Examining the Nature of Technology Graduate Education

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Introduction

According to the Association of Technology, Management, and Applied Engineering (ATMAE), graduate-level studies in technology are designed to prepare technologists to focus on the applied challenges of society, industry, and government through integration- and implementation-oriented activities (2009). Although the association's affiliated institutions and membership have been interested in research and graduate education for many years, increased discussion is needed concerning both the goals and delivery of graduate programs leading to master's and doctoral degrees related to the field for the 21st century. Many of the academic participants in this organization, as well as others, work at universities that include a College of Technology (COT) or similar department-level entity associated with applied engineering, management, or industrial technology. Many of these organizations are currently examining their research and engagement efforts in light of the currently shrinking state and federal budgets and an increasing demand on the part of faculty and students for resources to conduct research. As such, these institutions are exploring ways to align strategic plans with university, state, and federal objectives. They are trying to engage industry in a manner that provides value to both parties. All of this is taking place in an environment where future funding streams and organizational infrastructures are uncertain. In order to promote confidence in the academic research agenda of technology-based programs, a clear vision for research and engagement efforts in technology disciplines is necessary.

The authors advocate a definition of research activity and strategy that includes traditional funding sources for research, as well as a fresh look at how an engaged graduate program in a technology discipline would function. The strategic plans for both the university and the college where these authors are employed revolve around the following mission: serving the citizens of the state, the nation, and the world through discovery that expands the realm of knowledge; learning through dissemination and preservation of knowledge; and engagement through exchange of knowledge. A major goal of a technology department or college should be to further develop graduate education in fulfillment of this vision.

Presently at the authors' institution, the COT is going through a process of implementing individual master's degrees in the academic areas of each technology department in the college while continuing to deliver the Ph.D. in Technology at the college level. Such work has caused the technology graduate faculty to (a) formulate the role of graduate education within the context of the larger university community, and (b) articulate how graduate education in technology may differ from that of the other colleges and schools in the academy. While the authors acknowledge that the depth and breadth of implementation of the suggested research activities in this article will vary among institutions, it is hoped that any technology-based department or college could generalize this approach to advance graduate education at its institution.

The purpose of this paper is twofold. This work presents a general discussion of the theoretical foundation for graduate education in technology followed by specific applications of research activities within graduate education in technology. This paper represents the authors' view of the role of graduate education in (a) advancing the knowledge base, (b) adapting a research paradigm, (c) preparing the future Technology faculty, (d) capitalizing on the research interests of the faculty, (e) addressing industry's challenges in implementing and adapting technology, and (f) structuring graduate education in technology.

Advancing the Knowledge Base

Discovering, integrating, applying, communicating, and teaching the knowledge of doing are integral to undergraduate and graduate education for professions in technology, where technology is defined as those fields that apply practical knowledge in improving the human condition. A typical undergraduate technology program is based more on students' initial acquisition of knowledge and skill within the technical areas under study, graduate technology education is based more on developing students' abilities and achievements in scholarship. Boyer (1990) presented a model encouraging active participation in a wide range of scholarship for the higher education community, including the Scholarship of Discovery, the Scholarship of Integration, the Scholarship of Application, and the Scholarship of Teaching. Such a model is particularly salient in identifying the goals of technology graduate education. In a research-intensive university environment, these attributes cannot be demonstrated in a coursework-only graduate program. Graduate programs at such institutions require a student-specific degree plan of study that provides learners with the requisite experiences to acquire knowledge and skills needed for graduate students to develop focused research agendas. The plan of study should be a well-thought-out regimen of coursework enabling the learner to demonstrate scholarship by the completion of a directed project, thesis, or dissertation used to investigate and report on a significant undertaking in discovery, integration, application, or teaching related to technology.

Adapting a Research Paradigm

Central to identifying the mission of graduate education in technology is the articulation of the appropriate domains of inquiry. Bush's (1945) work titled Science:The Endless Frontier presented a linear model representing the post-World War II view that discovery in science gives rise to applications in technology. Based on this model, the domains of basic research and applied research are seen as independent and almost unrelated. Whereas basic research is conducted by "scientists" for the sole purpose of understanding the nature of phenomena, applied research is conducted by "technologists," and it is directed solely at solving societal problems. Stokes (1997) presented a more robust model for the domains of inquiry, which can become the research paradigm for technology graduate education. This model considers the desire of investigators to undertake the quest for basic understanding and the consideration of the use of research and inquiry. The mission for discovery, integration, application, and teaching in a COT context can be identified in a model adopted from Stokes' (1997, p. 73) four-quadrant graphic shown in Figure 1.

Research is inspired by whether it promotes understanding of the fundamental elements of a discipline and whether there is further utility to

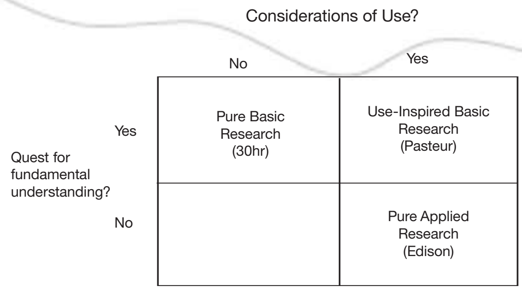

Figure 1. Quadrant Model of Scientific Research

the research results once they are known. Research in its pure, basic form known to other disciplines (e.g., physics, biology, chemistry) does not typically occur in technology disciplines mainly because of the mission of technology-centric education and research in general. However, use-inspired basic research and pure applied research are more common, and these can define that nature of scholarship in technology graduate programs. This focus is not on fundamental scientific behavior, but rather on applied usage of basic science and extension and validation of novel tools and techniques.

Preparing Future Technology Faculty

Demographic surveys conducted by Zargari and Sutton (2007) document the need for institutions offering technology degree programs to have a well-qualified faculty. Their survey demonstrates the need for providing graduate education leading to the terminal degree in the field because attaining such degrees is an important criterion in hiring, awarding tenure, and promoting technology faculty. Doctoral programs specific to technology are limited, creating a need that must be addressed as undergraduate programs in technology continue to grow. The work of Golde and Walker (2006) provides a paradigm helpful for identifying the goals of graduate education in technology in preparing the future stewards of the technology disciplines. According to their view, "a steward of the discipline considers the applications, uses, and purposes of the discipline and favors wise and responsible applications" (p. 13). Well-thought-out and delivered graduate programs in technology should focus on increasing productivity in the scholarship of discovery, integration, application, and teaching for the professions in technology. Such learning is often developed through a mentoring process where graduate students work closely with their major advisor pursuing discovery, learning, and engagement projects. Scholarship in technology that focuses on discovering methods for extending the state of the art (integrating cutting-edge tools, techniques, and methods) expands the literature in the field. Applying this knowledge in business and industrial settings, and improving technology teaching as a result of graduate education contributes to the field and will help address the faculty needs of future technology programs in the colleges and universities in the nation.

Capitalizing on Faculty Research Interests

College and university faculty members who are heavily engaged in research behave in a fashion similar to independent entrepreneurs who seek funding through grants to advance their research agenda. Much of the funding they secure is used to hire graduate students to engage in research work, which leads to student theses, directed projects, and dissertation topics. This work is disseminated through conference presentations and publications; often it leads to further research opportunities. This cyclical process, when implemented strategically, results in focused recruiting of graduate students into a program, funding to support graduate students, scholarly publications, course development, and advances in the application of technology. Prospective graduate students who are interested in becoming part of this entrepreneurial-scholarship model should find the work of Baylor, Ellis, and Redelfs (2000) to be a helpful resource in choosing the appropriate institution and program. Although these authors were not writing about graduate education in technology, their work is helpful for all prospective graduate students seeking an institutional match for their professional development. The following questions posed by these authors (p. 7) are important:

- Does the faculty exhibit special strengths and research qualities through their graduate advisees, published works, and funded research?
- Are the libraries, laboratories, computers, and other research facilities adequate for your educational needs?
- How senior are the professors in your area, what are their interests, and what will their availability be?
- Does the department of interest offer a sufficiently large and varied curriculum to allow you a broad offering of courses and options?
- What are the degree requirements? Number of hours of coursework required? Major exams? What are the expectations for a thesis or dissertation?
- How long will it take to complete the program?
- What is the completion rate of the general graduate population?
- Is there funding available in the form of teaching or research assistantships?

Addressing Industry's Challenges Implementing and Adapting Technology

It is well documented that industry faces a shortage of technical talent in the areas of engineering and science due to increasing competition from foreign states and the decreasing enrollment of domestic students into those fields at our own universities (Keating et al., 2005; Jackson, 2003). One of the key questions that many people within research universities, and specifically within technical domains, ask is how can a contemporary university partnership with an industry partner effect change and have an impact on industrial processes without changing the fundamental role of the university? The literature suggests that the fundamental nature of that relationship would not change the role of the university, but rather it could strengthen the bond between the corporate world and academia, as well as provide meaningful experiences for students at all levels. Because many large research institutions are also land grant universities, and there is at least one land grant university in most states, readers need to look no further than that model to draw inspiration for what is being proposed.

According to the United States Library of Congress Web site (2008), the original mission of a land grant college was to provide higher education opportunities for the citizens of a particular state, especially in the areas of agriculture and the mechanical arts. By design, a set of public universities was given a charter that included engagement with industry for the betterment of society. However, over time this has evolved into an enterprise of sorts as universities compete for industrial and federal funding to support research initiatives, which are often driven by regional economies or federal defense and energy agendas (Kennedy, 1995).

Complimentary to this larger federal initiative, Boyer (1990) has suggested a revised role for the universities based on several factors, including faculty compensation and incentives. One facet to his approach has been to delineate scholarship in certain areas: discovery, integration, application, and teaching, and the premise is that excellence in these areas by faculty makes for a more holistic experience for students and a more productive working environment. So how does this relate to graduate education and research at large universities? In the COT, the notion of the scholarship of application would likely be considered engagement-—with industry, federal agencies, education, or the community. It would involve bringing the intellectual resources of the university to bear in solving an applied problem that has affected the constituents or partners of the university. In the case of engagement with industry, this would likely mean funded activities to solve a specific problem.

The most expeditious method for doing this type of work is to have teams of undergraduate and graduate students funded to work on engagement projects. In a technology discipline, giving graduate students a thesis project that has real-world applications is ideal. It provides them an applied scenario upon which to direct their efforts, and it is more in line with their coursework than something that is rather esoteric in nature. However, the results of these activities may or may not be available externally because of intellectual property issues or federal controls, which should be carefully negotiated before the project commences. Although this secrecy of results may not coincide with the tenets of the original land grant mission, it is certainly a reality in the contemporary economic climate.

Even though engagement work with industry partners can contribute to the learning and maturation of graduate and undergraduate students, the university can also provide ongoing professional education to the incumbent workforce, which is also in line with the mission of a land grant university. Practicing professionals in technical disciplines struggle to keep pace with changing technology in light of their job requirements, and universities with technical- and technology-based degree programs can address the need for professional education (Dunlap et al., 2003; Keating et al., 2005) through the applied nature of the curricula. In doing so, technology departments could address the ongoing training and education of engineers, technologists, and managers from entry-level positions through senior managers and directors by providing coursework that deals with project management, measurement and analysis, training and human resource development, as well as many technical areas, depending on the company and faculty involved. These professional programs may best be delivered in non-traditional ways through distance education, weekend programs, or other hybrid delivery methods. It is also possible to develop a professional program that can become revenue-generating, which can be invested in both the traditional and professional graduate programs.

Table 1: Graduate Student Expected Outcomes (Purdue University College of Technology, 2007)

Each graduate student should be able to:
Envision, plan and conduct research and development activities;
Identify, comprehend, analyze, evaluate and synthesize research;
Evaluate technologies and technology-related programs;
Assess individual performance with, and understanding of, technology;
Communicate effectively and employ constructive professional and interpersonal skills; and
Function effectively in one or more of the technology disciplines.

Structuring Graduate Education in Technology

Based on the discussion of scholarship in technology, the graduate faculty at the authors' institution have identified a range of student outcomes. The outcomes, presented in Table 1, are helpful in communicating student expectations in technology graduate education and in providing a foundation for assessing the quality of the program.

Documenting the expected student outcomes is not only important for internal quality control but also for serving as the foundation for specialty and regional accreditation. Accreditation is paramount for the institution's credibility. Standards identified in resources such as the Handbook of Accreditation (2003) of the North Central Association–Higher Learning Commission require programs to identify and document student attainment of such outcomes similar to Table 1. Recently, the Association of Technology, Management, and Applied Engineering Board of Accreditation was granted permission by the Council on Higher Education Accreditation (CHEA) to accredit master's degree programs in addition to associate and baccalaureate degrees (Eaton, J., personal communication, May 4, 2009). The authors of this article predict the number of institutions undertaking such specialty graduate program accreditation will increase.

Master's-level COT graduate students are given the option of conducting a directed project ora thesis using an on-campus or a weekend model to demonstrate attainment of the program's learning outcomes. On-campus students are typically funded as graduate teaching or research assistants while weekend students typically work in industries related to the COT and receive a combination of at-the-workplace and on-campus instruction. According to the handbook for the Master's of Science degree at the authors' institution (Purdue University College of Technology, 2006):

> The directed project is an applied research project that is more extensive and sophisticated than a graduate-level independent study and less formal than a master's thesis. The overall objective of the requirement is to engage each graduate student in a study, typically industry or business focused, which is sufficiently involved as to require more than one semester to conceive, conduct, and report. The focus is to be placed on a topic with practical implications rather than original research. In so doing, the project should reflect the mission of the College of Technology by advancing technology through developmental research, innovation, and invention. (p. 8)

Graduates who wish to conduct more formal inquiry, or who intend to pursue a doctoral degree after completing the master's degree are encouraged to follow the thesis option to demonstrate the program's learning outcomes. The Handbook (2006) provides the following explanation of a thesis:

> A Master's thesis in Technology is a significant piece of original work, typically involving research, a formal written description of that research, and an oral defense of the research. It should contribute new knowledge to the discipline, but will include an extensive review of what others have contributed to the topic as well. The tone should be scholarly, with a primary audience of other researchers (p. 9).

COT doctoral students demonstrate achievement of the learning outcomes by completing coursework designed to further develop their scholarly abilities and by completing a Ph.D. dissertation that is a significant piece of original work conducted by the student under the direction of an appropriate graduate faculty committee, resulting in scholarship of discovery, integration, application, or teaching that contributes to the knowledge base of the field. Technology Ph.D. recipients pursue careers in higher education, business, industry, and government – regionally, nationally, and internationally.

In addition to the nature of technology graduate student research, a particular set of coursework is critical in achieving these research objectives and learning outcomes. It will provide a foundation upon which students build their research objectives. This coursework is also important in developing a suitable graduate to serve and engage industry in solving challenges with technology. Courses that would be critical in accomplishing this mission would include the following:

- Research Methods
- Data Analysis Techniques
- Project Management
- Global Technology Issues
- Ethics and Technology
- Integration and Implementation of Technology

Research methods and data analysis are important so students can make decisions while conducting research process and executing the project. Background in project management would be somewhat tailored to a specific technology domain; however, topics such as budgets, goals and objectives, and personnel selection can be common to all domains. The effect of technology on a global society has become increasingly important as commerce, academics, and government transcend national borders, and the impact that technology has regarding ethical decision making is important for both accepting and implementing that technology. The topics of implementation and integration help students to understand the effects that technology can have on people, systems, and organizations, regardless of the technology domain in question. Although this list of courses is not comprehensive, it can provide a foundation for many academic institutions to implement.

Conclusion

The work of Applegate (2002), titled Engaged Graduate Education: Seeing with New Eyes, offers inspiration that can be applied to graduate education in technology when the author discusses the role of three important attributes for improving higher education, namely vision, passion, and action (p. 4). The vision for technology graduate education presented in this article was centered on the scholarship of discovery, integration, application, and teaching. COT graduate students and faculty are challenged to pursue this scholarship with passion, thus improving undergraduate and graduate education for the professions in technology, integrating the unique contributions of technology into the academic institutions while contributing to the further development of the knowledge base in the field. Finally, a commitment to action is needed. Such actions can include technology professionals' commitment to continue process improvement in education, lifelong learning, and scholarly productivity in the field. Graduate students and academics in technology can facilitate this action by developing and pursuing clear agendas for the scholarship of discovery, the scholarship of integration, the scholarship of application, or the scholarship of teaching.

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