

## Perspectives from Science, Technology, Engineering and Mathematics (STEM)

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Interdisciplinary research enjoys an elevated status among university administrators and funding agencies. There are several compelling reasons for this, with the primary one being that many complex, hard problems do not respect disciplinary boundaries. The solutions to such problems will necessarily draw upon insights from multiple fields. Moreover, interdisciplinarity allows for creativity in novel, unpredictable ways. Also, there is a strong belief that new breakthroughs will occur at the interfaces of disciplines. That is where the limits of disciplines are stretched and are likely to experience advances in the state of the art.

However, the actual process of conducting interdisciplinary research is not easy. There are many barriers faced by institutions, faculty members and students. The institutional barriers mainly arise from the disciplinary structure of most universities within which academic territories are neatly demarcated. More importantly, resource allocation is usually determined by such structures. Finally, credit sharing is also influenced by the disciplinary structure of the organization. For faculty members, most journals and conferences are organized by discipline. While there are new interdisciplinary forums being established, the most prestigious ones tend to be the *intra*-disciplinary ones. Therefore, for obtaining peer recognition as well as for tenure and promotion decisions, there is a tendency to favor research *within* the discipline. Similar considerations exist for students. For them, there is also the additional factor of finding jobs for which there are fewer interdisciplinary units when compared to the traditional disciplines.

At NUS, we have tried to mitigate such barriers by creating institutional mechanisms to support interdisciplinarity. We decided to organize some of the larger research efforts around integrative clusters, many of them related to STEM fields:

- *Finance and Risk Management*: seeks to create fundamental and use-inspired research that can also contribute to Singapore's goal of becoming a leading financial center in Asia.
- *Translational Biomedical and Clinical Research*: aims to be a leader in medical and public health research, especially for diseases more common among Asians or with a different pathology in Asian ethnic groups.
- *Active Ageing*: carries out research that develops technologies, informs the formulation and execution of policies, which will lead to better culturally-aware strategies for healthy ageing.
- *Energy and Environmental Sustainability*: focuses on a wide range of research questions spanning exploratory science to future technologies to policy implementation and it is coordinated by the NUS Energy Office.
- *Global Asian Studies*: This cluster aims to take the lead in research and scholarship directed at topics pivotal to Asia's future. By focusing on integrative studies, the work will go beyond public policies and also deal with matters of technological importance.

- *Materials Science*: organically arose from a convergence of research strengths in science related to graphene and Nanoscience with the Nanotechnology efforts in Engineering.

These research efforts have been complemented by building strong interdisciplinary graduate programs:

**1. NUS Graduate School of Integrative Science and Engineering (NGS).** Established in 2005, NGS has grown from an initial enrolment of 31 PhD students to a total of 480 today. It has introduced an innovative interdisciplinary coursework curriculum combining skills workshops, immersion courses and education in ethics and integrity. Particular care is taken in recruiting students who:

- have a keen interest in integrative approaches to research,
- enjoy taking an analytical approach to problems,
- seek to deepen their knowledge in a focused research area but, at the same time, are aware of, and are interested in, a wide range of topics in science and engineering,
- adhere to the very highest ethical standards,
- appreciate the importance of developing excellent communication skills,
- are able to work independently whilst appreciating the value of team work and,
- can serve as role models to future generations of researchers and hopefully make an impact in their chosen fields of study.

Students are strongly encouraged to transcend traditional disciplinary boundaries in their doctoral work. PhD advisors at NGS are specially chosen via a stringent selection process that vets academic ability, interdisciplinary interest and track record of guiding students. The students are required to have thesis committee members from different disciplines. The coursework is tailored to the individual student's needs. By taking courses and carrying out lab rotations early on in the program, students have the opportunity to acquire new knowledge and tools in areas related to their doctoral research. Life scientists can gain proficiency in computation, physicists and engineers can acquire knowledge of biological concepts, and medics can learn about the molecular basis of disease. Every student has to do a compulsory course on "Interface Sciences and Engineering." It consists of a series of lectures/discussions/presentations that would provide students with an interdisciplinary exposure and knowledge foundation for selected research themes that are of prime importance to humankind, and where interdisciplinary science and engineering are frequently practiced. Each theme is taught and coordinated by two instructors who contribute to different, yet complementary, perspectives of the theme—such as "Infectious Agents and Global Pandemics," "Omics," "Renewable Energy," "Human-Computer Interactions" and "Environmental Problems/Climate Change."

**2. Interdisciplinary PhD Programs:** are also offered by the Centre for Quantum Technologies, the Mechanobiology Institute and the Cancer Science Institute of Singapore. These are nationally important research centres of excellence on the NUS campus. These Interdisciplinary PhD programs also help us attract top graduate students who in turn are highly important to the success of such multi-disciplinary research projects (in a virtuous cycle). These numbers are relatively small as compared to NGS.

Finally, NUS has encouraged and facilitated interdisciplinarity by consciously engaging in its practice of:

- Providing enablers and incentives from our internal resources (e.g. seed funds, priority access to research space, PhD scholarships) to groups willing to work across disciplines.
- Establishing coordinating offices such as the NUS Energy Office and Maritime Institute @ NUS to coordinate research programs across NUS and liaise with external stakeholders in energy research and marine offshore research respectively.
- Regularly engaging government agencies and national research funders to understand their priorities and research needs, particularly for holistic, multi-disciplinary solutions. We then share these insights with the relevant Schools/Faculties and assist them to strategize/organize into multi-disciplinary teams that are well-positioned to respond to these national calls for proposals.
- Factoring these considerations into our campus infrastructure planning so that new buildings are designed to encourage interactions and synergy across divisions and disciplines.
- Recognizing and rewarding interdisciplinary research during tenure and promotion considerations. Multi-author papers spanning disciplines are particularly recognized.
- Supporting an on-going mechanism to identify and develop future peaks of excellence. For example, the area of “Human Nutrition & Development” is currently being considered.

Thus, NUS has adopted a two-pronged strategy of developing institutional mechanisms for facilitating interdisciplinary research which are complemented by a strong suite of graduate programs.