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.

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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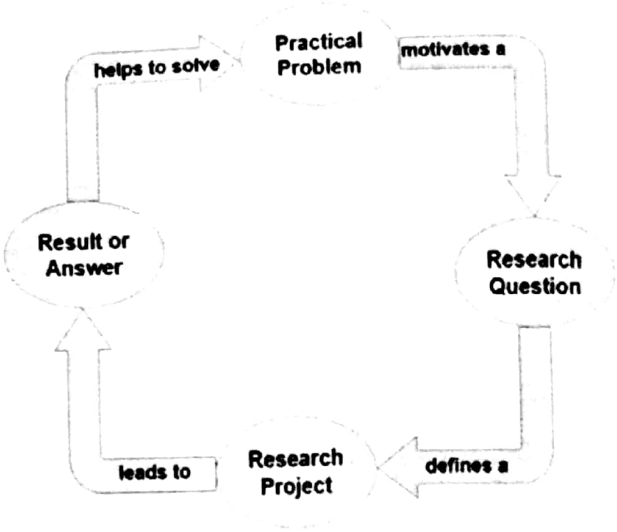

Fig. 1.1 The research flow diagram [1]

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

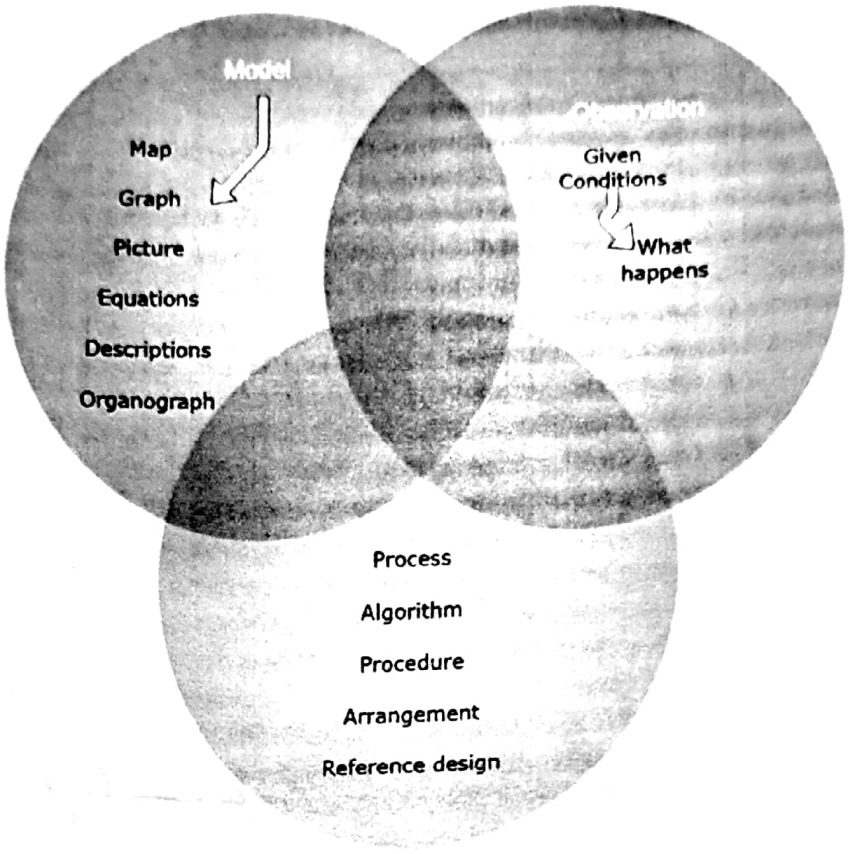

Fig. 1.2 The categories of knowledge in research

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.