SCIENCE AND ENGINEERING RESEARCH: ASSESSMENT METHODS

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Abstract-**The evaluation of research and indeed any aspect of science and engineering is a complex process. Engineering research encompasses a wide range of creative, theoretical and practical activities involving many communities within a country and beyond. Such diversity, both in the communities of interest that science and engineering serves, and in the character of the research itself, poses a number of challenges to the assessment of excellence.**

All those responsible for the funding of public research, across the globe, are re-examining the methods traditionally used to assess research quality. Government funded research agencies are increasingly under pressure to justify their share of tax- payers' money.

Meanwhile, research, particularly engineering research, is becoming increasingly more interdisciplinary, carried out by a wider set of practitioners, whose interests include simple wealth creation and academic excellence. It is in this complex, dynamic environment that the essential differences between science and engineering are sometimes overlooked.

This paper therefore presents in simple terms what we consider to be general principles for the assessment of excellence in science and engineering research, adaptable to different needs.

I INTRODUCTION

The bridge between science and its exploitation through technology to enhance wealth creation and quality of life is engineering research. It embraces a balanced portfolio of capabilities and activities, which serve the needs of many different communities including small firms, large firms, government bodies, academia and other interest groups. Research groups achieve excellence through a combination of high quality disciplinary and interdisciplinary work. To reward and encourage productive engineering research, quality assessment mechanisms need to consider comprehensively the ways in which research is taken forward and made useful to the different user groups.

Excellence in engineering is identified by five characteristics - including, but not limited to, the quality of published research findings - and that it is in the combination of these characteristics that excellence in engineering is to be found. Ideally the assessment methods should be applicable to a research group, programme or department in order to capture both single discipline and interdisciplinary research activities.

The paper begins with some essential definitions and moves on to state what is understood by research excellence in relation to science and engineering whether activities are carried out by small research teams or larger research groups working on a number of projects. These definitions provide a universal foundation on which to base the assessment and the determination of excellence. Following an account of current methods, an outline assessment process is described which can be developed to provide a robust and comprehensive methodology for assessment of excellence in science and engineering research.

II RELATIONSHIPS BETWEEN ENGINEERING, SCIENCE AND TECHNOLOGY

The nature of the relationship between engineering and science continues to be debated. From an engineering perspective,[1] science is viewed as knowledge that results from use of a scientific method to further understanding. In contrast, engineering not only seeks understanding but also creates devices and systems to meet human needs.

From this perspective, engineering impacts on society through the creative application of science.[1] Engineering is the process of assembling knowledge and experience to create machines, devices, systems, structures, processes and products to meet human needs and to improve and extend those previously created. Engineering research seeks fundamental understanding to improve the engineering process. The ultimate output of engineering research is the development of new or improved techniques and processes for creating machines and devices etc., with better specifications and/or lower costs, and the machines and devices etc. themselves - in short, technology.

Science is the knowledge and understanding of the character and behavior of everything that exists, be it natural or manmade. This knowledge and understanding is obtained through observation and experiment - the scientific method.

M. Iskander (ed.), Innovations in E-learning, Instruction Technology, Assessment, and Engineering Education, 163–167.

Science does not have practical use as a necessary objective - whereas engineering always does. The output of science is also, frequently, technology. Scientific knowledge and the scientific method are basic elements of engineering research.[2]

Basic scientific research provides us with information, which, though previously unknown, only offers hints of the future. It is the engineer who can take these theories and basic building blocks and from them create technology. Technology comes from employing and manipulating science into concepts, processes and devices. These in turn can be used to make our life or work more efficient, convenient and powerful.

So it is technology, as an outgrowth of science, which fuels the industrial engine. And it is engineers, not scientists, who make technology happen. An essential aspect of engineering is concerned with impact on society through wealth creation and improvement to the quality of life. High quality engineering research whilst producing scientific knowledge also produces a complex set of outputs that address particular social and economic needs. These are found in the development of the networks and processes that constitute the means of exploitation. These dimensions distinguish engineering research from scientific research.

In summary, successful engineering research will produce outputs -and processes that are relatively difficult to separate from the context of application in industry, government or any other section of society. The challenge for policymakers is to develop quality assessment mechanisms that measure the broad range of engineering research outputs that are relevant to a number of different user communities.

III CHARACTERISTICS OF EXCELLENCE IN SCIENCE/ENGINEERING RESEARCH

From an engineering perspective, there are several elements, which need to be considered when determining the overall measure of excellence in the research process.

Five characteristics of excellence in engineering research are identified:-

*A Strategy***:** directing the focus and scope of research activities. Strategic planning and resource management determines the eventual impact of engineering research; how the work is taken forward to its selected community or communities of interest; and the programme for developing excellence in the other four characteristics of engineering excellence.

*B Science-base research***:** focusing on the creation of new scientific knowledge needed to underpin novel and innovative engineering devices and processes. Here attention is normally focused on single-disciplinary problems which are set and solved by the largely academic community, and are communicated through institutional channels [3] (e.g. publications) and driven by curiosity and the desire to create new insights. A country with an engineering base that is weak in the production of science-base research will be relatively ill placed to develop the radical innovations that spring from new scientific knowledge.

*C Engineering-base research***:** impacting on society through the enhancement of wealth creation and quality of life by producing knowledge in the context of application in non-academic and academic activities which may be single or interdisciplinary in nature.

This type of research manifests itself ultimately through people-centered activities, (for example, the provision of advice, the appearance of new products, processes, start-up companies and collaborative networks) and scholarship. A lack of engineering-base research will fundamentally undermine the strength of the engineering research base, not simply in the application of new knowledge but also in the production of new research.

D Scholarship: high-standard, independent, science-base and engineering-base research, free of financial and political control, to promote the well-being of society. Scholarship pervades academia but is separated out here to identify one key aspect, namely independence. There is need to protect those interests that are not served by wealth creation alone (safety, environmental impact, academic freedom) and to safeguard the integrity of engineering as an independent and trusted source of knowledge and advice.

E Vitality and Sustainability: the vitality of the research group is a function of the group size and strength, quality of the researchers, interdisciplinary activity and the essential supporting infrastructure, such as equipment, administrative and technical support.

Collaborative capabilities and involvement in professional networks that cross-institutional and organizational boundaries are also essential to the vitality of the group. Sustainability requires development and maintenance of capabilities that support continued learning and participation in activities associated with diffusion of knowledge and public understanding.

Continued learning includes research and support staff training (and its continued refreshment) and career development. Sustaining research excellence requires that the core research staff have secure positions to allow a long-term focus on research projects and that the diverse backgrounds of society are represented so that the different individual insights can contribute to innovative solutions to a wide range of problems.

An engineering research group that suffers from a lack of vitality and sustainability will not have the strength to collaborate with its user communities and will therefore not be able to develop the usefulness and relevance of its technologies.