Curriculum Revision of a Ph.D. program in Technology Management to Keep it Relevant and Manageable

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Abstract

This work attempts to evaluate the consortium-based Ph.D. program in Technology Management at Indiana State University to offer needed curriculum changes applicable to modern time. Through over two decades of existence, the program has sought to update its curriculum to keep it relevant. Topical coursework concerning Technology Leadership, the Management of Technical Experts, Production Processes and Control, Fundamentals of Technical Finance, Project Management, Technology Marketing, Philosophy of Technology, and the Strategic Management of Technology is under consideration for inclusion in the curriculum. Increasing professional communication and collaborative proficiencies, promoting moral and ethical discourse concerning technology use, mastery of skill and professional discipline, and the ability to contribute to an ever-increasing diverse and complex professional community is sought to make the program more robust. Topical information content in terms of core and elective courses with the corresponding credit hours, skills, and experience necessary before admission and before graduation have been discussed in this paper. The discussion will be useful for universities in the US and outside that offer Ph.D. in Technology Management program or plan to offer in the near future.

Keywords
Technology, management, technology management, curriculum, Ph.D.

1. Introduction
Technology Management links engineering-related fields and management disciplines toward planning, developing, and implementing technological capabilities. It is pursed to shape and accomplish the strategic and operational goals of organizations. The field of Technology Management focuses on developing technical and management skills of people, projects, and business and industry operations. It involves the intentional supervision, control, application, and diffusion of innovation and technologies to better the intended individual, organization, or human civilization as a whole. The speed of technology transfer and technology diffusion, involves technology identification, selection, acquisition, and exploitation, which are critical toward reaching organizational strategic and operational goals.

However, the field of Technology Management can be thought of as a dichotomy too. Effective practitioners of Technology Management are concerned with the technology producer's viewpoint before technology deployment and the technology user's viewpoint upon technology deployment. This dichotomy promotes the use of applied science to determine and resolve technology-related problems. Technology management education and research activities cover this dichotomy of concerns, and the various disciplines, roles, and applications of both viewpoints. Whereas science deploys the scientific method to answer questions about the physical world, technology management deploys the scientific method to answer human-made, technological issues. As society becomes ever more complex due to human-made technology use, through technology management the need to address the issues that arise from this complexity increases.

Through earlier work, McKirahan et al. (2020) compared five Ph.D. programs in Technology Management in the United States. Indiana State University (ISU) offers one such program, which is consortium-based. They reported that

Ph.D. programs in Technology Management have similarities, but there are noticeable differences too as universities, in general, tend to differentiate themselves through their specializations. The ISU consortium-based Ph.D. program in Technology Management has existed for 23 years (ISU, 2021). The Consortium consists of Indiana State University (Terre Haute, Indiana) as the lead degree-granting institution, Bowling Green State University (Bowling Green, Ohio), East Carolina University (Greenville, North Carolina), and University of Central Missouri (Warrensburg, Missouri). None of these universities offer a Ph.D. in Technology Management outside of the consortium. The program requires a master's degree with a minimum grade point average of 3.5 on a scale of 4.0. Standardized test scores (such as GRE, GMAT) are necessary, and proven English competency (including the Test of English as a Foreign Language) is a requirement for international students. Three years of work experience in the field of technology management or a technical specialization is also required. The number of required credit hours is 83 of which 17 credit hours can be accepted from the master's degree making a minimum of 66 credit hours beyond the master's degree.

The ISU program is designed to prepare students for leadership positions in society's public and private sectors. The program seeks to provide opportunities for research toward the development, application, and transfer of technology. It prepares students to become specialists who can provide leadership in research, curriculum design, content development, and instructional strategies in teaching technological information. It also prepares them to provide service to industrial community by developing, applying, and transferring their technological expertise. Graduates of the program become faculty or leaders in academia, government agencies, or industries.

This paper is organized as follows: Next section presents a brief review of literature. The sections following the literature review discuss the current curriculum of the consortium-based Ph.D. in Technology Management, proposed curriculum, and concluding remarks.

This work attempts to evaluate the consortium-based Ph.D. program in Technology Management to offer needed curriculum changes applicable to modern time. Increasing professional communication and collaborative proficiencies, promoting moral and ethical discourse concerning technology use, mastery of skill and professional discipline, and the ability to contribute to an ever-increasing diverse and complex professional community is sought to make the program more robust so it remains relevant and manageable.

2. Literature Review

Technology is developed by people and presented in the form of tools, instrumentation, procedures, and human skills (van Wyk, 2017). Thus, technology provides assistance in human activity (Winner, 1986). Technology management is an interdisciplinary field overlapping engineering, science, technology, and management (McKirahan and Cheney, 2016). NRC (1987) reported that technology management involves planning, directing, controlling, and coordinating technological capabilities to achieve the strategic and operational objectives of an organization. Kerr et al. (2013) noted that technology management makes technology adequate, efficient, available, and practical. It is obvious from these definitions that the technology management field, hence its education is important for academia and industries because what is taught in universities is applied in industries. What is practiced in industry should be brought in to classes to provide experiential learning (Alberts et al., 2005). Therefore, Tas and Yeloglu (2018) advised for a partnership between universities and industries to strengthen knowledge transfer and develop innovative products and technologies. Industry and university partnership was also noted in Badar and Bozai (2011). Industry-sponsored projects at universities or industry-university collaboration can help find new markets, new industries and various types of innovations. Therefore, as Brent and Pretorius (2008), Yanez et al. (2010), and Zehner (2000) mentioned, institutions of higher education need to lead the way in developing programs, curriculums, departments, and institutes addressing and meeting the needs of industries and the organizations. Because of increased attention to the management of technology recently, numerous universities now offer graduate (M.S./Ph.D.) degrees in Technology Management in Canada and the United States.

In order to select and implement complex technologies, it requires engineers or technologists to understand the social, economic, and cultural context in which a technology is supposed to be used (Chanan et al., 2012) and some studies indicate that graduates are not prepared for such tasks. According to Baytieh and Naja (2011) about 70% of graduate students in engineering/technology and professionals prefer to first gain practical experience before starting a Ph.D. program. They are heavily focused on research in specialized field and there is discontent of industry that engineering/technology graduated are not sufficiently equipped with necessary skills to perform their job. Ph.D. programs should provide opportunities and training for students to become better thinkers, not just specialists. This

can be achieved by delivering inter-disciplinary programs/courses or by offering more flexibility in research or including professional development training in the Ph.D. curricula (Grimm, 2018; Bosch, 2018; Vanderford, 2012).

McKirahan et al. (2020) compared five Ph.D. programs in Technology Management in the United States: ISU consortium-based, University of Bridgeport, New York University, Portland State University, and Stevens Institute of Technology. There have been changes and new developments in this list of universities offering Ph.D. in Technology Management programs. In the Introduction section, four consortium members offering the ISU Ph.D. program have been enumerated instead of five members. Fifth consortium member, North Carolina A&T State University came out of the consortium and has started offering their own Ph.D. in Technology Management program (NCAT, 2021). From NCAT (2021), it's not clear if this is a separate degree or a concentration under Ph.D. in Applied Science and Technology. New York University archived its Ph.D. in Technology Management program and now offers Ph.D. in Human-Centered Technology, Innovation & Design (NYU, 2021). Students are required to complete 75 credits: 51 credits in course work and 24 credits in dissertation. The course work includes a certain number of Technology, Culture, & Society core courses. Stevens Institute of Technology – School of Business revised their Ph.D. in Technology Management program and instead offers Ph.D. programs in Business Administration, Data Science, and Financial Engineering (SIT, 2021). University of California Santa Barbara's Ph.D. in Technology Management is a new program (UCSB, 2021), which was not included in McKirahan et al. (2020).

Ferdous et al. (2021) reviewed and compared Ph.D. programs in Engineering Management worldwide and Ph.D. programs in Technology Management in the United States. They considered five Ph.D. programs in Technology Management in the U.S. as: ISU consortium, University of Bridgeport, Portland State University, University of California Santa Barbara, and Northcentral University. Northcentral's degree is Ph.D. in Technology and Innovation Management.

In light of these degree name changes and curriculum comparisons, we realized that ISU Ph.D. in Technology Management can be shortened by giving more credits to the relevant master-level courses and can be more manageable by adding more elective courses. The present article is an attempt to discuss a new curriculum for ISU Ph.D. in Technology Management which can make the program relevant and manageable.

3. Current Consortium-Based Ph.D. in Technology Management Program

Based on ISU website for the Consortium-based Ph.D. in Technology Management (ISU, 2021) and McKirahan et al. (2020), the program maintains most of the traditional requirement characteristics of advanced graduate study, but is unique in using resources of a consortium of four universities to present a robust platform via distance and face-to-face venues. These consortium universities have programs staffed by faculty with expertise in many areas of technology. Each university brings to the consortium a unique philosophical quality and extensive library holdings, which add depth and breadth to the program.

Goals of the Consortium-based Ph.D. in Technology Management Program are as follows to:

1. Enhance the level of study in selected technologies at the consortium universities by providing opportunities for research in development, application, and technological transfer;
2. Prepare students to become specialists who can provide leadership in areas of research, curriculum design, content development, and instructional strategies in teaching technological information;
3. Prepare students to provide service to the industrial community by assisting in the development, application, and transfer of technological expertise;
4. Prepare students to become leaders in institutions of higher learning, postsecondary schools, government agencies, and industry in the application and transfer of technological expertise.

To achieve the aforementioned goals, certain student outcomes are sought:

- Students obtain knowledge of advanced concepts and processes in technology management and their area of specialization
- Students obtain knowledge and skill in the consumption, design, and execution of advanced research in technology management and their area of specialization

- Students demonstrate knowledge of academic units and faculty roles in technology study programs in higher education.

Admission of a student to the Consortium-based Ph.D. in Technology Management Program is based upon the attainment or completion of:

a. A Master's degree in relevant field from an accredited university.
b. A graduate grade index of 3.5 on a 4.0 scale
c. The Graduate Record Examination (GRE) or Graduate Management Admission Test (GMAT) taken within 5 years of application—scores should be competitive, with no minimum score specified.
d. Five letters of recommendation
e. A career goal statement.
f. Six thousand hours (three years) of validated occupational experience relevant to the field of technology management and/or a technical specialization.

Once accepted into the program, students work with a faculty advisor to formulate, review, and revise as needed a draft Program of Study (POS). Within this POS a student chooses one of the Consortium schools as his/her home institution at the time of admission. An advisor and or chairperson is selected to direct the student to pick appropriate subject matter and study specialization toward a student's course of study. The Student's POS requires study concentration in one of five area options:

- Construction Management Systems
- Digital Communication Systems
- Human Resource Development and Industrial Training Systems
- Manufacturing Systems
- Quality Systems

Selection and use of the advisor and or chairperson by the doctoral student is critical to the student's success. The POS is a roadmap for the student to follow toward successful completion of their Ph.D. degree. The advisor and or chairperson, who typically becomes the student's POS chairperson, facilitates the student toward the forming a preliminary examination committee, once the student has successfully completed the online workshop provided by the College of Graduate and Professional Studies.

In the twenty-three-year history of the Program, student enrollment numbers increased slowly and then leveled off as the Program reached capacity due to the number of advisees felt comfortable managing to ensure a quality experience for the student. A minimum of 30% growth in number of applications has occurred within the last 3 years. Currently, the Consortium has 87 students, but the number of enrolled students in the semester is less because some students do not register in every semester.

The minimum number of credit-bearing hours required toward degree attainment in the Ph.D. in Technology Management program is 83 out of which 17 credits can be transferred from the master's degree, making 66 credits as the minimum beyond master's degree.

In the Ph.D. in Technology Management program, a student is required to take courses from the following areas:

- General Technology Core (12 credit hours)
- Major Area of Specialization (18 credit hours)
- Professional studies (9 credit hours)
- Research Core (9 credit hours)
- Foundational Studies at Master's level (minimum of 17 credit hours)
- Dissertation Research (18 minimum credit hours)

General Technology Core coursework is designed to enhance effective communication, collaboration, and management strategies. Additionally, this coursework serves to foster extensive understanding of legal and ethical issues associated to technology use which can develop as a result of federal and governmental restrictions.

Coursework taken in a student's Major Area of Specialization is meant to provide concentrated study to develop and enhance a student's broader understanding of the interrelationship that exists between technology and other disciplines (science, economics, sociology, and government policy).

Professional Studies requirements include students being tasked with satisfying areas of professional development and portfolio requirement toward degree attainment. All students are required to complete 9 credit hours of professional studies to support/round-out their developmental curricular experience. This component may be satisfied through a variable approach with approval of Advisor/Chair and Program Director. An internship or independent study component, which aligns with research interest, publication, conference presentation or other, may be the focus of the completion sequence. Also, a directed elective sequence may be utilized to satisfy this component.

Through the Research Core, Advanced Research Methodologies and Advanced Statistical Analysis are required of all subject matter expert practitioners. This serves to support continued professional development by the graduate Ph.D., toward maintaining current content knowledge in their field.

In order to assure that admitted students have a background related to their specialization, students may be directed to take Foundational Studies at the Master's level coursework to make up for background deficiencies. A conferred Master's level degree is reviewed for application of appropriate coursework toward degree attainment. Such coursework is supportive in nature and does not necessarily align with the specialization. The intention with direction to take additional coursework is to verify foundational support in the following areas, but may not be limited to same:

- Specialization
- Communication
- Ethics
- Management
- Areas of Business
- Marketing
- Legal Studies
- Other as evaluated

The doctoral dissertation is the final product prepared by the student under the guidance of his/her dissertation committee, and it is formally assessed by the dissertation committee. The dissertation is assessed in two basic phases: the dissertation proposal and the defense of the final dissertation document. The three-person dissertation committee is made up of Ph.D. consortium faculty, and in few cases, an outside expert on the topic of the dissertation research and approved by the dissertation committee and program coordinator. The dissertation topic is selected and approved by the dissertation committee and is fundamentally based on the student's area of specialization.

Concerning Coursework taken during a student's POS, course content, syllabi, assessment and revision are established by faculty in the specialization areas/departments (Construction Management, Digital Communication Systems, Human Resource Development and Training, Manufacturing Systems, and Quality Systems). Technology core and research course content, syllabi, assessment and revision are established by various faculty across traditional department boundaries.

The major comprehensive assessment of a student's content knowledge is the Preliminary Examination. The examination is tailored for each student based on their POS, but must be structured according to the following emphases:

- Six (6) hours of questions in the specialization core.
- Four (4) hours of questions in the research core.
- Two (2) hours of questions in the technology core.

Annually, Council and Lead Faculty meetings are conducted to review content quality, relevancy, and potential overlap in each specialization. Upon completing the coursework and before registering for dissertation credits, students are required to apply for preliminary examination. Once the student has applied and been reviewed/approved for eligibility, the written examination is conducted with a standard testing facility reviewed and approved by the

Program Office. If the student achieves pass of the written examination, he/she moves to the oral component of examination with their committee. Successful completion of the oral component of examination serves to move the student to all but dissertation (ABD) status, doctoral candidacy toward dissertation phase completion.

In the beginning of the section, four goals and three student outcomes of this Ph.D. program are enumerated. These have been re-phrased into five Student Learning Outcomes (SLOs) which are assessed to satisfy the ISU assessment council requirement (see Table 1). The findings of SLOs assessment between academic year 2016-17 and academic year 2019-20 are presented in Table 1. The assessment methods were a combination of direct and indirect measurement coupled with rubric scale to determine whether students achieved the SLOs. The findings of the assessment indicated that some adjustments in rubrics are needed. For example, the rubric used for evaluating SLOs on large assignments such as dissertation, should include analytical dimensions corresponding for each SLO, or expectations of student performance need to be better defined in each criterion.

There were two questions in a survey conducted among the students who participated in the residency course (COT 711) in fall of 2020 specifically asking about their satisfaction regarding this program. Total of nine students were enrolled in the course, and the answers showed that eight students believed that the Ph.D. program has been "*very*" or "*very to moderately*" helpful to improve their professional portfolio and all nine students answered that they were "*very*" or "*very to moderately*" satisfied with the Ph.D. program.

Table 1: Summary of the findings of Student Learning Outcome (SLOs) Assessment

SLO	**Method of Assessment**	**Assessment Results**			
		2016-17	**2017-18**	**2018-19**	**2019-20**
Students demonstrate professional communication proficiencies.	1. Preliminary exam (oral and written) 2. Student portfolio in COT 710 course.	M/E	M/E	M/E	NA
Student engage in and meaningfully contribute to diverse and complex communities and professional environment.	1. Student survey in COT 711 course. 2. Teaching Fellowship	NA	M/E	M/E	M/E
Students recognize and act on professional and ethical challenges that arise in their field or discipline.	1. Dissertation	NA	M/E	M/E	M/E
Students achieve mastery of the knowledge required in their discipline or profession.	1. Student survey in COT 710 course. 2. Preliminary exam (oral and written)	M/E	M/E	M/E	M/E
Students achieve mastery of the skills (including using appropriate tools) required in their discipline or profession.	1. Student survey in COT 711 course. 2. Dissertation	M/E	M/E	M/E	M/E

NA – Not Assessed
M/E – Met or Exceeded Expectations

4. Proposed Curriculum Improvement

In order to revise the existing consortium curriculum, curriculum of four other Ph.D. in Technology Management programs in the U.S. have been reviewed (Ferdous et al., 2021). Table 2 shows the institutions and their needed credit hours beyond master's degree. As shown in Table 2, the number of credit hours beyond the master's degree varies from 60 to 66 semester credits amongst three of the five universities. From the remaining two: University of Bridgeport

requires 45 credits only and University of California Santa Barbara requires 42 semester credits and dissertation is additional. Table 3 shows a comparison of course curriculum of the five Ph.D. in Technology Management programs.

Table 2: Credit hours needed of the five Ph.D. in Technology Management programs (source: Ferdous et al., 2021)

Institution	**Credit Hours (beyond master's degree)**
Indiana State University - Consortium	66 excluding 17 transferable from master's degree
University of Bridgeport	45
Portland State University	99 quarter-hrs (66 semester hrs)
University of California Santa Barbara	64 quarter-hrs (42 sem hours) + dissertation
Northcentral University	60 credit hours (20 courses)

Table 3: Comparison of Curriculum of Ph.D. in Technology Management Programs (source: Ferdous et al., 2021)

Institution	**Curriculum/Courses**
Indiana State University - Consortium	Transferable from Master's degree (17 cr hrs), General Technology core (12), Research core (9), Professional Studies (9), Specialization (18), and dissertation (18). Five specializations are: Construction Management Systems, Digital Communication Systems, Human Resource Development and Industrial Training Systems, Manufacturing Systems, and Quality Systems.
University of Bridgeport	30 credits (10 courses): seven from the four areas: Area 1 - New Technology Venture Creation, Area 2 - Information Analytics, Technology and Decision Support Systems, Area 3 - Bio-Technology and Bio-Medical Technology, Systems and Process, and Area 4 - Manufacturing, Supply Chain and Logistics Technology, Systems and Processes, and three elective courses, and 15-credit dissertation.
Portland State University	99 quarter-hours: core (20), specialization (20), methodology (20), Independent study (12), and dissertation (27).
University of California Santa Barbara	64 quarter-units: Theory/research (32), research methods (16), elective courses (8), and qualifying courses (8). Dissertation units are extra as needed.
Northcentral University	20 courses (60 credits): Ph.D. Technology and Innovation Management. Six specializations: Computer Science, Data Science, Information Systems, Cyber Security, IT Project Management, and Engineering Management.

ISU consortium Ph.D. program has been in continuous curriculum improvement since 1998. The recent major curriculum improvement initiative was started in Fall 2019, and a college committee prepared a proposal in early Spring 2020. The consortium's council reviewed the proposal and recommended some revisions to the initial proposal. The revised proposal is summarized in Table 4. According to this proposal, students need to take fewer courses by receiving more credits for their relevant master-level courses and they can manage the program better by having more elective courses. The proposal is under the process of approval by different levels at ISU. It should be noted that the consortium members are ISU as the lead degree-granting institution, Bowling Green State University (BGSU), East Carolina University (ECU), and University of Central Missouri (UCMO).

Table 4: Credit-Bearing Coursework required with an aligned Bachelor's degree and Master's degree

Aligned Bachelor's degree	Aligned Bachelor's and Master's degrees
Required/Core (42): Research (27) + Management (15) Research (27): Same as the current program • COT 702 - Advanced Research Methods (3) • COT 703 - Advanced Statistical Analysis (3) • COT 710 - Research Residency Orientation Seminar (1) • COT 711 - Research Residency Seminar (2) • Dissertation (18)	Required/Core (36): Research (27)

Management (15) Select 5 of the following. • ECU: Management Course (3) • ECU: Management Course (3) • BGSU: Management Course (3)	Management (9)

Table 4 (cont.): Credit-Bearing Coursework required with an aligned Bachelor's degree and Master's degree

Aligned Bachelor's degree	Aligned Bachelor's and Master's degrees
• BGSU: Management Course (3) • UCMO: Management Course (3) • UCMO: Management Course (3) • Organizational Leadership (3) • ISU: MET 605 - Advanced Economic Analysis (3) • ISU: MET 504 - Engineering Design and Management (3) • ISU: SFTY 630 - Foundations in Occupational Health and Safety Mgt (3) • Possible others, e.g., strategic planning	
Specialization (18): Six courses in one of the following specializations allowing a new custom specialization: • Construction Management • Digital Communication Systems • HRD and Industrial Training • Manufacturing Systems • Quality Systems • Custom (six committee approved courses)	Specialization (12)
Committee approved electives (24) • ISU: COT 799 - Internship (3) - Same as the current program • ISU: COT 799 - Independent study (3) - Same as the current program • Possible others	Committee approved electives (6)
Total credits: (minimum 84)	Total credits: (minimum 54)

Admission and other requirements remain same as mentioned in the previous section. Aligned degree means a degree from an ABET accredited program or a degree in Technology Management, Technology, Engineering Management, Engineering, or a similar discipline. Beyond bachelor's degree, current program requires a minimum of 83 semester credits whereas the proposed program requires a minimum of 84 credits. It does not seem to be much different; but the proposed curriculum gives more flexibility which can reduce the minimum to 54 credits beyond a master's degree as compared to 66 credits in the current curriculum. Students with a master's degree may substitute 18 credits in the electives, 6 credits in the specialization, and 6 credits in the management categories from their master's degree, which will reduce the minimum required credits to 54. Also courses in Technology Leadership, Management of Technical Experts, Production Processes and Control, Fundamentals of Technical Finance, Project Management, Technology Marketing, Strategic Management of Technology, etc. are now included under management and elective courses. Further, the proposed curriculum gives an option for a custom specialization depending on the interest of students and recommendation of the committee.

5. Concluding Remarks

This work has evaluated the consortium-based Ph.D. program in Technology Management at Indiana State University to offer needed curriculum changes applicable to modern time. Topical information content in terms of core and elective courses with the corresponding credit hours, skills, and experience necessary before admission and before graduation have been discussed. Through over two decades of existence, the program has kept updating the curriculum to maintain its relevancy. However, the curriculum does not contain topical coursework concerning Technology Leadership, the Management of Technical Experts, Production Processes and Control, Fundamentals of Technical

Finance, Project Management, Technology Marketing, Philosophy of Technology, and the Strategic Management of Technology, etc.; hence such topical coursework is under consideration for inclusion in the curriculum. Increasing professional communication and collaborative proficiencies, promoting moral and ethical discourse concerning technology use, mastery of skill and professional discipline, and the ability to contribute to an ever-increasing diverse and complex professional community is sought to make the program more robust and manageable.

In addition to maintaining a relevant curriculum that is applicable to modern time, another advantage of curriculum revision is to provide flexibility to students and advisors to conduct more independent studies. The current curriculum offers five specializations or concentrations. The proposed change by adding a custom specialization allows this flexibility to students and faculty to study and explore subjects that seem to be beyond the existing concentrations.

This paper adds knowledge to the area of Technology Management curriculum for Master's and doctoral degrees. The discussion will be useful for universities in the US and around the world that currently offer Ph.D. in Technology Management program or plan to offer in the near future.

References

Alberts, T.E., Badar, M.A., and El-Mansour, B., Teaching engineering economics to engineering technology students, *Proceedings of the IIE Annual Conference 2005,* Atlanta, GA, May 14-18, 2005.

Badar, M.A., and Bozai, G., Importance and benefits of engineering economy in construction management curriculum, *Sixth International Conference on Construction in the 21st Century (CITC-VI)*, Kuala Lumpur, Malaysia, Jul 5-7, 2011.

Baytieh, H. and Naja, M.K., Factors influencing the decision to enroll in an engineering PhD program, *Frontiers in Education*, Rapid City, USA, 2011.

Bosch, G., Train PhD Students to be thinkers not just specialist, *Nature*, vol 554, no. 7692, 2018.

Brent, A.C., and Pretorius, M.W., Sustainable development: A conceptual framework for the technology management field of knowledge and a departure for further research, *South African Journal of Industrial Engineering*, vol. 19, no. 1, pp. 31-52, 2008.

Chanan, A., Vigneswaram, S. and Kandasamy, J., Case Study research: training interdisciplinary engineers with context-dependent knowledge, *European Journal of Engineering Education*, vol. 31, no. 1, pp. 91-104, 2012.

Ferdous, S.F., Badar, M.A., McKirahan, J.N., and Shahhosseini, A.M., Comparing Ph.D. in Engineering Management and Technology Management programs, *Proceedings of the 11th International Conference on Industrial Engineering and Operations Management,* Singapore – Virtual, Mar 7-11, 2021, pp. 441-452, http://www.ieomsociety.org/singapore2021/papers/90.pdf.

Grimm, K., Assessing the industrial PhD: Stakeholder insight, *Journal of technology and Science Education*, vol. 8, no. 4, pp. 214-230, 2018.

ISU/Indiana State University, Ph.D in Technology Management, retrieved on Jan 15, 2021 from https://www.indstate.edu/technology/consortphd.

Kerr, C., Farrukh, C., Phaal, R., and Probert, D., Key principles for developing industrially relevant strategic technology management toolkits, *Technological Forecasting and Social Change*, vol. 80, no. 6, pp. 1050–1070, 2013.

McKirahan, J., and Cheney, A., Technology management: Adapting to a rapidly changing world, *The Technology Interface International Journal*, vol. 17, no. 2, pp. 64-76, 2016.

McKirahan, J., Shahhosseini, A.M., and Badar, M.A., Lessons Learned: A comparison of Ph.D. in Technology Management Programs, *2020 ASEE Virtual Annual Conference*, Online, 16 pages, June 22-26, 2020, https://peer.asee.org/34917.

NRC/National Research Council, *Management of Technology: The Hidden Competitive Advantage*, National Academy Press, Washington, DC, 1987.

NCAT/North Carolina Agricultural and Technological State University, College of Science and Technology: Graduate Programs, Available: https://www.ncat.edu/cost/graduate-programs/index.php, Oct 5, 2021.

NYU/New York University, Tandon School of Engineering, Human-Centered Technology, Innovation & Design Ph.D., Available: http://bulletin.engineering.nyu.edu/preview_program.php?catoid=15&poid=4448&returnto=1246, Oct 5, 2021.

SIT/Stevens Institute of Technology, School of Business, Business Ph.D. Programs, Availble: https://www.stevens.edu/school-business/business-phd-programs, Oct 5, 2021.

Tas, M., and Yeloglu, H.O., The Need for Technology Management Education for Undergraduate Programs: A Conceptual Framework, *Universal Journal of Educational Research*, vol. 6, no. 2, pp. 249–256, 2018.

UCSB/University of California Santa Barbara, Ph.D. in Technology Management, Available: https://tmp.ucsb.edu/academics/phd-technology-management, Oct 5, 2021.

Vanderford, N., Broadening Ph.D. curricula, *Nature Biotechnology*, vol. 30, no. 1, pp. 113-114, 2012.

Van Wyk, R., *Technology: Its fundamental nature*, Lambert Academic Publishing, Beau Bassin, Mauritius, 2017.

Winner, L., *The Whale and the Reactor: A search for limits in an age of high technology*, The University of Chicago Press, Chicago, USA, 1986.

Yanez, M., Khalil, T. M., and Walsh, S. T., IAMOT and education: Defining a technology and innovation management (TIM) body-of-knowledge (BoK) for graduate education (TIM BoK), *Technovation*, vol. 30, no. 7-8, pp. 389-400, 2010.

Zehner, W. B., The management of technology (MOT) degree: A bridge between technology and strategic management, *Technology analysis and strategic management*, vol. 12, no. 2, pp. 283-291, 2000.

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