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An Online Professional Engineering Doctorate Program: Getting the Program Launched from Design to Delivery

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An Online Professional Doctor of Engineering Program: Program Design to Delivery

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Abstract
The online Doctorate in Engineering (D.Eng.) that we have developed for working professionals, increases access to advanced graduate education by affording working professionals the opportunity to earn their terminal degree in engineering while maintaining employment. Earning a terminal degree in engineering enhances one's technical skill set and increases domain knowledge. In this work-in-progress paper, we outline the design and delivery of the D.Eng. program offered by Penn State's College of Engineering via World Campus. The journey from conception to initial delivery, focusing on best practices and lessons learned, is discussed.

Introduction
Opportunities to obtain a terminal degree (Ph.D. or Doctorate) for engineering industry practitioners, without putting their professional advancement on hold, have been limited. To continue their education at the graduate level, these practitioners complete one—and often more than one—master's degree via the many part-time master's program opportunities, both in-residence and online.

Earning a terminal degree in engineering can enhance one's technical skill set and increase domain knowledge depth that puts a student on the path to becoming a subject matter expert. Until recently, completion of the traditional engineering terminal degree, the Ph.D., usually requires enrolling as a full-time student, as the programs require attending on-campus classes, working on fundamental research, teaching, and fulfilling a program's full-time residency requirements. This is not an option for many professionals given financial, family, and career responsibilities that preclude them from leaving their job, even for a year. In addition, obtaining the Ph.D. may be perceived by industry as a desire to switch careers to academia; thus, employers may not offer tuition reimbursement support even if the program is offered online. The Doctor of Engineering (D.Eng.) degree, a professional engineering doctorate, addresses these concerns as it provides access for working professionals to the highest education level, while enabling continual professional growth with an employer.

The competitiveness and economic growth of the United States depends on engineering doctorates transitioning from academia into the workforce [Chang et al., 2022]. More doctoral graduates in the STEM fields, particularly with respect to underserved populations, is critical for addressing these innovation needs. This pipeline challenge requires a rethinking of the resident-only, full-time doctoral degree. An effective option is urgently needed such that doctoral students can remain in the workforce while earning their degree. In a feasibility analysis for a Penn State D.Eng. performed by the University Professional and Continuing Education Association (UPCEA), consistent hiring and valuing of doctoral degrees was reported. In addition, three quarters of the industry opinion leaders interviewed conducted some research and most of that research engaged those with doctoral degrees [UPCEA, 2018]. It was also reported that most potential students interviewed indicated they would prefer to keep working while earning their degree part-time.

There are only a handful of institutions that offer part-time doctorate programs, let alone professional programs that enable a student to remain in industry. Even fewer institutions deliver the program online as it is a challenge to design a program with similar rigor as a residential doctoral program. An online program is necessary and ideal in assisting doctoral students to support the life obligations of professionals (work and family commitments), reach students all around the world, and provide access to underrepresented students.

The Penn State Online D.Eng. Program

Creating a rigorous and effective doctoral program to support a diverse set of disciplines as well as a diverse set of students can be a challenge. To meet this challenge at Penn State, we built and launched an online Doctorate in Engineering program aimed at working professionals who desire to advance their career by demonstrating the ability to conduct and lead applied research within an industrial, military, organizational, or governmental setting.

Penn State, long respected and consistently recognized for having one of the top engineering programs in the country, offers its online D.Eng. program through the Penn State World Campus. The courses are taught by Penn State faculty with strong academic credentials and real-world experience. The D.Eng. program positions doctoral graduates to advance to high-level leadership positions in research and engineering in both the private and public sectors. With the guidance of a faculty advisor assigned within the student's first semester, the D.Eng. recipient will be prepared to:

- research and develop new products or processes that can benefit industrial, governmental, or military entities;
- analyze and synthesize critical information within a discipline, and, where appropriate, across multiple disciplines;
- communicate the major issues of a discipline and effectively disseminate research findings through technical reports, presentations, and peer-reviewed papers; and
- lead high-performing research and development teams, divisions, and corporations.

D.Eng. Learning Objectives

The D.Eng. program established a set of learning objectives, which are:

1. *Develop knowledge of major concepts and issues pertinent to the student's area of specialization*. The D.Eng. program requires the student to have a master's degree in a discipline relevant to the field of research being pursued and take a minimum of 15 credits of graduate-level technical electives providing additional breadth and depth in the fields relevant to the praxis research. In addition, the extension of required courses to include leadership and innovation management provides knowledge applicable to their work in an industrial, governmental, organizational, or military field.
2. *Employ disciplinary methods and techniques to apply knowledge and create new knowledge or achieve advanced creative accomplishment*. The D.Eng. student will identify a research program that is related to the field in which (s)he is either in currently or desires to be employed. The research shall develop new products, processes, or knowledge that can benefit industrial, governmental, organizational, or military entities. Appropriate research methods and statistics are covered in two required courses, which includes ENGR 820 Applied Engineering Research Methods and one 3-credit course in an approved statistics or numerical methods/analysis course (appropriate to the student's specific research question).

3. *Analyze and synthesize analytical and critical thinking within their discipline, and, where appropriate, across disciplines, building appropriate depth and breadth in the student's area of specialization*. The D.Eng. program will provide opportunities for both discipline-specific as well as cross-disciplinary research, as appropriate for the individual student's situation. The associated research will be overseen by a doctoral committee consisting of a minimum of three faculty members (on graduate faculty at Penn State) and allows for inclusion of the associated technical advisor. When pertinent to the student's praxis topic area and personal circumstances, an additional member can be added as a "special outside industry member" from the associated industry, military, organization, or governmental function. This doctoral committee will require demonstration of analytical and critical thinking, consistent with the expectations for a doctoral research program.
4. *Communicate the major issues of their discipline and disseminate research findings effectively*. Dissemination of research findings may be through technical reports, presentations, and peer-reviewed papers. One of the unique attributes of the D.Eng. is that it incorporates leadership and innovation management skills into the program. As such, the ability to effectively communicate issues and potential solutions associated with the student's field of research will be directly enhanced by coursework and associated teamwork and feedback. The professional core courses all require a demonstration of written and oral communication competencies.
5. *Conduct themselves in accordance with best practices, highest ethical standards, and values of their discipline*. Students in the D.Eng. program are required to complete the Scholarship and Research Integrity (SARI) requirements governing ethical research methods. In addition, the combination of courses in the technical field and leadership elements of this D.Eng. program will further educate and evaluate ethical awareness and behavior in the student's field of study.

Coursework

The program requires 45 credits, of which 9 credits are focused on developing leadership and innovation management skills of value to the student's career growth; 6 credits are focused on developing research skills; and 15 credits are focused on developing the needed technical background through graduate-level technical courses relevant for addressing the student's praxis, i.e., an applied research topic. The graduate technical courses are drawn from over 20 of Penn State's graduate programs already offered through World Campus. 15 research credits are required working toward and completing the student's praxis research project.

Qualifying Exam, Comprehensive Exam, and Final Praxis and Defense

In addition to the course work, there are three major milestones in the program: qualifying exam, comprehensive exam (written praxis proposal and oral exam), and final written praxis and defense.

Qualifying Exam

The primary purpose of the Qualifying Examination is to provide an early assessment of whether the student is developing the knowledge, skills, and attributes the program has defined in the D.Eng. Program Learning Objectives, including evidence of critical thinking skills necessary for successful applied research at the doctoral level. The Qualifying Examination is conducted early

in a student's program to ensure that the considerable investment of time, resources, and effort required by the student has a high likelihood of leading to completion of the DEng degree.

The DEng Qualifying Examination is prepared and administered by a Qualifying Exam Committee comprised of members of the D.Eng. Graduate Faculty, working closely with the D.Eng. Graduate Program Office. It is structured around the review and critical assessment of literature that is related to the student's proposed praxis research as well as an assessment of their proficiency with applied engineering research methods. The exam consists of a proctored online written exam.

Comprehensive Exam, Final Praxis, and Advising

The students entering the D.Eng. program are self-funded and have identified an applied research topic. The praxis research topic is further refined and finalized by the student in consultation with the praxis committee, which is comprised of the faculty praxis advisor and other graduate faculty.

The Comprehensive Examination consists of a written praxis proposal and an oral examination that is a presentation of the praxis proposal. The praxis research project is analogous to the dissertation research project that is a requirement of a Ph.D. program. The final praxis is the written document, along with an oral exam, of the culminating applied research project. Because the student may be working on an applied research problem supported by their employer; it is typically at the employer's facility where the research is performed. However, as a Penn State student, they have access to university services in support of their research, including the Penn State Libraries, resources to which their advisor has access, and World Campus support services.

Similar to a Ph.D. program, academic advising typically is provided by the faculty member who supervises the student's praxis research, i.e., the praxis advisor. Other members of the student's praxis committee may also serve as advisers. A newly admitted student is assigned a temporary adviser who provides initial advising at the beginning of their program. The student is matched to their praxis advisor by the end of their first semester.

Lessons Learned

In the launch of this program and in its first full semester, there are a number of lessons that we have learned, including:

1. Program Capacity: Launching a D.Eng. program started at full speed. In only a few months, there have been hundreds of inquiries and applications. The official first semester has 40 students enrolled. Interest in the program indicates continued growth.
2. Advising: This demographic generally does not have a solid research background. Many earned a professional master's degree, which may not have required a research paper or thesis. Advising is needed from day one to guide the student through a research ramp-up period, which is further solidified with the ENGR 820 applied research methods course.
3. Because the program is new, in addition to explaining the program to prospective students, there is a need educate faculty more familiar to advising resident Ph.D. students on how to work with remote D.Eng. students.
4. Resident doctoral programs often hold major milestones in person (e.g., qualifier and comprehensive exams). The need for remote access to these necessitates a revisit of how they are offered.
5. D.Eng. students can be valuable resources for an advisor's larger research group, providing feedback and insight into life in industry.

The table below provides a comparison of the Ph.D. and D.Eng. programs over several metrics, to highlight differences and similarities.

Metric	PhD (typical)	DEng
Research	Fundamental	Applied
Documentation	Dissertation	Praxis
Oversight	Advisor/Committee	Advisor/Committee
Engagement	Other PhDs	Corporate/Government
Course and Res. Credits	21 and 15	30 and 15
Professional Dev. Courses	Not required	Eng. Lead, Proj. Man., Innov. Man.
Financial Aid	Assistantships (typ.)	Corp. tuition plans & self funded
Time to Complete	Varies, 5–6 yrs avg from BS	Varies (5 years with 3 cr/sem)
Residency Required	Yes, min. 1 year	5 days
Master's Required	No	Yes (not "master's along the way")
Departments/Majors	Traditional engineering	Customized and interdisciplinary

Discussion and Conclusion

The online D.Eng. supports several strategies related to Penn State's strategic initiatives:

- **Transforming Education**: Providing an opportunity for advanced study to professionals whose interests lie more in applied research and practice will expand the realm of research within the College of Engineering and attract students whose career focus is more applied. By utilizing the capabilities of World Campus in delivering the doctoral program online, we extend the Penn State's College of Engineering's reach, both nationally and globally, as well as provide advanced educational opportunities for students constrained by family, work, and/or location. Examples of these constraints include military servicemembers and veterans, young engineers starting families, or more seasoned engineers whose career paths will not allow the disruption a residential program requires. Further, this program incorporates professional skill development, covering skills of great value to emerging, innovative engineering business leaders.
- **Constituent Outreach and Engagement**: The D.Eng. degree extends the type of academic programs offered through World Campus and opens up opportunities for a larger online presence for the World Campus and related programs. The nature of the D.Eng. provides for an acceleration of knowledge transfer from research to application.
- **Driving Digital Innovation**: The program develops personalized learning elements given the broad range of interests within industry-based research and development.
- **Enabling Access to Education**: Increases accessibility to doctoral studies through distance learning for employees and individuals whose work/personal responsibilities preclude a residential program.

- **Engaging with Students**: Provides opportunities to engage with industry (and real-world needs). The research the students present address problems identified and developed in close collaboration with industry.
- **Fostering and Embracing a Diverse World**: The online doctoral program lends itself to recruiting non-traditional adult learners who cannot leave their work or family responsibilities to attend a residential doctoral program. This creates opportunities to increase diversity among the student population, including opening more options for any learner who struggles to balance career and family.
- **Enhancing Global Engagement**: One of the core professional courses is our cross-cultural, international collaboration and virtual teaming course. Partner institutions may see this as an attractive adjunct to their programs. By providing opportunities to pursue this advanced degree online, international students may be attracted to join the program, for which travel and living expenses may otherwise deter participation.
- **Driving Economic Development**: Focused on industry and applied applications, graduates will drive research and new product development within their organizations. Creating an avenue for additional students to pursue applied engineering research creates a greater skilled workforce to address the key issues facing our world in the future. By engaging various departments across the College of Engineering in an applied research focused doctoral program.

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