The Professional Doctorate in Technology Leadership, Research & Innovation

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ABSTRACT

Expertise demands engendered by the convergence of pressure for increased competitiveness and the accelerating advance of technology have become obvious to leaders in technology-centric business and industry. Because the Polytechnic's faculty maintain active engagement with such business and corporate leaders and their enterprises, they also recognized signals which evidenced that there were responsible personnel in the private sector who would benefit from, and actually want, an advanced technology-oriented degree above the master's level. But, the faculty also noted that because of the career development stage and responsibilities of these personnel, they were not likely to be willing, or able, to pursue a traditional university Ph.D.

A thought-leading team of Polytechnic faculty from diverse departments was assembled to research and conceptualize what such a degree might look like and how it might be best delivered. The team launched two parallel research efforts, one to ascertain what precedents and experiences with similar goals existed around the world, i.e., an international review of other doctoral programs addressing similar needs, and the second was to conduct an interest and needs assessment of a sample of high probability individuals. The findings of both studies were positive, and their key features incorporated in this paper.

This paper describes the outcomes of a successful program development and approval process and the planned phasing of its implementation. The development team treated the

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existing program approval mechanisms, as found in most universities and states, as a staged-gate approval process. This necessitated the development of (1) a conceptual proposal, (2) a competitive analysis, (3) a detailed program plan, (4) an implementation plan, and (5) a formal proposal with supporting data as required by the state coordinating body for higher education.

The program that evolved from this process was an industry-facing, distance/on-campus-hybrid professional doctoral program permitting extensive tailoring of the learning experiences. This enables enrollees to address a need/problem/issue specific to their enterprise while simultaneously accomplishing and advancing along on one or more of the program's key competency vectors. This paper provides an overview of the initial set of program competencies and describes their intended use for candidate assessment (both self and by program faculty). Competency components and scaffolding for building expertise as candidates progress to earn their degrees are also described.

In addition to the description of the actual doctoral program, this paper will also share the support mechanisms necessary to deploy such a program in a doctoral extensive land grant university. Specifically highlighted will be the role of a dedicated business unit designed to streamline typical university bureaucracy in order to provide responsiveness and services consistent with the expectations of a competitive private sector world.

Finally, this paper concludes with an overview of the program's next steps and the sharing of a set of collegial questions directed to other institutions interested in addressing similar needs.

Introduction

The Purdue Polytechnic Institute's Doctor of Technology program, recently fully approved by both the university's and State's authorities, has been launched and is currently underway in its soft-start phase. A pilot cohort began January 2019 with a hybrid learning experience consisting of two courses presented in a semester-long, on-campus, weekend format.

This paper overviews the vision, rationale and design of the Polytechnic's Doctor of Technology program. Subsequently, it describes the implementation strategy and then concludes with an overview of next steps and collegial questions to be considered by colleagues also addressing similar purposes and target audiences.

Our work has resulted in a program that is believed to be a model for a professional doctoral program designed to meet the current and future needs of contemporary business and industry for people with **advanced technology research and development skills and leadership competence**. In an earlier paper [1] where the rationale and its foundation in an extensive review of professional doctorates in the USA, England and Australia was presented, we reported that "Clearly competitiveness, efficiency, quality and sustainability are critically important and increasingly interrelated characteristics that determine the future viability of enterprise on both sides of the Atlantic and in fact around the world." Our assessment was that these characteristics would require a small number of high-level professionals with practical, i.e., applied expertise in systematic research and development – not the abstract disconnected basic research so prized by universities and academics. Instead, we sought to emphasize the "use-inspired, agile and practically-focused research called for in *Pasteur's Quadrant* [2] and more recently by the Swiss National Science Foundation [3]. Fraunhofer

IAO's Gelec & Wagner [4] noted in particular the increasing need for, and importance of, highly skilled R&D personnel as a major conclusion of their 162 advanced industry study[5]." Note that we do not claim that all doctoral graduates go to academia, but the cited literature indicated that universities have frequently, if not predominantly, structured their PhD programs as if this was the case.

We posit that a Doctor of Technology (D.Tech) will attract and develop professionals with such skills and inclinations! Such a doctoral level program will generate leaders at the highest end of the capability spectrum. People with such a competence profile should be in high demand around the world, particularly by start-ups, emerging businesses and established corporations operating in the advanced technology arena.

What Is A Professional Doctorate?

The Polytechnic's professional doctorate in technology is designed to be delivered by both on-campus and distance methodologies, primarily in a hybrid fashion. We are seeking to enhance the performance of industry, business and other enterprises by providing high-capability leaders competent with a significant technological R&D skill set <u>and</u> the motivation to innovate. We are not alone in seeing such needs. English, North American and Australian colleagues have also noted and responded by evolving what we perceive to be similarly oriented degrees. See Maxwell [6] and Zusman [7] for example. The latter reported that "by 2013 there were professional practice doctorates in at least a dozen fields in the U.S. with "more than 10,000 degrees awarded just in 2011-12 and roughly 35,000-40,000 students enrolled. (p.1)" However, it is important to note that just as Kot & Hendel [8] reported in 2012, we also observed that now, some seven years later, there is still no single definition of the professional doctorate. The authors [1] found, however, that there seem to be a convergence of thought along these lines:

> Simply put, professional doctorates focus on in-depth, cutting-edge technologies, innovation skills and the leadership and effective organization of teams and corporate units. Such programs seek to prepare advanced level practitioners for business and industry rather than basic researchers for the academy. The goal is enabling increased competitiveness, sustainability and socially responsible endeavor. (p.27).

Because contrast often engenders clarity, we noted and cite Bourner et al. [9] who have used nineteen attributes to differentiate the professional doctorate from the traditional Ph.D. as shown in Table 1.

Table 1. Professional vs. Research Doctorates [9] (p.30)

Attribute	Academic Ph.D.	Professional Doctorate
1. **Career focus**	Entry into academia	Professional doctorates nearly always claim to address the career needs of aspiring professionals
2. **Domain of research topic**	Disciplinary theory	Professional practice
3. **Research type**	'original investigation undertaken to gain new knowledge and understanding but not necessarily directed towards any practical aim or application' (p. 71)	Issues of real interest to the profession
4. **Research focus**	A perceived gap in the literature	A problem encountered in practice
5. **Starting point**	Finding what is known in the literature	A problem for which the solution is unknown
6. **Intended learning outcomes**	Contribution to the literature	'A significant original contribution to knowledge of • professional practice through research, plus one or more of the following: • personal development (often specifying reflective practice); • professional level knowledge of the broad field of study; • understanding of professionalism in the field; • appreciation of the contribution of research to the work of senior professional practitioners.' (p. 72)
7. **Entry qualification & degree**	Undergraduate degree with high marks	A Master's degree is often required
8. **Experience as admissions requirement**	None	1-5 years usually expected, with a median of 3
9. **Taught component**	Minimal, under the "traditional Ph.D. model"	Ranges from 15 to 50% of degree requirement
10. **Modularity**	Relatively unstructured according to the "traditional Ph.D." model	Modular course and credit structure
11. **In-service vs. Pre-service**	Pre-service for research career	In-service for professional career, often taken while working
12. **Mode of study**	Full-time	Part-time
13. **Integration of work/study**	N/A	High
14. **Integration of practice/theory**	Low	High
15. **Cohorts**	No	Yes
16. **Variability of duration**	Very high	Low
17. **Research outcomes**	Long dissertation	Shorter dissertation, often more than one; project reports
18. **Assessment**	Dissertation driven	Separately assessed components
19. **Breadth**	Narrowly focused	More broadly focused, problem-driven

Another primary factor in the design of the Purdue Polytechnic's Doctor of Technology was the necessity of meeting the US Government's requirement for recognition of a doctoral level degree. Specifically, the US Department of Education's Integrated Postsecondary Education Data System (NCES, n.d.) (IPEDS) states a "Doctor's degree-professional practice" is [10]:

> A doctor's degree that is conferred upon completion of a program providing the knowledge and skills for the recognition, credential, or license required for professional practice. The degree is awarded after a period of study such that the total time to the degree, including both pre-professional and professional preparation, equals at least six full-time equivalent academic years.

Program Development

In addition to the extensive review of the literature, of which only highlights were shared in the preceding paragraphs, the faculty team designing this program conducted a survey and needs assessment of a large (300+) cohort of professional master's degree alumni. This work, and the experience of dealing with a similar clientele, albeit at the master's degree level, enabled the development team to draft a proposed program. Subsequently the proposal was reviewed by the Institute's regular graduate programs committee consisting of representatives from each constituent department or school. This committee included representatives from the disciplines of Aviation Technology, Building Construction Management, Computer Graphics, Computer & Information Technology, Electrical & Computer Engineering Technology, Mechanical Engineering Technology, and Technology leadership and Innovation. After several iterations of feedback and revision, the proposed degree was approved by the Polytechnic Institute. Then the process was repeated at the University's Graduate School level. Once approved there it received further approvals from the Provost and University president who then forwarded it to the state's coordinating board for higher education. Because of the substantial rationale and evidence that was presented there were no issues raised once the proposal was approved by the Graduate School.

Professional Doctorate Program Description

The resulting degree, i.e., the Doctor of Technology, will be awarded pursuant to successful completion of a three-year program of study and an industry-relevant dissertation based on applied research, i.e., use-inspired, technology-focused research. With all approvals in hand, the developing team then turned their attention to finalizing the specific features of the degree. The program builds upon the knowledge and skills developed in a previously earned MS degree or alternatively it requires completion of the equivalent as a prerequisite to candidacy.

Delivery

One of the design specifications contained in the approved proposal was that the Doctor of Technology graduate degree program would be delivered as a hybrid model from Purdue University's West Lafayette campus to active/employed technology professionals. In the approved program proposal, we [11] stated:

> Our vision is to employ a hybrid delivery system involving predominantly distance learning education plus some campus-based experiences that make the achievement of a doctoral degree far more accessible to practicing professionals who would not pursue a doctorate or Ph.D. in a traditional campus setting due to their work and home responsibilities.
>
> …
>
> The proposed Doctor of Technology degree is a professional doctorate [12], i.e., a terminal degree, focusing on in-depth understanding of and capability with technology and the concomitantly necessary, innovation and leadership skills of middle and senior leaders in industry, business, and government as well as NGOs. As contrasted to the 'traditional' Doctor of Philosophy's intent to develop *professional researchers*, the professional doctorate is designed to develop *researching professionals in technology* primarily for environments other than the academy. (p.3)

Outcome Competencies
The Doctor of Technology will require candidates to demonstrate the following competencies prior to graduation:

- Envision, plan and conduct applied research and development activities;
- Employ quantitative, qualitative, analytic and statistical techniques to technological problems;
- Identify, comprehend, analyze, evaluate and synthesize research and professional practice;
- Evaluate technologies and technology-related programs and leadership activities;
- Assess individual performance with, and understanding of, technology;
- Function at a high level in one or more of the technology disciplines;
- Apply advanced leadership practices to organizational challenges; and
- Communicate effectively and employ constructive professional and interpersonal skills.

Examples of sub-outcomes for learning outcomes listed above include but are not limited to:

- Envision, plan and conduct applied research and development activities:
  - Generate a proposal for an applied R &/or D project
  - Write and defend an applied dissertation
  - Understand and employ Research & Development processes
  - Use basic and advanced statistics appropriately

- Identify, comprehend, analyze, evaluate and synthesize research and professional practice:
  - Advanced literature search & retrieval from technological, government, corporate, and international sources
  - Assess & synthesize information
  - Employ data analytics & visualization
  - Identify the R&D spectrum & TRLs within a field
  - Become aware of the forms and characteristics of intellectual property

- Evaluate/assess technologies and technology-related programs:
  - Perform a technology assessment employing critical criteria
  - Describe the pros and cons and intended and unintended consequences of technology policy
  - Create a technology roadmap & forecast
  - Benchmark a technological system with key performance indicators

- Assess individual performance with, and an understanding of, personal characteristics, leadership, and technology:
  - Engage in systematic technological futuring
  - Develop and implement a personal professional development plan focusing on technological and leadership capability
  - Conduct a personal SWOT analysis
  - Maintain a portfolio documenting personal growth and performance

- Employ constructive professional, interpersonal and communication skills;
  - Document the conceptualization and conduct of an industrial/business technology-related research R and/or D project with an in-depth cogent research report
  - Prepare compelling presentations tailored for specific audiences

    - Generate written professional, technical and public-oriented documents

- Function at an advanced level in one or more of the technology disciplines:
    - Apply systems theory to root cause analysis of a technological challenge/problem
    - Demonstrate the ability to resolve technological problems into their energy, material and information components
    - Develop an analysis matrix of information, material, & energy flows in a technological system
    - Employ systems analysis to describe an unknown technological solution
    - Perform systems engineering in designing a prototype technological solution
    - Analyze new product development & technology management cases
    - Apply technology management processes and strategy
    - Conceptualize technological innovations in the field

- Employ quantitative, qualitative, analytic and statistical techniques to technological problems:
    - Perform multivariate analyses and test the significance of the finding
    - Demonstrate effective content analysis of textual, audio, or visual data

- Apply advanced leadership practices to personal and organizational challenges:
    - Employ conflict resolution techniques to increase the effectiveness of an organizational unit/team
    - Evolve a plan to capitalize on the diversity of a work group

These target competencies will be systematically developed as candidates progress through the D.Tech program. We are employing scaffolding of outcome competencies, both across and within courses, to ensure that existing entry level competencies are progressively raised to higher performance levels over the duration of the program. Overall, we are seeking to create in our program, and have assimilated by our candidates, a high performance, research-informed culture balanced between the immediacy of business/industry and the longer reflective nature of academe.

Target Clientele

The target clientele for the program is envisioned to be practitioners from the middle and upper ranks of business and industry, i.e., persons with a documented record of performance and considerable relevant experience and who already possess their master's degree. Typically, this upwardly directed career trajectory of increasing responsibility is observable in vitae and thus has become a component of the applicant selection process.

Because this is an industry-facing doctorate, intending to primarily serve those already employed in a significant position, our goal is NOT necessarily to help enrollees change to another employer, but rather to help build enrollee competence to enable them to accelerate their career trajectory. If that enables them to move to another employer fine, but this is not our primary goal.

The intended enrollees are already employed in a significant position in industry/business. Given this they are viewed as having the means necessary to fund their enrollment and/or that they will be sponsored by their employer.

Instructional strategies

The development team sought to incorporate best practices, such as those highlighted in the National Research Council's *How People Learn* [13] and *How People Learn II* [14], in the learning activities experienced by the candidates. Our goal was to deepen and accelerate learning by employing andragogic approaches, instructional technology and extensive and tailoring of the learning experiences to aid aspirants in furthering their competence. All students will be required to complete a culminating/capstone research and development experience and documenting this by means of a formal dissertation focusing on applied/use-inspired research of direct relevance to professional practice in any of the arenas of today's complex technology-based enterprises. Typically, such dissertations will advance the state of a technology or practice from one Technology Readiness Level to the next higher level. This dissertation must necessarily be defended before the candidate's graduate committee. We anticipate including a senior industrialist/technologist from the candidate's technological field in the graduate committee.

But more needs to be said about the instructional strategies that will best fit the mature and busy professionals targeted by the D.Tech. Beyond just a constructivist approach, the design team was guided in particular by the valuable insights in the previously cited *How People Learn II*. We were informed by Chp. 4 Processes that Support Learning which led to our engaging candidates in collaborative knowledge building (e.g., by cohort construction of a field's/process' knowledge base using Wiki technology). We also incorporated self-regulation of learning as required by our mix of synchronous and asynchronous learning activities. Then, to insure critical reflection, we installed frequent opportunities for self-assessment (of the quality of their information sources and subsequent analyses of the extracted material; of their writing and presentation skills when compared to outstanding experts; are incorporated in their course work). Note also that, to accommodate different learning styles/preferences or personal situations, we are deploying both a hybrid (Face-to-Face combined with distance-supported) learning opportunities.

Similarly, *How People Learn II* (Chp. 6), highlighted the importance of motivation and we address this by (1) only selecting highly motivated and capable people into the program and (2) providing extensive opportunities for candidates to tailor their learning experience to their stage of development, their needs, and their future – both within their courses and by their selection of specialized courses in their disciplinary track. Another design feature that augments motivation is that we are encouraging candidates to situate their research within their employer's context and needs.

Course & Other Requirements

The Doctor of Technology degree requires successful completion of a plan of study involving courses, beyond the master's degree, developed in concert by the student and their graduate committee and adhering to all Graduate School requirements. The Plan of Study requires students to take:

- 21 credit hours of core curriculum consisting of:
    - Technology and Society (3 credit hours)
    - History of Science and Technology (3 credit hours)
    - Global Supply Chain Management (3 credit hours)
    - Global, legal and Ethical Issues in Technology Leadership (3 credit Hours)
    - Philosophy of Technology (3 credit hours)
    - The Design Process (3 credit hours)

    - Technology from a Global Perspective (3 credit hours)
- 15 credit hours (minimum) for a dissertation is required for the Professional Doctor Technology degree. This will be an applied R&D project focused on a current problem of a company or industry and the results must be defended to the graduate committee. Depending on the nature of the applied research dissertation, it may or may not require laboratory research. And, if it does this may or may not occur at the university or in the employer's research facilities. Our design goal is that each candidate will complete an applied research study, and document it via a doctoral dissertation, that engenders ROI (Return on Investment) for the candidate's employer.
- 24 credit hours of specialization in any of the technological fields offered by the Polytechnic Institute and by Purdue University. These specializations range from aviation technology, various computer technologies, electrical, mechanical and industrial technologies, as well as technological innovation and leadership.

These courses are taught at a significantly higher level than our UG and Master's degree courses. Expectations are increased for both the quantity, nature, and quality of their work. In addition, our rules require that a substantial proportion of these courses be at the 600 level, a designation the university employs to indicate courses primarily restricted to doctoral students. Of the plan of studies courses, about a third of the specialized and in-depth focused courses come during the departmental/disciplinary track tailoring.

The program's direct instructional duration is scheduled to be three years, but graduation time depends on how successfully the candidate integrates their research with their course work. The most likely time to graduation will range from 3-4.5 years depending on the nature of the applied research dissertation.

Given the fact that his program has been approved by College, Graduate School, University, and State Coordinating authorities as a doctoral program, the graduates will be entitled to call themselves Doctor and to indicate this with the DTech suffix after their name.

Institutional Strengths
The program builds upon the particular strengths of Purdue University, and its Polytechnic Institute (the largest technology unit at a Research 1 institution in the nation), by leveraging the national recognition and well-established capabilities from existing units including Aviation and Transportation Technology, Computer and Information Technology, Computer Graphics Technology, Construction Management Technology, Engineering Technology and Technology Leadership and Innovation.. Given the importance of information to advances in technology, engineering and science the noted strength of Purdue's Potter Library is germane to this point also. Central to the program's success will be the roles of a dedicated business unit focused on the special needs and expectations of mid and senior level clients from business and industry, and one focused on learning across the globe. Furthermore, other units across the Purdue University Campus also provide a rich environment for the proposed professional doctoral program by enabling supporting/cognate areas of study. These units include, but are not limited to, the Krannert School of Management, and the Colleges of Education, Engineering and Science. [11]

Implementation

Implementation of this new degree involves a two-phase startup. The first is a soft start, currently underway, with a pilot cohort of six students that began January 2019. The second phase is scheduled to begin in Fall of 2019 and a cohort of 12-20 is planned. Instructional delivery of the first phase is by means of a Weekend Model consisting of three full-day intensive on-campus weekends spanning the regular 16-week semester. In addition to the three on-campus weekends taught in a face-to-face mode by the program faculty, learning is augmented by faculty with regular weekly on-line help and supplemental instruction. The primary vehicle for these sessions is WebEx.

Next Steps and Collegial Questions

The first and second phases of the startup are being carefully monitored and extensive interaction with students is occurring. Tools to this end include each student developing a personal SWOT and then evolving a set of personal goals in addition to, and within the scope, of the program's goals. Students are also tracking their learning progress using a portfolio structured to reflect both program and personal goals.

The second phase will also provide students with an additional choice. The new cohort will be offered a choice to pursue their degree primarily on line or by the hybrid model described in the soft start phase. Subsequently, the program authors are planning a follow-up study to secure feedback from the first two cohorts and their employers.

More immediately, however, the faculty team will be engaged in a process to harmonize and scaffold objectives and assignments across the core courses taken by all candidates. This is critical because it was recognized that the high-level competencies being addressed by the Doctor of Technology degree do not exist in binary form, i.e., that candidates either have them or not. Instead, they exist in a range of levels, i.e., for example that communication or problem-solving skills can be manifested across a range from only very basic to very sophisticated capability. Given this, in order to ensure that the program develops the high level of skill commensurate with what is expected of doctoral level graduates, the program must take every step to build and reinforce the skills of its candidates with a form of spiral curriculum culminating in ever higher proficiencies.

Because the faculty are committed to continuous improvement and in recognition of the pilot nature of the first two cohorts in this program, we are also designing a follow-up study of the first graduates and their employers. This research will be guided by the currently implemented formative evaluation process results and by suggestions from the cohort members themselves.

To conclude this paper, the authors wish to share with their colleagues addressing similar clienteles a set of questions and opportunities to collaboratively engage in discussions furthering this important direction for the academy:

1. How are you addressing the needs of industry for doctoral level personnel?
2. How do you teach development as in R&D?
3. What are the cutting-edge instructional technologies in distance learning?
4. How can the persistence and throughput of distance programs be increased?
5. What forms of inter-institutional collaboration could exist to advantage both institutions and candidates at this level?

References

[1] M. Dyrenfurth, K. Newton, M. Springer, M. Johnson, and R. Rapp, "The Professional Doctorate for Engineering & Technology Professionals," paper presented at the 2016 ASEE

Annual Conference & Exposition, New Orleans, LA, USA, June 26-29, 2016, Washington, DC: ASEE, 2006 paper 26996. Available: https://peer.asee.org/26996 [Accessed January 26, 2019]

[2] D.E. Stokes, *Pasteur's Quadrant – Basic Science and Technological Innovation.* Washington, DC: Brookings Institution Press, 1997.

[3] Swiss National Science Foundation, *Use-inspired basic research,* 2017. Available: http://www.snf.ch/en/theSNSF/research-policies/use-inspired-basic-research/Pages/default.aspx. [Accessed January 2017]

[4] E. Gelec and F. Wagner, "Future Trends and Key Challenges in R&D Management-Results of an Empirical Study within Industrial R&D in Germany," in *Proceedings of the R&D Management Conference*, June 3, 2014. Stuttgart, Germany: Fraunhofer IAO, IAT Universität, Vol. 6, pp. 920-26, 2014. Available: *publica.fraunhofer.de/documents/N-307380.html*. [Accessed January 2017].

[5] M. Dyrenfurth, K. Newton and M. Springer, "Fueling Industry 4.0: A professional doctorate in technology," paper presented at the 2017 SEFI Conference: Education Excellence for Sustainable Development, September18-21 2017, Angra do Heroísmo, Terceira Azores (Portugal): Brussels, Belgium: SEFI-European Society for Engineering Education.

[6] T. Maxwell, "From first to second generation professional doctorate," *Studies in Higher Education,* vol. 28, no. 6, pp. 279-291, August 2003. DOI: 10.1080/03075070310000113405

[7] A. Zusman, "Degrees of change: How New Kinds of Professional Doctorates are Changing Higher Education Institutions," *Research & Occasional Paper Series*: CSHE.8.13. June 2013, Berkeley, CA, USA: University of California, Berkeley. Available: http://eric.ed.gov/?id=ED545185 ERIC Number: ED545185.

[8] F.C. Kot and D.D. Hendel, "Emergence and growth of professional doctorates in the United States, United Kingdom, Canada and Australia: a comparative analysis," *Studies in Higher Education*, Vol. 37, No. 3, 2012, pp. 345-364, DOI: 10.1080/03075079.2010.516356 Available: http://dx.doi.org/10.1080/03075079.2010.516356

[9] T. Bourner, R. Bowden and S. Laing, "Professional doctorates in England," *Studies in Higher Education,* Vol. 26, No. 1, pp. 65-83. 2001.

[10] National Center for Education Statistics. Glossary: Doctor's Degree-Professional Practice. (n.d.). Available: https://nces.ed.gov/ipeds/glossary/index.asp?id=942

[11] K. Newton, Proposal for a Doctor of Technology Degree. Unpublished proposal submitted to Purdue University Graduate School. West Lafayette, IN. April 2017.

[12] T.G. Gill and U. Hoppe, "The Business Professional Doctorate as an Informing Channel: A Survey and Analysis," *International Journal of Doctoral Studies,* Vol. 4, 27-31, 2009, Available: http://www.ijds.org/Volume4/IJDSv4p027-057Gill267.pdf

[13] National Research Council, *How People Learn: Bridging Research and Practice*. Washington, DC: The National Academies Press, 1999. Available: https://doi.org/10.17226/9457.

[14] National Academies of Sciences, Engineering, and Medicine, *How People Learn II: Learners, Contexts, and Cultures,* Washington, DC: The National Academies Press, 2018. Available: https://doi.org/10.17226/24783.