguments against JIF by Clarivate are listed below:

(i) There is a wide disparity across journals on what constitutes the numerator and the denominator described in Sect. 10.1. Older journals seem to get weighted higher than the ones publishing more articles. There is room for error and inflation by the inclusion of letters to editor, editorials, and book reviews, as research articles, thereby indicating that this criterion may not be absolutely objective [1].

(ii) The impact factor (IF) is possibly a flawed metric and at best is an indicator of the ***visibility index*** or ***cosmetic*** descriptors of research quality. Journals are also influenced by commercial factors and marketing policies of the publishers [2].

(iii) IF does not necessarily reflect the impact of an article, but the number pertains to the journal and is influenced by other articles in it. A low-cited article published in a high IF journal is inappropriately attributed higher value than a well-cited article in a journal that has low IF [3].

(iv) Review articles generally get cited more, and so a journal that publishes more review papers may be inappropriately spiking the IF.

Due to these disparities, certain institutions and publishers have signed DORA, a declaration that rejects IF as a determinant of a researcher's credentials [4]. There are several journals in Engineering category published by some publishers which are not registered with SCI and not having IF, but follows neatly peer double-blind review system with a very good and decent editorial board. Publication of works in good IF journals is not always carried out fairly and there is room for bias arising out of commercialization of IF as has been highlighted in many references. A journal with a good editorial support and a good review system is indeed a good journal but if it is not registered with SCI then it may not have any IF. Researchers/academicians in different areas are pretty aware of which journals in their area of specialization have rigorous peer reviews and command reputation, and so their expertise can be sought for deciding that factor by an academic/research organization.

IF has been accepted almost by all the premier institutions and universities of our country in assessing the quality of publication, quality of degree awarded, for recruiting people in academic/research organization and even for awarding sponsored projects and grants. However, this quantification is not adequate as already explained. Nevertheless, it is the sole existing yardstick to measure performance, and constantly IF calculation is also being improved by introduction of 5 years IF by most of the publishers. Every analysis is subject to some assumptions and flaws, and there is always a scope of improvement in the quality index called IF.

Some positive discussions, research, and even reviews can be set in motion in order to adopt quantitative parameters for selection and appraisal, as well as minimize subjectivity. This field is still open for discussion in the academia. Management can think seriously to set a standard to quantify the research works carried out in the university by critically considering some attributes highlighted above which can better define the quality of research suitable for the university.

10.3 Quality of Research Outcome

In the previous chapters, various attributes and issues relating to methodology of engineering research have been discussed. Next, as an outcome of the discussions provided in succeeding chapters, the authors would like to place a quantitative analysis on the quality of research output, i.e., Ph.D. scholars being produced by the universities. This chapter specifically discusses the assessment of Ph.D. (Engineering) quality by proposing a decision model purely in Indian Context.

Qualities of postgraduate and Ph.D. degree are important parameter in determining effective intellectual manpower directly contributing to teaching standards and R&D related progress in a country. However, it is known that the quality of postgraduate students is assessed using certain metrics but there does not exist any metrics for measuring the quality of Ph.D. recipients. Thus, a debate is presented to investigate the existence of chasm between the current and desired quality of Ph.D.s [5]. This investigation is accomplished by identifying few key parameters that authors feel may influence and streamline a policy regarding quality of the topmost degree conferred by any university.

The Government of India realizes the importance of science and technology that is needed for overall development of the country. India is creating infrastructure in terms of educational centers of excellence, R&D bodies, institutes of national importance, and private organizations covering S&T disciplines upon the recommendations and observations as per "Scientific Policy Resolution of 1958" and the "Technology Policy Resolution of 1983" [6]. But it is of grave concern that the pace of growth of engineering research outcomes has been abysmal [6], due to insufficient support for research and delays caused by bureaucracy.

In last few years, authors have witnessed a positive change in the scientific and technology policy in India in terms of certain new initiatives like Make in India, start-up projects, high-risk high-reward projects started by department of science and technology, and encouraging many bilateral projects between India and other developed countries. But one issue that is still not decided or a matter of concern is the production of quality Ph.D. manpower due to the nonavailability of firm measuring index.

10.3.1 Why Quality Ph.D.s?

According to a 2010 NASSCOM report, India's engineering R&D services industry is growing rapidly [5, 7, 8] and is forecasted to cross $45 billion by 2020. The report reveals that there is a huge need of quality engineers (postgraduate and Ph.D.s) for engineering R&D enterprises in India (for statistics please refer [5]). Again to capture the global revenue share, India needs to produce quality Ph.D. that is globally accepted for employment. The matter of global acceptance of Ph.D.s being produced in a country must be validated by a well-justified mathematical model. In this chapter, authors thus propose a conceptual model for Ph.D. quality evaluation in engineering.

In developed nations, a significant proportion of Ph.D.s take up industry jobs [9], but in India they predominantly become academic professionals. For statistical survey, one may refer [5, 10]. If India has to emerge as an industrially developed country, similar trends as developed countries in west must follow. To accomplish this goal, India must be determined to revamp its production of intellectual property (in terms of patents, high-quality publications, technology transfers, etc.) which in turn can be achieved by producing high-quality Masters and Ph.D.s. Our technical universities or institutions can play a vital role in accelerating the growth of industrial research in India.

Some steps have been initiated in the recent past by the regulatory and policy-formulating bodies in higher and technical education to produce quality Ph.D.s, like setting up of many institutes of national importance and the approval of many private universities that help to produce the intellectual pool. Nonuniformity still remains in the quality of Ph.D.s being conferred across the country. If a significant segment of universities in India do not appropriately deal with the need of high-quality researchers, the dream of India being a knowledge superpower would not be realizable [6].

At this stage authors opine that, due to opening of large number of universities, there is a considerable increase in Ph.D. enrolment attributable to a radical social change regarding career choices of students [6, 9] with limited employability opportunities, thus bringing negative impact to the society despite positive initiatives. The sequence of negative impacts on the society has been explained [5]. If this negative impact is to be compensated, then there must be a policy in place for producing quality Ph.D.s with uniform requirements irrespective of the pedigree of universities.

Few questions are posed here to set a debate between quality and quantity [10] of Ph.D.s produced: (i) proper assessment of Ph.D. quality, (ii) uniformity in assessment of the quality, (iii) quality monitoring, (iv) scientific model for assessment of quality Ph.D., (v) industry collaboration in the Ph.D. problem or work, and (vi) collaboration between universities or institutes across developed and developing countries like India. These questions have helped to identify some of the representative parameters (not exhaustive) for proposing a decision model to assess the quality for Ph.D.s across various institutes (both public and private).

10.3.2 Parameters for Ph.D. Assessment

Until recently, the norms for Ph.D. selection to award in India were entirely as per the respective university/institutes alone. The quality of Ph.D. was entirely dependent on the standard set by the supervisors according to their own merit and expertise. One can find that there was nonuniformity prevailing in deciding the inputs (enrollment) as well as output (Ph.D. awarded) [5]. In 2009, UGC issued mandatory strictures for enrolling and assessing Ph.D.s applicable for both public and private universities which is now followed by the newly set up institutes of national repute also [6]. This is a step forward toward uniformity but it accounts to only input and not the outcome. Next, some key assessment parameters are defined by considering the standards and best practices in different institutes of national importance across India in an attempt to suggest uniform assessment of the Ph.D. in engineering [6, 11].

Generally, every university or institute conducts Ph.D. admission test (written), followed by interviews to assess the suitability of the applicant [6]. Unless the turn out is high [12–14], such a system may turn out to be a damp squib. In [5], it is suggested that a national or international level test must be conducted to address the issue of uniformity and quality, thereby eliminating the bias introduced by autonomy. The obtained rank (or grade) in the test and interview can serve as an assessment parameter.

The students who succeed in the test may submit a synopsis to the department or school on the topic of research or it can be a tentative research plan. Based on assessment of the research plan or synopsis, department should take decision on allocating appropriate supervisor(s) to the candidate. The credentials of the Ph.D. supervisor are of utmost importance and must be highly correlated with the registered topic of the Ph.D. student. Academic performance index (API) can be one of the metrics to decide the credential of the supervisor. It is suggested that a newly joined faculty member may guide Ph.D.s independently after being a co-guide under an experienced faculty for a limited period of time. It is suggested as per the framework of producing quality Ph.D. that a consortium of universities may be formed within a certain geographical proximity to do collaborative research as most of the universities or institutes in India do not have an adequate number of experienced supervisors.

As per the present Ph.D. guidelines of UGC [15], the research scholar is required to enroll in graduate-level courses for at least a semester with a mandatory course of research methodology. A candidate may be asked to register for other courses at the discretion of the supervisor depending on the preparedness and performance in the test. A minimum cumulative grade point average (CGPA) is to be earned to continue in the program. This attribute is definitely a favorable one in terms of assessment of the quality.

The registered topic of Ph.D. is to be finalized after a minimum period of 6 months of sufficient interaction between supervisor and the candidate. Further, the topic of the thesis may be reviewed by the doctoral committee or any expert committee on the subject. It must be emphasized here that committee must find out whether such research topic can be pursued using the existing infrastructure (experimental setup or human resources). If it is not possible, then a suitable locally situated collaborating university may provide an appropriate guide. The doctoral research committee (DRC) is formed by the department of the university or institute, or can be from collaborating organizations.

The publication of partial work of Ph.D. regularly facilitates intermediate assessment by expert reviewers outside the university of the registered Ph.D. student [5]. The grade and the number of publications required for the award of Ph.D. must be uniformly decided across the various disciplines, and the quality of publication would be judged by impact factors and other such attributes. The quality is assessed by the number of publications in (i) SCI(E)-indexed journals or (ii) peer-reviewed (Scopus) journals. An evaluation of the quality of Ph.D. assessment with respect to publications is found in [6], and the measurement of technological growth in India based on SCI-indexed journal is studied in [11]. In view of these literature, this attribute is treated as an influencing parameter for assessment.

A research scholar must present his work in the form of seminar in front of DRC members every 6 months. The DRC will be grading the quality and quantity of the progress. The evaluation and regular assessment of the progress has to be carried out rigorously by the DRC, and used for final Ph.D. quality assessment. At the recommendation of the supervisor(s), DRC members, and the departmental level committee, the scholar can submit Ph.D. thesis which is then sent to neutral reviewers with direct expertise in the field. It is suggested that a quantitative analysis must be sought from the reviewers, in addition to the prevalent subjective assessment and corrections. The guidelines on the selection of reviewers have been discussed in [5].

The Ph.D. defense must be conducted openly in the presence of all the committee members, experts, and students (within and outside the department). It is suggested that certain weight must be accorded toward presentation, results, quality of work, and quality of publications by various members present during the defense. This will help to quantify the quality of the Ph.D. to a great extent. It is worth mentioning at this stage that, in India, such practices are not prevalent and it is only customary to present the defense in front of a select few members.

10.4 Decision Model for Assessment

Presently, in India the quality of Ph.D. produced varies to a large extent due to non-availability of a decision model for quality assessment. A scientific decision model [5] based on analytic hierarchy process (AHP) [16] is adopted to suggest introduction of a prudent decision-making scheme for awarding quality Ph.D. degrees. If this can be achieved, then we can relate quantitatively to a greater extent how these intellectuals will contribute to toward technological development of the country. The indices (or attributes) under consideration are listed below:

(i) Performance in Ph.D. admission test (I1),
(ii) Coursework credits (I2),
(iii) Assessment of half-yearly progress seminars (I3),
(iv) Publication portfolio (I4),
(v) Quantitative assessment by external reviewers (I5), and
(vi) Defense assessment (I6).

AHP accounts for minor inconsistencies in judgment by performing a consistency check prior to proving a decision, as humans are sometimes inconsistent [17]. The steps followed for quality assessment of Ph.D. based on AHP model are as follows:

(i) Aggregate assessment of indices for a Ph.D. scholar on a 10-point scale.
(ii) Inputs are obtained from the subjective opinion of the indices from the DRC, departmental research committee members, and external reviewers to form a pairwise companion matrix (PCM) as explained in [17].
(iii) Compute the eigenvalues and eigenvectors for individual PCM [17] and find out if the consistency test is satisfied, and if not then request the experts to repeat step (b), else those results are removed from the subsequent analysis.
(iv) For aggregation of expert choices, geometric mean method is used in AHP when there is more than one expert at disposal. Next, geometric mean of the choices is determined and inserted in the judgmental matrix.
(v) After obtaining single judgemental matrix eigenvalue, the normalized eigenvector corresponding to maximum eigenvalue is determined. The column sum of the normalized eigenvector is one.
(vi) Priority vector indicates the preference order in grading the quality of Ph.D.
(vii) An equivalent grade is obtained by multiplying the weight of priority vector and the cumulative grade obtained (graded in a 10-point scale) for each assessment attribute.
(viii) To find the final grade or quality of Ph.D. work, the column sum of equivalent scaled grade is computed and further multiplied by a factor of 10.
(ix) If the grade obtained meets the minimum prescribed grade of the university or the national standard, then Ph.D. is awarded or else it is denied until prescribed grade is attained.

10.4.1 Case Study for Student-1

A case study of the assessment scheme for a single student is presented next to further explain this scheme. Let us say that Ph.D. student-1 has obtained grade points as given in Table 10.1 in the selected attributes discussed above. The disclosure of these is withheld from the members participating in decision-making for selecting the priority of the indices.

As a representative case, we choose three experts to provide opinion about the relative ranking of priorities of selected indices, that is, to formulate PCM (Table 10.2).

Table 10.1 Grades obtained in selected indices

Selected indices	Grades obtained (10 point scale)
I1	6
I2	7
I3	8
I4	7.5
I5	6.5
I6	8

Table 10.2 PCM of expert 1

	I1	I2	I3	I4	I5	I6
I1	**1**	0.2	0.2	0.111	0.111	0.143
I2	5	**1**	0.25	0.143	0.125	0.25
I3	5	4	**1**	0.333	0.167	0.333
I4	9	7	3	**1**	0.25	0.5
I5	9	8	6	4	**1**	3
I6	7	4	3	2	0.333	**1**

Consistency check

(i) Expert 1: Largest eigenvalue is $\lambda_{max} = 6.5986$. The consistency index (CI) [5, 17] shows the amount of deviation from the consistency in judgement.

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{6.5986 - 6}{6 - 1} = 0.11972.$$

Next, consistency ratio (CR) is evaluated by dividing the CI by random index (RI) which is as per the order (n) of PCM. The RI for $n = 6$ is found out from [17] to be 1.24. Hence, CR is

$$CR = \frac{CI}{RI} = 0.096.$$

Since CR is 9.6%, we consider it to be consistent judgment (CR below 10% is accepted).

(ii) Expert 2: For any given PCM, let the CR and CI value obtained be

$$CI = 0.0836, \quad CR = \frac{CI}{RI} = 0.0674.$$

CR in this case is 6.74%, and so judgment is consistent.

(iii) Expert 3: For any given PCM, let the CR and CI value obtained are

Table 10.3 Final judgmental matrix and rank of indices

	I1	I2	I3	I4	I5	I6	PV
I1	**1**	0.237	0.322	0.132	0.131	0.131	0.027
I2	4.217	**1**	0.275	0.151	0.138	0.25	0.052
I3	3.107	3.634	**1**	0.237	0.138	0.281	0.082
I4	7.560	6.649	4.217	**1**	0.63	0.793	0.242
I5	8.320	7.269	7.230	1.587	**1**	2.080	0.377
I6	7.652	4	3.557	1.260	0.480	**1**	0.220

Table 10.4 Final judgmental matrix and rank of indices

(PI)	(PV)	(NG)	(IWG)
I5	0.377	$\frac{6}{10} = 0.6$	0.226
I4	0.242	$\frac{7}{10} = 0.7$	0.169
I6	0.220	$\frac{8}{10} = 0.8$	0.176
I3	0.082	$\frac{7.5}{10} = 0.75$	0.062
I2	0.052	$\frac{6.5}{10} = 0.65$	0.034
I1	0.027	$\frac{8}{10} = 0.8$	0.022
Sum	1		0.72

$$CI = 0.12136, \quad CR = \frac{CI}{RI} = 0.0979.$$

CR in this case is 9.79%, and so judgment is consistent.

Geometric mean of individual expert opinions is entered in the final judgmental matrix to rank the indices or prioritized indices (PI), as in Table 10.3.

Based on the indices prioritized via AHP, the final assessment for the student-1 is evaluated. The scheme is shown in Table 10.4, wherein PI is organized in descending order of rank, PV is priority vector or rank, NG is normalized grade, and IWG is indexed weighted grade.

10.4.2 Final Assessment of Ph.D.

Ph.D. quality assessment of Candidate-1 may be performed. Grading evaluation is done by calculating priority-weighted grade point (PWGP) [5] given as

$$P = \left(\sum_{i=1}^{6} (IWG)_i \right) \times 10 = 0.72 \times 10 = 7.2.$$

If P ≥ the desired standard, then Ph.D. is awarded, else it is denied or modification in certain areas identified from the analysis is demanded.

In this chapter, the quality of Ph.D. awarded by the Indian universities/institutes follow certain norms and standards which is mostly university/institute dependent in the present scenario and there exists no decision mechanism for assessing the quality or grading the Ph.D. being awarded. The investigation of the present status of the Ph.D. regulation in India leads us to discuss few crucial issues in developing a decision tool for assessing Ph.D. quality. Some understanding of the quality of one's Ph.D. work is an important part of the goals and objectives of a research methodology course, and so the authors have introduced it here in this chapter.

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