Toward a Personalized Graduate Curriculum

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Dramatic changes in graduate education education are taking place due to the emergence of knowledge-based societies, where new knowledge has become a valuable commodity, strategic national resource, and political agenda item (Kehm, 2006). Key trends have been articulated as (Uronen, 2005): from national to international, from basic, curiosity-driven research to results-oriented research, from individual to team research (Hand, 2010); from disciplinary to multi- and interdisciplinary, from smaller laboratories to larger research institutes, programs, and centers (Hand, 2010); from fragmented projects to “Big Science” (e.g., sustainability, energy, health, security, infrastructure, etc. → complex systems) (NAS, 2008; Hand, 2010; Cambridge, 2006); from public or university funded to multiple funding sources, from unbounded research to research within pre-defined programs and projects, from purely academic to the professional, from national security to competitiveness and job creation, and from utilization of resources to sustainable development. Additionally, an increasingly diverse graduate student population is expected due to demographic shifts, i.e., larger numbers of competitive international student applications, and larger numbers of female and U.S. underrepresented minorities.

In parallel, significant modifications to the graduate student experience have taken place. For the latter years of the graduate program during the research thesis, there is an enhanced concept of apprenticeship, i.e., that it is more than technical training which requires mentoring as well (U. Michigan, 2006). Graduate programs are becoming more and more reliant on technology for formalized coursework and research (e.g., the Internet, videoconferencing, Wikis, video and audio podcasts, blogs/vlogs, message boards, etc.) (Murphy, 2001; Salmon, 2000; Housego, 2000).

Increased productivity is expected of our graduate students by doctoral advisors and research sponsors, as well as rising expectations for accomplishments prior to graduation. Students obtain much larger amounts of data and analyze, assess, and write up their results for publication much more rapidly than their predecessors.

Graduate students are increasingly in need of transferable personal and professional skills, e.g., leadership, global cognizance, entrepreneurship/intellectual property, human sciences, ability to work as members of a diverse team, creativity, innovation, open-ended problem solving, communication, ethics/social responsibility, etc. (NAE, 2004; Fallows, 2000). This concept has been referred to as the creation of a “T-shaped” graduate (Plummer, 2009), mostly in the context of undergraduate education. The base of the “T” involves a breadth of knowledge in the aforementioned topics, while simultaneously having a depth of knowledge in a specific discipline (Plummer, 2009). At the undergraduate level, where many curricula are already packed, the reduction/loss of academic and technical rigor is a major concern and the “aspect ratio” of the “T” is of importance (Thomas, 2009). Lastly, there is a demand for personalized and flexible curricula (Sunstein, 2002), which is discussed further below.

Hence, as articulated by Prendergast (Prendergast, 2006), a new benchmark for doctoral graduates has evolved which includes not only the creation of new, original knowledge at the frontiers of the discipline, but also the ability to appreciate this new knowledge in a
broad context (e.g., socioeconomic, global) and to have a more extensive skill set to be able to act on this new knowledge (Prendergast, 2006; NAE, 2004, 2005). In essence, we are continually “raising the bar” on what we expect our graduate students to achieve upon graduation. For financial and competitiveness reasons, there is significant pushback on extension of the time-to-graduation and, hence, the rate of skills acquisition in graduate programs is expected to increase.

Starting in the fall of 2008, the MIT Department of Materials Science and Engineering (DMSE) began an extensive evaluation and revision of its graduate doctoral curriculum, which included in-depth discussions of the above trends and their implications for our graduate program. The MIT-DMSE doctoral program has had a long history of leadership through interdisciplinary collaboration, a culture of innovation, and spanning fundamentals to real world applications (Flemings, 1985), and has been ranked #1 consistently by U.S. News & World Report since the rankings were first established in 1996. DMSE research, via the graduate program, continues to play a critical role in the “Big Science” research initiatives throughout the Institute, the nation, and the world. Our graduate students form the backbone of these efforts and compose a core intellectual hub of a dynamic, rich, and broad materials network/community. We have an important responsibility to provide our 225+ graduate students with the highest quality and most current educational, research, and personal development experience while at MIT by continually adapting it to the changing nature of engineering education and the MS&E discipline.

The structure of the DMSE doctoral program has undergone significant changes in recent decades, including: the establishment of a required set of four core classes (a prescribed materials-generic foundation for all graduate students), structural variations of required post-core classes (first established in 1995), and the requirement of a two-course minor. The current DMSE graduate program structure is shown in the figure.

In the spring of 2009, the DMSE faculty voted to convert a mandatory sub-disciplinary based post-core into a more flexible consolidated system. In the prior system, students chose one of four academic panels/tracks (i.e., Electronic, Photonic, Magnetic and Materials, Bio- and Polymeric Materials, Structural and Environmental Materials, Emerging and Fundamental Computational Studies) after completion of the core and had to take electives specified within each panel that were directly linked to the oral qualifying exam. In the current system, students may choose three electives from an extensive consolidated list of all DMSE graduate electives, as well as from advanced graduate-level technical classes outside of the Department.

Overall, the aim of the new post-core is to provide a “personalized” or
Schematic of current doctoral program structure for the MIT Department of Materials Science and Engineering. The numbers in parenthesis are the number of courses required for each component of the graduate program. A total of nine courses are required for completion of the doctoral degree.

and direction of their educational path, this will stimulate creativity, inspiration, excitement, new interdisciplinary ideas, and provide support for research endeavors. There is some evidence that such flexibility will be particularly beneficial and attractive for female and underrepresented minority students (Vincent, 2001). “Creative studies programs” have long made use of these concepts (e.g., see University of California, Santa Barbara (UCSB) undergraduate College of Creative Studies). However, such programs rigorously pre-select relatively small cohorts of students with exceptional abilities to carry out advanced and independent studies that take place in small group settings such as tutorials.

While personalized education, in general, may provide the numerous advantages described above, a completely unrestricted non-prescribed curriculum may have numerous risks, such as group polarization and fragmentation and students lacking experience to make fully-informed choices (Sunstein, 2002). It has been suggested that an appropriate level of personalization is necessary, in particular, a curriculum that includes a set of common experiences and exposure to unanticipated topics and points of view (Sunstein, 2002). In our case, the core serves this purpose.

Hence, in the new DMSE post-core curriculum, doctoral students may choose to create a specialization/concentration by creating a post-core sub-program of three courses in a particular sub-discipline (emphasizing depth). Conversely, graduate students also have the option to formulate a broader educational experience, for example, by choosing courses in three different sub-disciplines or disciplines.

Options include a focus on the previous academic panel areas, a number of DMSE emerging research areas, and materials-generic options such as a focus on materials design, materials economics, materials processing, and materials for energy and environment. Another optional sub-program available is a “skill-based” post-core with selected classes in experiments/characterization/laboratory, computation, and application/design. It should be noted that if a broader post-core is chosen by the student, this does not in any way imply a lack of rigor or superficiality, since each class taken will be required to adhere to the standards of technical rigor set by the Department for advanced-level graduate study. The optional post-core sub-programs suggested by the Department will be helpful for recruitment to demonstrate current Departmental research areas to prospective graduate students.

The structure can also easily evolve with the discipline (i.e., adding new sub-programs, eliminating outdated ones) since it is no longer explicitly coupled to the oral qualifying examination. Within the new consolidated post-core infrastructure, there is now a place for new classes that may arise which are not easily categorized into existing smaller sub-programs. Lastly, the new post-core (in addition to the two-course minor) will readily enable the inclusion of transferable skills into the curriculum.

A 65-page report on the DMSE graduate curriculum revision with complete reference citations is available via e-mail: cortiz@mit.edu.

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