2

Research Environments

Read this chapter if you would like to have the following questions addressed:

- *Where do postgraduate research programs fit within the overall research environment?*
- *What are the pressures on the research environment that are significant to postgraduate research?*
- *What are the roles and values of postgraduate research in an academic and commercial sense?*

2.1 Overview

Research is sometimes described as a "*diligent search or enquiry*" with the objective of uncovering facts or information, the merits of which can be assessed by some unbiased mechanism or review.

Although generally associated with scientific study and university environments, research can equally well be undertaken in a garage or workshop, and some of the most notable advances in human history have come from such environments. For example, the Wright brothers (c1900) conducted pioneering research in the field of aviation independently of the mainstream research environments. Thomas Edison (1847-1931) was viewed as a "workshop inventor" far more than as a researcher and, yet, despite negligible schooling, became renowned for his private research. Some of his pioneering work was noted in the field of pure physics, and the subsequently-named "Edison Effect" (1883) became cited in university circles and was the basis of the radio valve.

In this text, however, we are, somewhat unfairly, confining our definition of research to that which is undertaken, by professionals, in some formal professional environment, be it a university, industrial research facility, government research agency or whatever. This is not to demean work outside this arena (which is, indeed, sometimes of greater benefit to society than that conducted within the formal environment), but merely to confine the discussions herein to a range of areas that can be systematically reviewed within a single text.

Postgraduate research is only one small part of the overall professional research environment and, in order to understand the significance of postgraduate research, and the outcomes of that research, one needs to have a good understanding of the total research environment that operates in many countries. There are essentially five major areas in which professional research is conducted:

- University departments (including research centres and institutes)

- Benefactorial research institutes (which are independent of universities but receive funding from charitable or industrial donations, organisations or individuals)

- Government research agencies (defence, aerospace, agricultural, etc.)

- Hybrid research organisations and institutes (which are an amalgam of the other elements, working in cooperation)

- Industry research facilities.

Traditionalists tend to view research in all areas, except industrial, as an altruistic search for truth, which is unsullied by financial concerns. However, the reality is that research in the modern world, regardless of where it is conducted, is subject to a range of input and output parameters in the same way as any other business activity.

All research organisations have budgetary constraints and all divide funds between a range of recurrent and capital expenses, overheads and a number of research projects. Within such a budget, the financial inputs to a specific research program can therefore include:

- Higher-level salaries (professional researchers and research leaders)

- Lower-level salaries (postgraduate researchers and research assistants)

- Capital expenditure (buildings, infrastructure, large-scale equipment or software, etc.)

- Recurrent expenses (rental, cleaning, etc.)

- Consumable items (stationery, etc.)
- Travel and accommodation.

All of these research inputs are readily measurable, regardless of whether they occur within a university system or an industrial research facility.

However, regardless of the level at which it has been conducted, the problem with research is that the outputs tend to be somewhat intangible because they are knowledge-based. Some typical parameters that are used to assess the outputs from a research project include:

- Patents (i.e., protected knowledge that, given further investment, can potentially be converted into a financial return)
- Successful peer reviews of knowledge (i.e., publications that have been refereed by knowledgeable outsiders and deemed to have merit)
- Books (i.e., texts that contain core knowledge derived from research and which can pass that knowledge on to future generations)
- Royalties (i.e., monies that can be derived from those willing to use and pay for the knowledge that has been generated)
- Consultancies (i.e., monies that can be paid for the use of individuals who have increased their knowledge as a result of research).

In addition to the above outputs, universities and research institutions are often measured, in terms of output success, by the amount of funding that they can acquire in a competitive environment - either from government granting agencies or industry groups.

Success in acquiring competitive funding is, in turn, generally dependent upon:

- Peer reviews of grant applications
- The quality of previously conducted research
- The research standing of the research organisation and its researchers.

Ironically, therefore, in the research environment, the funds that are competitively acquired as "inputs" to research are also used as a measure of research output because they relate to a historical profile of success.

Thus far, we have only examined the basic inputs and outputs for research. Another important factor that needs to be considered and recognised is the time-span over which inputs are translated into outputs. In research terms, this can be months, years, decades or even centuries, depending upon the research that is conducted. If one considers that many industries, involved in the generation of products, expect to see human resource inputs translated into outputs within:

- Seconds or minutes (by production workers)
- Hours (by technical or trade workers)
- Days or weeks (by professional employees),

then it is not difficult to understand why research is sometimes misperceived, by industry, as an indulgence - even though it may form the very basis of products or services that can generate profits.

A further complication, in terms of the way in which research is perceived (particularly by industry), is the nature of the research process which can involve days, weeks or months of reading, study and analysis - none of which may ever be directly translated into

outputs but all of which may increase the knowledge level of the researcher so that valuable outputs may be produced at a later stage.

Understanding the rate, at which inputs are translated into outputs, is often of critical importance to postgraduate researchers involved in collaborations with industry because it ultimately reflects upon the perceptions that industry has of the researcher or the university. In Chapter 6 of this text, we will examine the conflicts and complications that arise from such differing expectations and the measures that postgraduate research students can use to address them.

In general, postgraduate research students are involved in all sectors of the professional research environment, from the traditional university to the industrial environment. However, the demands upon the student can vary markedly, depending upon:

- The environment in which the research is conducted
- The input and output measures that are used to monitor the effectiveness of the environment in which the research is conducted
- The number of different organisations collaborating on a research program.

Therefore, one needs to have a clear understanding of why differing demands can arise and how conflicts can be analysed and diffused when they arise.

A good starting point in understanding the role of the postgraduate researcher is to understand the financial value of research in the modern world. An often-cited industry ratio, which defines the expenditure on research, relative to development, relative to commercialisation, is called the 1:10:100 ratio. Simply, the ratio suggests that for every dollar expended upon research, ten dollars need to be expended upon development and one hundred dollars expended upon commercialisation in order to convert an embryonic

research idea into a commercial product. In other words, despite the fact that research is the starting point for a product or service (and despite the fact that a product or service may only arise because of research), its relative contribution is small.

Despite the claims that the world has moved towards being a "knowledge-based" society, many large organisations still tend to derive their profits from a small range of ideas (i.e., research, inventions or knowledge) that are used to generate businesses that repetitively generate large volumes of products. As an example of the 1:10:100 ratio, if a pharmaceutical company had 100 employees, solely paid to undertake research (and, if the 1:10:100 ratio was translated solely into staffing), then it would require another 1000 staff involved in development and 10,000 staff involved in commercialisation to make the developed products viable.

Of course there are variations on the 1:10:100 principle, with some companies trading more on knowledge output than repetitive product outputs. Overall, however, one needs to consider that research, in the classical sense, is no longer an end in itself. It is only one part of the broader chain of human input that is required to drive a developed society. One could equally argue that there is as much, or more, human knowledge now required to take a research idea and convert it into a commercial product than there is in the original research. Hence, in endeavouring to understand the "diligent search" that is embodied in the classical idea of research, it is also important to recognise the "diligent search" that is required in the development and commercialisation stages of an overall product development cycle - whether it be for pharmaceuticals, automotive components or aircraft.

In Chapter 10 of this text, we will examine the issue of a "broader context" for postgraduate research. This is a view that needs to be developed by the modern postgraduate researcher, in cognisance of the changing environment in which the "diligent search" is conducted, and the relative contribution of research to other knowledge inputs involved in commercialisation of ideas. In this chapter, however, the objective is to provide a clearer image of the various environments in which research is conducted.

2.2 Pure and Applied Research

In Section 2.1 it was noted that the concept of research as a "diligent search" needs to be broadened in line with the increasing complexity of the modern world. Although one could describe all research as being a "diligent search", modern research is often divided into a number of categories which, herein, are simply divided into two categories:

- Pure / Fundamental / Basic Research
- Applied / Pre-Competitive Research.

As is the case with many definitions, the boundaries between the different types of research are unclear and often semantic in nature. From a classical perspective, one could define pure or basic research as being a quest for knowledge, the application of which may be undefined at the time of conduct. Conversely, applied research could be defined as being a quest to refine and extend existing knowledge for some utilitarian purpose.

From an economic perspective, one could simply define pure or basic research as being research that is undertaken with no financial objectives. Conversely, applied or pre-competitive research could be defined as research that is conducted in an environment in which the probability of a successful financial outcome has been assessed.

The issue facing many governments, in the developed world, is the ratio of money that should be expended on pure research, as opposed to applied research. The conflicting arguments generally put forward are that:

- Without pure/basic research, knowledge generation in society ceases and the future advancement of that society is impeded
- Pure research often yields no financial outcomes for decades or even centuries - therefore, public monies are

better expended on research that can yield results for the current generation.

These arguments are further complicated by the fact that developing countries focus on applied research, in order to obtain rapid economic growth, and utilise pure research outcomes generated in other countries as the basis of their applied research. This means that developed countries are left to fund pure research while, at the same time, grappling with economic and employment problems arising from higher levels of industrial competitiveness in developing countries. Therefore, many developed countries experience significant pressure from industry groups to provide a shift in the traditional research funding arrangements from pure to applied research.

A further complication in the definitions and the division of funding between pure and applied research also arises because of the changing nature of knowledge and its value. For example, it may be that some applied advancement in human-computer interaction may be of far greater significance to a society than an advancement in theoretical physics. Research into automotive safety systems may save more lives than pure research into the treatment of medical diseases. Applied research and development into minimising the cost of sewerage pipes and septic systems may provide greater humanitarian benefits to an undeveloped country than advances in immunology, and so on.

Postgraduate research programs can be conducted through the spectrum of activities, from pure research into a core science, through to applied research in marketing or business development. Despite the broad spread of postgraduate research areas, in each research program, it is incumbent upon the research student to present an argument that clearly defines the contributions of the work at hand. Further, the researcher, working in an applied research environment, must also understand that potential examiners may be predisposed to traditional concepts and values associated with pure research. The onus then is upon the postgraduate research student to convince an examiner that a contribution has been made by the research, through

emphasis of the broader issues that flow through from the research program - perhaps through meaningful comparisons with results that may have been achieved by other pure researchers in similar fields.

The converse problem also arises when a piece of pure research work is submitted to an examiner that is predisposed to applied research. In this instance, the problem tends to be that a reviewer considers an advancement in a theoretical area to be trivial because of its lack of applicability in, say, a commercial arena. In such an environment, the postgraduate student's line of argument, in terms of contributions, can be forcefully made using examples where similar work has been developed through further applied work.

Needless to say, there will be instances where postgraduate research in a pure field can only be legitimately justified in terms of adding to knowledge, and there will be other instances where work in an applied field can only be legitimately justified on the basis that the knowledge contributes to a meaningful development that can be assessed in commercial terms. The important point here is that the modern postgraduate research student, whether operating at Master's or Doctoral level, must consider not only the total environment of pure and applied research but, additionally, the natural biases that may exist within the minds of research peers and potential examiners.

Therefore, while the concept of pure or applied research is of little consequence in terms of a broad-minded reflection upon research and its value to society, it is critically important during the early phases of a research program. All postgraduate research students need to assess:

- Where a research program will fit into the research spectrum
- The types of peers that operate in the field and their natural biases

- How the research program needs to be structured, and how arguments for the contributions of the work can be made to satisfy the natural propensities of peer reviewers

- If the research program is to go against traditional thinking or peer methods, will the program, researcher's arguments and results have sufficient inertia to sway general opinion on the subject?

While many traditionalists may disapprove of the notion of conducting one's research in terms of how it may be assessed by peers, this is a part of the research learning process. It is also an important part of the process of meaningful change in an arena of research.

The achievement of peer acceptance gives researchers sufficient credibility to further push the boundaries of a particular field of endeavour. However, the starting point for pushing the boundaries is a clear and unequivocal understanding of where these boundaries lie and why they are in place in the first instance.

2.3 Research as Part of the University System

Modern universities have generally evolved from traditional learning environments in Europe that emerged over one millennium ago, with the more renowned universities, such as Oxford and Cambridge, having roots some seven centuries old. However, since the origins of tertiary education, there have been dramatic changes in the societies in which such establishments function. The most significant changes of relevance have included:

- The increase in societal education levels
- The increase in participation rates in tertiary education (most notably during the course of the 20th Century).

In developed countries, it is not uncommon for more than half of a populace to progress from secondary to tertiary education and, within the next century, it is likely that tertiary education will be an integral part of the overall education system for all members of a developed society.

The increasing levels of education in society, and participation in universities, have led to the occurrence of two interesting, and related, phenomena:

- A large increase in the amount of money invested in tertiary education since the 19th Century
- An increase in scrutiny/accountability levels associated with university activities.

The latter phenomenon is particularly significant in terms of research, because of its many intangible traits, and has led to the introduction of university performance factors, such as those discussed in Section 2.1. Undergraduate course-work activities, on the other hand, produce tangible products (i.e., accountants, doctors, engineers, veterinarians, dentists, etc.) that society can readily use to measure the effectiveness of the system. However, adding to the need for accountability in

research is the fact that universities (and tertiary institutions, in general) are a highly costly component within any society's educational system and can consume in the order of one tenth of a developed nation's entire taxation revenue (or the equivalent in fees where universities are privately funded).

Universities in all developed countries are therefore all subject to financial constraints in the same manner as any other government or industrial sector of a society. Increasingly, universities, around the world, are also being scrutinised in terms of their ability to convert financial inputs into research outputs that society can associate with some tangible meaning.

The inputs to a university are generally composed of student tuition fees, government funding and competitive grants, industry grants, benefactorial donations, and so on. Within a university, some of these funds are centrally expended upon capital infrastructure (e.g., libraries, laboratories), recurrent staff costs, etc. The remaining funds are generally devolved to individual departments, research centres or research institutes which, in turn, again divide their funds between central costs and those associated with particular activities, staff or projects.

Regardless of whether a university is a government ("body politic") or privately-funded (profit-oriented or benefactorial) institution, measures are generally put into place to ensure that some form of accountability exists between the inputs to, and outputs from, the university. These accountability measures are then devolved to individual cost centres (departments, etc.) and the fed-back results aggregated to provide a profile of a university's performance. In as much as most of the inputs to a university or department are financial, it is perhaps more worthwhile to examine some of the outputs that can provide a measure of a university's performance. These can include:

- Number of undergraduate completions
- Number of postgraduate completions

- Number of patents
- Number of research citations
- Number of internationally eminent staff (e.g., Nobel Prize winners, Fields Medalists, etc.)
- Number of text books, journal and conference publications
- Overall pass rates
- Undergraduate/postgraduate student satisfaction.

It may appear trite to measure a scholastic institution in terms of numerical outputs but there is a general recognition that some form of metered feedback is more likely to lead to better development of that institution than a simple open-ended commitment to "excellence". The difficulty is that, particularly in terms of research, the outputs that need to be measured are often complex and multi-dimensional - some outputs are interrelated or contradictory. For example, there is generally a correlation between the number of postgraduate completions and the number of publications in a university because postgraduate students tend to publish their work to achieve a peer review. On the other hand, there may be little correlation between pass-rates and student satisfaction because more rigorous or demanding teaching methods are employed to increase student understanding.

Nevertheless, leaving aside the vagaries of the parameters by which universities can be assessed, in terms of converting inputs into outputs, the typical university input/output list indicates that postgraduate research students are generally of major significance because they are:

- Contributors to university outputs

- Paying clients (inputs) whose needs have to be addressed during the course of a postgraduate research program.

The position of postgraduate research students, within the university environment, is therefore somewhat complex because despite being contributors and clients of the university, they are also there to be assessed on their ability to learn the processes of research. This may involve work, scrutiny or tasks with which they disagree and can lead to conflicts between their needs, as paying clients, and the universities' needs to ensure academic excellence. In a sense, the resolution of conflicts in such areas ultimately depends on a recognition, by both parties, of the complexities of the university/postgraduate student relationship.

It is also particularly important to note that postgraduate students tend to form the engine of a university's research efforts. With the exception of large, traditional and/or renowned universities, many other institutions could not sustain any meaningful research effort without postgraduate students. The reasons for this are relatively straightforward and primarily stem from the difficulty involved in funding staff, whose sole purpose is to conduct research, rather than to teach or supervise research students. Secondly, because of their typical turnover rate (two to three years), postgraduate students tend to provide a highly-motivated, unencumbered, fresh input to research programs which can generally not be sustained by ongoing research staff over very long periods of employment.

In Section 2.1, it was noted that there were essentially five major areas in which professional research could be conducted, ranging from the traditional university environment, through to an industrial research arena. However, at this point, it is valuable for to further explore the typical research profile that might be associated with a university's postgraduate research efforts. To this end, one could say that postgraduate research, within the university system, could be conducted in:

- Teaching departments or faculties (i.e., medicine, history, archaeology, engineering, etc.)

- Specialist research centres or institutes (e.g., a physics research institute within a university)

- Government research facilities (in which the university or its staff have established cooperative or joint-venture projects)

- Cooperative research facilities established by a university (e.g., a medical research institute established by a university in conjunction with a hospital, or a semiconductor research institute established in collaboration with a large corporation)

- Industry research facilities (as part of projects associated with industry collaborations)

In each of these areas, a university has the ability to deploy a range of human resources to the research projects at hand. These include:

(i) Academic staff who normally engage in both teaching and research activities

(ii) Specialist research staff (e.g., research fellows, postdoctoral researchers, etc.), whose sole function is the conduct of research

(iii) Postgraduate research students, who undertake a research degree at a Master's or Doctoral level, in order to learn the research process and, at the same time, complete a research exercise which contributes to a research project

(iv) Postgraduate course-work students, who normally undertake class-room studies, but are required to undertake a research project in order to satisfy "minor thesis" requirements

(v) Undergraduate course-work students, who may take research projects in fulfilment of senior year thesis requirements.

It is important to note that the people involved in projects, at levels (iii) - (v) are all amateur researchers, whose principal objective is to learn the "skills of trade" - in other words, the ability to systematically conduct an investigation and have work subjected to peer review. The project that is allocated to those individuals is the mechanism by which they can focus their attention to learning the processes of research and is secondary to the principal learning objective.

Of course, in terms of postgraduate research, it would be altogether simplistic to dismiss the project as though it was of minor significance because of the environment in which modern universities need to function. This environment requires that the university satisfy:

- University output performance requirements
- Client (e.g., collaborative partner) concerns and requirements
- Departmental, research centre or institutional requirements.

The dual requirements, of providing an environment in which students can learn the processes of research, and providing project outcomes that satisfy the university, department or collaborative partners, can often cause considerable conflict and confusion in the minds of research students and research supervisors.

Adding to the elements that cause conflict and confusion is the fact that an integral part of postgraduate research is the need for a student to make some form of tangible contribution to knowledge in order to convince peers of the level of understanding of research process that has been achieved. The tangible contribution to

knowledge is often embedded in the conduct of projects that are allocated to students and, hence, there needs to be some demarcation between what constitutes research (in terms of the student's learning process) and what constitutes development (in terms of the actual conduct of a project). Moreover, a good deal of learning is also derived from "doing" and:

- The conduct of a research project
- The development work within a research project
- Practical implementation

may all contribute towards the student's knowledge of important factors in the research process (in general) and to knowledge in the specific field in which research is undertaken. In general, there are seldom clear demarcations between the university's interests (as a corporate entity) and the student's interests (as a scholar, a contributor and a client).

It is relatively easy to cite scholastic and academic excellence as being the only issue in any postgraduate research. However, the reality is that the modern university environment has now become complex, in terms of its operation, and there has to be a detailed student understanding of that environment, as well as a university understanding of the needs of the student (as a scholar and client) in order to resolve the inevitable conflicts and difficulties that will arise.

2.4 Levels of Postgraduate Research

In this text, the view that has been adopted is that, in principle, there is only one level of postgraduate research - and that is, a level in which a student learns:

- How to undertake an unbiased, systematic investigation
- The mechanisms by which any biases and/or personal prejudices can be identified and eliminated from the investigation through appropriate experimentation and/or analysis
- How to evaluate the benefits and shortcomings of the investigation
- How to accurately convey the outcomes of an investigation to peers and how to interpret and respond to their feedback.

Unfortunately, the view that has emerged within many universities is that different levels of postgraduate research warrant different levels of investigative quality. Herein, we dismiss that view outright and examine the different levels of research only in terms of the knowledge contributions that need to be made by research students and the expectations that examiners may have of the submitted work.

Essentially, there are several categories of research that can be considered:

(i) Doctoral level research work (either by research or publication - this is generally referred to as an "earned" Doctorate)

(ii) Doctoral level research work (by minor thesis, as part of a larger program of study - a professional Doctorate)

(iii) Master's level research work (by thesis or publication)

(iv) Master's level research work (by minor thesis, as part of a larger program of study).

Within a given university, there may be other sub-divisions or minor variations on the above categories. Moreover, the expectations, associated with the sorts of studies categorised in (ii) and (iv) also tend to be university dependent, rather than universally accepted criteria. However, in this text, the adopted view is that, for Doctoral studies, in which the only assessment criterion is the presented research:

> *The researcher needs to demonstrate a significant contribution of knowledge to the field of endeavour, through a clearly-defined investigation, analysis and peer review*

whereas, for Master's level studies, in which the only assessment criterion is the presented research:

> *The researcher needs to demonstrate a mastery in a given field of endeavour, through a clearly-defined investigation, analysis and peer review.*

Ultimately, both levels of study depend upon a subjective peer assessment of qualitative terms such as *significant*, *considerable*, *substantial*, *mastery*, and so on. While each university provides more specific definitions for its research programs, the research student, the research supervisors, and the peer reviewers are, ultimately, left to interpret the qualitative terms within the given definitions.

A contribution, which may appear significant to a research student and the research supervisors, may appear insignificant to a peer reviewer or examiner. Work which, in the opinions of the research student or supervisors, is deemed to demonstrate a mastery of a subject, may appear inadequate to a peer reviewer or examiner. The preceding statements, in this paragraph, may appear to be a reflection of the obvious but they strike at the very core of what is to be achieved in postgraduate research programs.

Previously, it has been noted that the principal objective for a research student is to learn about the process of conducting an unbiased and systematic investigation. However, in the definitions that have been adopted above (and variations of which are commonplace in many universities) another key factor that needs to be recognised is the requirement to *demonstrate*. In other words, not only does a postgraduate research student need to learn about the techniques within an unprejudiced process of discovery but, additionally, to *demonstrate*, to a peer (that, for the purposes of presentation, it always needs to be assumed, is prejudiced) the extent and scope of the presented work.

As an amateur, and a research apprentice, the research student can only resort to impartial mechanisms and evidence to convince a peer reviewer of the worth of a piece of research. As an expert, the peer reviewer may use personal experiences and biases to question the worth of the research. Hence, at each level of research, the research student needs to use the research learning process as a means of presenting an argument to a "*devil's advocate*". In each case, a research student needs to adopt the position that the peer reviewer will hold a diametrically-opposed view to that of the research student and will use prejudices to test the validity of presented arguments.

It then follows that, regardless of whether a research program is conducted for the purposes of a minor thesis (at Master's level) or as the major thesis of a Doctoral research program, the quality of the investigative work must remain the same. The strength and impartiality of the presented arguments must remain the same. The difference, between one level of research and another is therefore, fundamentally, in the sorts of arguments that need to be presented and in the manner in which they need to be presented, in order to demonstrate a subject mastery or a contribution of knowledge. In simple terms, a minor thesis, presented at Master's level, is not intended to be a poor quality Doctoral submission and neither is a Doctoral submission intended to be a high quality Master's level submission.

The above points appear to be trivial but they do need to be considered very carefully in order to prevent Doctoral research students from presenting lengthy Master's theses in consideration of their work or, conversely, to prevent Master's students from presenting abbreviated Doctoral theses in consideration of their work. Although many universities do allow mid-stream interchanges between Master's level and Doctoral level research programs, one needs to understand that what needs to be demonstrated in each instance may be quite different.