Bridging Gaps Between Science and Engineering

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Doctoral Education at TUM

As a Technical University, or Institute of Technology, Technische Universität München (TUM) has a research and education portfolio which is not only focused on science and engineering but also covers life sciences, medicine, and economics. To understand a university-wide framework for doctoral education not as a restriction of disciplinary variety, but as a unique chance to both enrich traditional disciplinary paths and increase quality of education, has been one main pillar in the design of TUM Graduate School (TUM-GS). Established in 2009 as an optional program and since January 2014 mandatory for all doctoral candidates, TUM-GS today is the home to doctoral education across all thirteen departments at TUM. TUM-GS acts as an umbrella organization with currently 26 Graduate Centers providing tailored programs that mirror its regulations. Among these, 14 Department Graduate Centers attend to the disciplinary doctorates and 12 Thematic Graduate Centers foster interdisciplinary doctoral education. The most important of the latter is IGSSE, the International Graduate School of Science and Engineering.

IGSSE and its Structure

Built upon project teams operating at the interface of the natural sciences, engineering, and medical research, the International Graduate School of Science and Engineering combines exceptional research approaches with an outstanding doctoral education program. All project teams at IGSSE link basic science to engineering paths and give young researchers the opportunity to join scientific forces across the classical disciplines. This concept has won highly competitive funds of the German Excellence Initiative in 2006 and 2012.

Besides the unique opportunity for PhD candidates to either learn the language of a natural scientist or learn to understand the thinking of an engineer, they have access to about 200 courses on topics such as entrepreneurship, personal development, project management, and many more. These courses—offered each term—are tailored to the needs of PhD candidates, most of them provided by TUM-GS. IGSSE especially fosters international collaborations via a compulsory 3-month stay abroad and its annual forum with international guest researchers.

As IGSSE project teams do cutting-edge research off the beaten track, they are expected to act as incubators for emerging research fields of strategic importance to TUM. This, of course, calls for a strict and transparent granting process. Up to twice a year, IGSSE calls for new project proposals, conceived by at least two senior scientists from different groups and departments (e.g., natural sciences, engineering, medical sciences) at TUM. Since 2007, more than 80 project teams have commenced their work within IGSSE.

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Project Teams

An IGSSE project team comprises at least four doctoral candidates, a young postdoc (project team leader, PTL) heading the group, and two or more senior scientists as PI's, representing a synthesis of science and engineering. If suitable, master's students are welcome to join the team, too. After the individual project kick-off meeting, all teams discuss their research results in project team sessions, held on a regular basis. IGSSE has funds available for project issues, for all doctoral candidates involved, as well as for the PTL. Since its foundation, more than 280 doctoral candidates from next to all TUM departments have done research within IGSSE.

Cornerstones of the IGSSE Educational Program

IGSSE encourages its PhD candidates to broaden their disciplinary and personal horizons through its educational program. The starting point is a supervision agreement, ensuring a PhD project roadmap. After two years, the development and quality of the dissertation phase are certified by an interim evaluation. In addition, all IGSSE PhD candidates have to complete four training modules complementing their dissertation phase. 50 credit points have to be collected via (1) disciplinary training (summer schools, scientific workshops, etc.), (2) scientific skills training (paper elaboration, teaching, etc.), (3) a three-month research stay abroad, and (4) transferable skills training (entrepreneurial know-how, presentation skills, ethics, personality training, etc.).

As an *international* graduate school, scientific activities abroad are supported via additional grants. The active participation in conferences and especially the research stay abroad at a foreign lab are vital parts of IGSSE's qualification program. Both activities have proven to establish new international networks and stimulate joint publications.

Regarding the *interdisciplinary* approach, IGSSE supports trans-disciplinary lectures and workshops both in Munich and outside Germany. To give some examples, in October 2013, IGSSE supported a cross-department delegation to attend the Leichhardt-Symposium in Australia; in May 2014, IGSSE supported doctoral candidates in organizing the first lecture of a cross-departmental series. An interdisciplinary highlight is IGSSE's annual meeting at the Raitenhaslach monastery in Burghausen, where networks across all project teams and a true interdisciplinary spirit develop. During this three-day symposium, about 200 IGSSE members meet with international guests in scientific workshops, lectures, and ambitious training programs. "I would say the combination of such fabulous people and quality outreach is what makes the IGSSE the state of the art and at the forefront of the international scientific networking. This is immensely rewarding and posits inspiring research coordination," said Dr. Mohamad Araji, Environmental Design Program, University of Manitoba, about the graduate school's meeting in 2014.

Experiences

So far, IGSSE doctoral candidates have benefitted a lot from its concept. IGSSE has been able to support research stays around the globe—at MIT, ETH Zurich, National University of Singapore, University of Berkeley, or the Scripps Institute, just to name a few. The feedback has always been extremely positive, with respect to both research and personal skills. But keeping up with the interdisciplinary idea has not always been an easy task. Besides the classical reservations concerning trans-disciplinary research, especially the PTL model is sometimes problematic.

Although in a responsible position, the young postdocs are at a career stage that requires mobility and sometimes implies leaving TUM and their IGSSE doctoral candidates behind. As it was difficult to find appropriate replacement for these postdocs, some teams could not find a way to continue their regular meetings. IGSSE responded to the problems with extra funds for PTLs, to be used for their personal career development and special training offers.

A recent example of the successful link of doctoral education and interdisciplinary research is the project "Coating of Stent Surfaces," closed successfully in July 2014. Conceived by a TUM chemistry chair and a heart surgeon of Deutsches Herzzentrum in Munich, the aim was to improve stents for heart surgery. The involved doctoral candidates published 22 peer-reviewed papers, 6 of which were first-author ones, and filed 3 patents. All of them received a broad range of high-profile job offers and are now working for international companies and German national research institutes. Regarding IGSSE's aim to foster innovative research, some project teams succeeded in acquiring grants for new research proposals (EU funds within the FP7 program, e.g.), some have fostered TUM's international collaborations (e.g. Solar Decathlon 2015).

With more than 90 Alumni, now working as professors (e.g., in the USA, Germany, or China), research fellows (e.g., in the USA, France, or Germany), lecturers (e.g., in the UK), as well as senior project managers in industry and science or as entrepreneurs, the graduate school has met its expectations to prepare young scientists for leadership positions in both academia and industry.