

Engineering Research in Irish Economic Development

December 2010

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The Irish Academy of Engineering

The Irish Academy of Engineering is an all-Ireland body with the mission to analyse and report on important national issues where the engineering profession can make a unique contribution to economic, social and technological development.

Its members are Irish engineers of distinction, drawn from a wide range of disciplines, and membership currently stands at approximately 120.

Drawing on the experiences and knowledge of its members, the Academy works to facilitate communication and dialogue on engineering-related matters. It publishes reports and analyses, some jointly with other learned and professional bodies.

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Acknowledgement

The Irish Academy of Engineering gratefully acknowledges the assistance of Intel in organising a seminar on 'Engineers, Entrepreneurship and Wealth Creation', at which the issues raised in this paper were considered.

1. SUMMARY & KEY RECOMMENDATIONS

Context

The primary objectives of the Irish Academy of Engineering in producing this paper are to:

- Facilitate more effective commercialisation of Engineering Research with a view to job creation.
- Highlight the importance of Applied Engineering Research to the Irish economy.
- Promote the idea that academically based Engineering Research should be directly linked to the development aims of industry in Ireland.
- Encourage stronger links between Irish Schools of Engineering, with a view to avoiding duplication and fragmentation of research programmes, and to developing critical mass in key research areas.
- Focus on the need to modify and develop engineering education and research to reflect the current and future needs of the economy, by fostering a more innovative and entrepreneurial culture among high-calibre, well-qualified engineers.

Key recommendations

Engineering Research

- Engineering Research in Irish universities should be directly related to innovation in industry in Ireland.
- The structures and procedures governing Engineering Research should foster greater collaboration between universities, research institutes and institutes of technology, through the establishment of **Engineering Research Platforms** in selected topics of national importance, with a focus on industrial innovation.
- Universities should work together in reviewing intellectual property procedures, in order to optimise collaboration with industry and to facilitate start-ups from research.
- Universities should expand the role of their innovation centres so that they reach inwards into undergraduate and postgraduate research laboratories, providing encouragement and business advice to potential entrepreneurs, and reach outwards to secure support from high-tech personnel in Irish industry.
- Each university should establish a **Entrepreneur-in-Residence** position in its engineering school; this adjunct appointee would have a broad responsibility in stimulating and supporting the development of an entrepreneurial spirit across the university.

- Irish universities should pool intellectual capital to achieve the critical mass required both for enterprise development and to attract venture capital.

Engineering Education

- Engineering Schools should take responsibility for the education of wealth-creating graduates, through the development and inclusion of taught modules in entrepreneurship in both undergraduate and PhD curricula, as well as industry-related projects for undergraduate students.
- Engineers from industry should be involved in undergraduate and postgraduate teaching and research supervision, and appointed to adjunct positions within the Engineering Schools.
- An engineering doctorate (**DEng**) should be established for engineering researchers employed in industry.
- The engineering undergraduate curricula should be modified to encourage and support students taking a professional experience year for a supervised industrial placement, with academic recognition.
- Engineering Schools should continue to seek to attract more high-calibre foreign students to their masters and PhD programmes.

Research Funding Agencies

- A single national agency for the funding of science and Engineering Research should be established.
- The statutes of SFI should be modified to include an applied research component in its funding mandate.
- Greater recognition in funding criteria and assessment procedures should be given to Engineering Research projects with direct industrial relevance.

Irish Industry

- Arrangements should be made for industries from related sectors to support university-based Engineering Research with advice and funding that is eligible for tax relief.
- An ethos of greater industrial involvement with university Engineering Schools should be developed in teaching and research, through membership of industry boards in Engineering Schools/Departments, and through the employment of students as engineering interns.

2. INTRODUCTION

The current global recession is the most severe since the 'Great Depression' of the 1930s, with the world's leading economies facing years of adjustment to reduce public debt. The International Monetary Fund estimates that debt adjustment in Europe could take up to 15 years, which will make economic recovery slow and painful. In Ireland, the recession has been exacerbated by the collapse of an enormous property bubble requiring a rescue of the banking sector, which has further increased public indebtedness.

Over the past two decades, the success of the Irish economy has depended on annual exports of approximately 80% of GDP. These exports, mainly to the US and Europe, came principally from high-tech, multinational companies who had invested here: for example, chemicals including medical and pharmaceutical products accounted for 51% of exports in 2008.

The future, however, is likely to be different and certainly far more challenging. At a time when we appear to have lost our competitive edge, our previously successful economic model of low corporate tax rates, coupled with an educated workforce, is being replicated by many emerging economies. In developing a national strategy to support our recovery from the current recession, the Academy believes that there is no alternative to growth based on industrial enterprise, and that this can be best achieved through innovative and advanced technologies. Ireland has certainly been successful in attracting high-tech industries. However, with a few exceptions, their main activities have been in manufacturing rather than in research, which is primarily retained in the multinational company's home country. Manufacturing industry is always vulnerable to relocation to lower-cost countries. Furthermore, with only 8% of Irish exports coming from indigenous Irish industries, this vulnerability must be the compelling impetus for research-based industrial innovation. High-tech manufacturing is an essential element of recovery from the current recession and, for this reason, the Academy believes that the wealth-

creating potential of Applied Engineering Research, undertaken in the Irish universities and institutes of technology, and in active collaboration with Irish industry, must be given a higher priority than it is currently accorded.

The Academy proposes that the overriding criterion for the Government's research funding should be the impact of the research on the economy, in the short to medium term. It believes, too, that investment in high-quality, basic scientific research is important and must be maintained, while acknowledging that the associated outcomes, in terms of impact on the economy, are unpredictable and may not be realised for many years. Accordingly, the Academy proposes that there is now a compelling case for a national strategy for greater investment in Engineering Research, where that research is directly or indirectly relevant to industry, and that this strategy would complement, but not diminish, State support for basic scientific research.

Improved funding of Engineering Research will require urgent development of appropriate metrics for the evaluation of associated research proposals and subsequent research outputs. The UK Royal Academy of Engineering recently criticised the Office of the Director General, Science & Research for "*its single-minded use of metrics, especially citation analyses, to determine the relative performance of UK research across the disciplines*", saying that "*engineering and technology are far too important to the economy to be compared with basic sciences in an inappropriate way*". This Academy believes that this criticism applies equally well to the Irish situation. A similar view was expressed in the report of the Innovation Task Force,¹ which called for more meaningful metrics to measure the performance of research in our universities. It is increasingly evident that future economic success in Ireland will be dependent on our ability to grow indigenous sectors of the economy, such as high-value food exports, biomedical products or even education services which are currently Australia's third biggest

¹ *Innovation Ireland – Report of the Innovation Taskforce, March 2010.*

export earner. Within the high-tech sector, it is now generally accepted that in order to continue to attract foreign investment, to facilitate indigenous start-ups and to retain and expand existing high-tech manufacturing, the emphasis must shift to research and development-based manufacturing.

The views in this paper strongly echo many of those expressed in the recent report of the Innovation Task Force, in particular those relating to the need to change our education system, so that entrepreneurial skills are actively fostered at second, third and fourth levels. If we are to continue to produce engineers of the highest international standards, then the much-publicised problems with maths education in our schools must also be urgently addressed. The Academy was recently informed that the Irish operations of a major high-tech multinational company lost out to Romania in a bid for a new research laboratory with 400 jobs, because of better availability there of high-calibre engineers; another indigenous engineering company was forced to recruit its last eight engineers from overseas.

At a recent lecture to the Royal Irish Academy, Craig Barrett, former Intel CEO and Chairman, said that Ireland needs a system of education that values research, that encourages spin-outs from that research, and that allows universities to be *“wealth-creation centres”*. *“Ireland’s universities”*, he says, *“will have to change their ethos and practices in order to meet this challenge”*.

In a recent *Irish Times* article, Martin Murphy, CEO of Hewlett Packard (Ireland), referred to the highly-skilled graduates who drove the economy in the 1980s and 1990s, but reported that *“...what we are not now seeing is an emerging workforce that is fit for purpose, whose talents have been honed, primed for innovation and creativity, and that has the necessary language and technical skills to drive this economy into the 2020s”*.

At the OECD 2010 Conference in Paris, it was emphasised that higher education can play a critical role in helping countries to recover from the global recession. *“Higher*

education must think more creatively,” said Dr Jamil Salmi, World Bank Post-Secondary Co-ordinator. *“It’s not about doing more with less, it’s about doing it differently and innovatively.”*

In this paper, the Irish Academy of Engineering seeks to address these issues. In particular, it explores how Applied Engineering Research could play a much more significant role in contributing to Irish economic development than it has in the past. This paper identifies and considers the three principal sectors that control the performance of Engineering Research:

- the universities,
- the research funding agencies; and,
- Irish industry.

The paper examines how strategic changes in the structures and procedures in each of these sectors, and across the spectrum as a whole, would enable Engineering Research to make a greater contribution to Ireland’s economy. While the discussion relates principally to the university sector, much of it applies equally well to the institutes of technology.

3. THE UNIVERSITIES

3.1 Research Funding

'Intellectual capital' may be defined as the knowledge and skills of individuals, and the collective knowledge, competence, experience and memory contained in institutions. Intellectual capital is now recognised as the main source of wealth, and through wealth, the source of progress and prosperity in society. The Academy acknowledges that financial and strategic support for the creation of intellectual capital through research and development has been at the heart of the Government's approach to the programme for 'Building Ireland's Knowledge Economy', resulting in significant and very welcome increases in funding of scientific research. This investment is now delivering, at least in primary outputs: publication levels have doubled in little over five years; and, relative citations have improved dramatically in the same period, from an international ranking of 34th in 2003, to 19th in 2008. However, the data obtained from the various relevant national funding agencies (i.e., SFI, IRCSET, HEA/PRTL) clearly show that, relative to the sciences, the funding allocated to university research in engineering has remained at a very low level (**Figure 1**). The data for this chart were obtained from the funding agencies.

Between 2005 and 2009, the total allocated for Engineering Research amounted to just 8% of all associated funding. It is acknowledged that the various engineering disciplines have all changed substantially in recent years, in response to the

Total research funding per discipline (2005-2009)

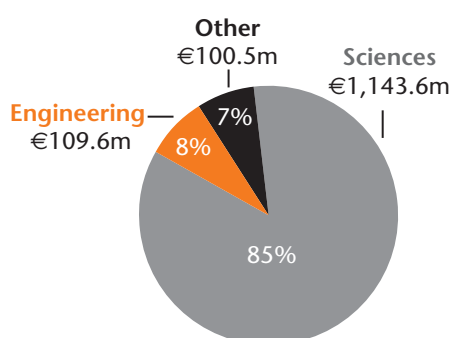


FIGURE 1: Discipline-based allocation of combined research funding from Irish funding agencies (SFI, IRCSET, HEA/PRTL), 2005-2009.

'knowledge economy' era, moving closer to the sciences; in developing Figure 1 from the available data, where the classification of a funded project as either 'engineering' or 'science' was not obvious, the discipline of the principal investigator was taken as the deciding factor. In considering these data, it is appreciated that academic staff in the sciences greatly outnumber those in engineering, typically by about 3 to 1; however, the disproportionately low level of Engineering Research funding cannot be fully accounted for on this basis alone.

3.2 Engineering Research

It is acknowledged that research in Irish university Engineering Schools that is funded by the agencies is of international standard. However, it is noted that the number of engineering applications for such funding is at a low level. This situation is confirmed when the relevant data are analysed in terms of funding agency, university and discipline. It is further acknowledged that the tradition of research in the engineering disciplines is not as strong or as institutionally well developed as in the sciences, so that if Engineering Research is to contribute more effectively to the revitalisation of the Irish economy, this issue must be urgently addressed. It is recognised that few industrial start-ups derive directly from the specific topic of a PhD research thesis; rather, they develop from the wider academic domain in which the research topic was located. The Academy, therefore, believes that Engineering Research, whose fundamental unit of accomplishment is problem-solving, and which is focused specifically on the challenges facing industry in Ireland, has a greater potential for innovation than research in other disciplines. Below are a number of specific observations and recommendations, designed to strengthen the university-based Engineering Research that the Academy believes will contribute directly to the regeneration and growth of the Irish economy:

- Greater collaboration between universities is seen as key to the generation of new vitality in Engineering Research activity. This is a significant recent development in international academic research, with clusters of institutions combining and co-operating in research

activities in the science and engineering disciplines; this collaboration is specifically aimed at promoting transfer of their research into industrial innovation. In the USA, for example, Engineering Research centres have been established by the National Science Foundation, uniting universities in long-term, productive research partnerships. Venture capital, essential to business start-ups, is not attracted by small pockets of research and the Academy believes that the combination of universities in specific research areas can provide the critical mass essential for that research to make a significant contribution to economic development.

- The Academy therefore recommends that, for each identified national priority research area in engineering, consortia of university researchers and associated technical colleagues from industry should collaborate in the establishment of **Engineering Research Platforms**, to pool their intellectual and physical resources, discuss theoretical and methodological aspects of their research and, where appropriate and practicable, achieve critical mass in specific projects. These platforms, focusing on a small number of selected national engineering priorities, would be a development of the existing SFI programme for Centres for Science, Engineering & Technology (CSETs). However, the prime mission of the platforms would be the promotion of technology transfer and industrial innovation in the relevant priority research areas.
- Likewise, it is recommended that the innovation centres based in Irish universities should collaborate as partners in enterprise development and collectively support the growth and success of new business opportunities, through spin-outs, licensing and incubation. The combined services of this collaboration should be available to early-stage technology enterprises emerging from both industry and the universities.
- Innovation centres can provide excellent laboratories for training both undergraduate and postgraduate students in innovation and entrepreneurship. The current role of innovation centres should be expanded, so that they reach inwards into the university research laboratories with encouragement and business advice to potential entrepreneurs, as well as reaching outwards for support from high-tech personnel in Irish industry.
- Within our universities, greater engagement with successful entrepreneurs, particularly with those from engineering backgrounds, would provide inspiration and support for a new generation of entrepreneurs. This could be achieved through the establishment of **Entrepreneur-in-Residence** positions within the Engineering Schools in each of the Irish universities.
- In general, Engineering Research projects should start with a problem to be solved or a technological challenge to be met. However, it does not follow that Irish Engineering Schools should be viewed as short-term, problem-solving facilities for industry, or that all Engineering Research must be applied. Rather, Engineering Research projects should relate to the development interests and challenges of industry and of the Irish economy. This philosophy is not inconsistent with the criterion for SFI funding, where the “*oriented basic research*”, which SFI is mandated to support, is required to relate to the future development of industry and enterprise in the State.
- The Irish universities must recognise the potential contribution of Applied Engineering Research to economic development. Increased support in their administrative procedures, academic structures and achievement awards must be provided for research in the Engineering Schools, with particular emphasis on collaboration with industry and on technology transfer from this research.
- It is incumbent on the universities to ensure that their intellectual property (IP) is propagated into the industrial world, to support innovation and to create jobs. For university-based Engineering Research in Ireland, existing IP systems present real barriers to the establishment of university–industry collaborations. The CEO of Boston Scientific in Ireland, Paraic Curtis, recently said that “...*academic institutions need to be less guarded about ownership of intellectual property and develop more of a partnership with industry*”. The Academy accordingly recommends that the Irish universities collaborate to resolve this issue, starting with a review of the current best international practice.

3.3 Engineering Education

The Academy believes that the importance of research and the creation of an enterprise development culture in our universities is not the exclusive domain of postgraduate education, but applies equally in the undergraduate education of the modern engineer. Engineering academic staff who are engaged in high-quality research which is linked with industry, are better positioned to bring real-life examples and state-of-the-art knowledge to enrich their teaching and project supervision in the undergraduate curriculum. In addition, through project work and other appropriate means, undergraduates should be exposed to research activities related to real-life engineering problems. Although certain basics of engineering education will not change in the future, the rapid explosion of knowledge, the advent of the global economy and instant, world-wide communication are changing the ways in which engineers work, and it is important that the education of engineers, at both under- and postgraduate levels, changes to meet these evolving circumstances in the professional engineering world. The Academy believes that the challenge for Irish Engineering Schools is, through the medium of research projects at both undergraduate and postgraduate levels, to teach the effective application and use of scientific principles for the solution of real-world engineering problems, which are changing at a faster pace than ever before. While this document is focused on Engineering Research, the Academy proposes the following initiatives and changes in Irish engineering curricula, with a view to strengthening the contribution of engineers and their research to the country's economic development:

- Engineers Ireland requires that all students graduating from professionally accredited, level 9 engineering programmes have "*the ability to design and conduct experiments and to apply a range of standard and specialised research tools and techniques*". Currently, these abilities are most effectively developed through the final year projects, which introduce undergraduates to research related to national or international industries. The Academy recommends that project-style research, starting with the problem to be solved, and involving linkages with relevant industry in Ireland, should be the accepted format for these final-year projects.
- Similar, but less intensive, project work should be a core item in each year of all undergraduate engineering education and not just the preserve of the final year. Ideally, engineering students should work in teams with

students from other disciplines, such as business studies, the sciences and also the humanities, to reflect the diversity of the professional engineering workplace. Projects in areas such as renewable energy, nanotechnology, hydrology, biotechnology, environmental technologies and ergonomic design, for example, could reflect the exciting spectrum of engineering disciplines.

- As an overriding ethos, the Engineering Schools should assume responsibility for producing wealth-creating graduates, and this element of engineering education should be reflected in both their undergraduate and postgraduate curricula. Traditionally, it was believed that 'creativity' and 'entrepreneurship' were native personal qualities, which could not be taught. This view is rigorously contested and it is now recognised that these skills can certainly be nurtured. The Academy believes that entrepreneurship, including 'starting your own business', should be a core module in all engineering PhD programmes. It further believes that Engineering Schools should teach their undergraduate students how to innovate and be creative.

This proposal reflects emerging trends world-wide. For example, the engineering school at Stanford University in the USA requires their engineering students to take a course in entrepreneurship; the school has established internship programmes based in companies worldwide. Similarly, in the University of Toronto, and in most Canadian universities, entrepreneurship training is a core subject in the curricula of all university disciplines. Additionally, Canada has a programme which funds the placement of over 1,500 graduate and postdoctoral students in companies that have identified practical business problems which would benefit from scientific and technological solutions.

- The Academy recommends that students should be introduced to examples of innovation successes based on Engineering Research, in modules given by graduate engineers who have successfully established their own companies. Recently, the importance of 'experience-led education' has been emphasised by the UK Royal Academy of Engineering, which specifically recommends that, in academic appointments to Engineering Schools, the industrial experience of candidates should be an important selection criterion. The more common procedure, whereby academic appointments are made directly on completion of a

higher postgraduate degree and/or primarily on the basis of criteria developed for the basic sciences (e.g., refereed publications, citations, funding track record) will undoubtedly continue, but it should no longer be the norm. Schools of engineering should be encouraged and supported in recruiting highly qualified engineers from industry. It is further recommended that each school of engineering should appoint senior persons from industry as adjunct professors, with specific, appropriate responsibilities in both teaching and research. As an introduction to the engineering profession, first-year students should have a lecture programme given by practising engineers from industry.

- A professional experience year, which allows engineering students to take a full year away from university to pursue a professional internship in industry, has been seen elsewhere to have had substantial developmental benefits for engineering students. The Academy recommends that the Engineering Schools should consider introducing this option for students before their final year, and that this period should be properly resourced and structured, and receive academic recognition. Tax breaks should be provided to support companies in hiring such students.
- Engineering Schools should be further encouraged to attract high-calibre foreign students to their masters and PhD programmes. These students should be seen not just as a source of revenue but also as potential future entrepreneurs in Ireland.

3.4 Engineering Schools: links to industry

The Engineering Schools have a unique and extensive source of potential support in the professional engineering and industrial domains in Ireland, and this fertile area should be developed to yield greater interaction and collaboration than currently exists. Ireland is the envy of other European countries in that it hosts a cluster of the world's leading engineering companies, offering the Engineering Schools a valuable, but largely underexploited, opportunity for interactive research and industrial innovation. The Academy has no doubt that the active involvement of senior engineers from high-tech Irish and multinational industries in teaching and research within Engineering Schools, at under- and postgraduate levels, will effect a vital change in the professional education of our students. The Academy believes that the rapidly evolving technological world demands a new breed of engineer and that the engineering

curricula and research ethos in Irish universities should reflect this new and evolving situation. Increased involvement of the engineering profession in the Engineering Schools will play a crucial role in the education of the entrepreneurial engineers required for industrial innovation and technological leadership in Irish industry. This new breed of engineer will also provide the internal entrepreneurship essential for high-tech companies in securing ongoing parent company investment in their Irish operations. The following innovations are proposed:

- The Academy recommends that Engineering Schools should establish industrial liaison boards to provide advice on curriculum development and research philosophy and strategies. The practice of appointing industrialists as adjunct professors has been introduced in Irish universities in recent years and this should be systematically extended to each of the departments in the Engineering Schools.
- A professional engineering doctorate – a DEng as distinct from a PhD – whereby the student undertakes the relevant research in an industrial engineering setting supported by university specialist laboratories and expertise, while under the joint supervision of industrial and academic staff members, is an interesting development, successfully introduced elsewhere, which should be established in Irish Engineering Schools. The rigorous academic criteria of scientific analyses, experimentation and discovery which apply to PhD programmes, apply equally to DEng studies, but the research typically has a stronger industrial flavour. The Academy believes that the major engineering companies would support this development and should be invited to participate in a pilot DEng programme.
- The SFI-sponsored Centres for Science and Engineering Technology (CSETs, **Section 3.2**) are an encouraging development, through which more than 100 Irish-based companies are currently co-operating with university research teams. It is suggested that such co-operation should not be confined to Irish-based industries. In particular, it is recommended that greater efforts be made to establish research linkages with European and US engineering industries, following the model whereby the French company Airbus is currently supporting PhD students through a scheme funded by IRCSET.

4. THE RESEARCH FUNDING AGENCIES

As previously noted (**Section 3.1**), relative to the sciences, the Irish funding agencies receive proportionately smaller numbers of research applications from academic staff within the university Engineering Schools. The following observations and suggestions are made with a view to improving this situation:

- Since its inception, and in accordance with its statutes, Science Foundation Ireland (SFI) has not been supportive of applied research in engineering. In its statutes, SFI is mandated to provide funding for “... *oriented basic research in strategic areas of scientific endeavour that concerns the future development and competitiveness of industry and enterprise in the State*”. Accordingly, the awarding criteria and grant assessment panels, as well as membership of the SFI Board and senior management, are all largely focused on supporting basic scientific research. It is recommended that the statutes of SFI be modified to include an applied research component in its funding mandate.
- In discussions for this paper, rationalisation of the number of Irish agencies funding research undertaken within the higher education sector has been widely and repeatedly proposed. Government support for research through the various existing agencies provides funds for a range of different, but related, research activities, principally including the remuneration of PhD students, the running costs of their research projects, and the engineering laboratory facilities and buildings in the university campuses. The Academy believes that for a more effective national programme for research in engineering and the sciences, these different funds should be managed by a single agency.
- All research funding, whether classified as basic or applied, should be subject to rigorous assessment and evaluation, measuring the contributions of each funded project, based on the following outputs:
 - ▶ Publications
 - ▶ Actual or potential economic impact
 - ▶ Creation of intellectual capital
 - ▶ Collaboration with industry and other universities
 - ▶ Delivered outputs

The Academy further recommends that the detailed assessment and evaluation results, under these headings, for all successful applications for government funding should be made public on the agencies’ websites and publications.

5. INDUSTRY

Ireland lags behind other countries in the commercialisation of university research. The Academy believes that the creation of stronger links between Irish industry and the higher education sector is the essential and vital step in the commercialisation of the Engineering Research undertaken within our universities. The following proposals to improve this situation are suggested:

- It is acknowledged that starting one's own business from one's research or 'eureka' idea is a very difficult and challenging process, with more failures than successes. National structures should be enhanced to provide both support and financial assistance to researchers who believe that their research has a real possibility for industrial innovation.
- Successful foreign entrepreneurs should be attracted to Ireland by the IDA to assist in changing the current national negative mindset on research-based innovation.
- There is a need to provide a new strategy to encourage engineering researchers to participate in start-ups, allowing them to forego temporarily the relative security of academic life for the uncertainties of an industrial venture. One model suggested is to provide tax incentives for researchers to spin out technology. In such activities, the Academy recommends that pathways be established to allow these researchers to re-enter the university world, thereby encouraging them to leave, set up a company, and subsequently return to university research.
- The traffic in graduates and research outputs from our higher education institutes to the world outside has, for the most part, been one way, with the industrial sector playing no substantive role in determining the philosophy and practices that control the nature and qualities of these outputs. As previously outlined (**Sections 3.2-3.4**), the Academy believes that industry, and society generally, should have a much more interactive role in Irish higher education, and that robust procedures for accountability for research expenditure should be established. Without doubt, academic freedom must be maintained in the educational roles of our universities, but in Government-funded research, controls on both finance and the selection of priority topics should fall within nationally established boundaries.
- Existing IDA and Enterprise Ireland programmes supporting industry clusters have been very successful. Industrial innovation within these clusters could be enhanced by improved collaboration with university-based Engineering Research. This collaboration could take the form of competition between university consortia for industry-funded research projects. The Academy believes that this type of partnership would encourage student interaction with industry, increase the visibility and economic relevance of high-tech research, and provide a mechanism for highly-skilled researchers to participate productively with industry, while simultaneously maintaining their research and teaching activities.
- Industry should be further encouraged, with tax incentives, to support university-based research. Additionally, a proportion of government grants to industry should be ring-fenced for collaboration with university research.



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