Thinking Foundation for Product-Process-People Model

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Abstract

What happens when a professional engineer and a higher education professional become faculty colleagues at a statewide location of Purdue University's Polytechnic Institute? An interdisciplinary approach to course transformation! Over the last year, we have developed and refined a model to facilitate our students' understanding of the relationships between products, processes, and people. Across the majority of engineering disciplines, focus is directed upon the product (e.g., design, composition, structure, sustainability, life cycle; discovery, theory, application). Our areas of industrial engineering and leadership focus more on development and improvement of processes and people. In transforming the teaching and learning in first-year courses, we ground the content in foundational theories and concepts and address the need for polytechnic thinking, including systems, process, relational, reflective, and metacognitive thinking. Through our work, we seek to teach students to be flexible and innovative thinkers who see process- and people-oriented solutions and implications from multiple perspectives.

Keywords

Conceptual models, learning environments, course revisions, thinking, interdisciplinary

Introduction

Employers expect graduates of STEM-related degree programs to have deep technical knowledge, applied discipline-based skills, and problem-solving, critical thinking, communication, and leadership skills. Accrediting groups and standards organizations are having critical conversations with business and industry about the STEM workforce of the future. What we are learning from the employment community is that the workforce of the future requires more from college graduates, more in terms of understanding how to work in complex systems of processes and people. What types of discipline-based and interdisciplinary skills, competencies, and concepts prepare STEM students/graduates for the career ahead of them?

The American Society for Engineering Education (ASEE) advocates for interdisciplinary academic experiences. ASEE's Transforming Undergraduate Education in Engineering (TUEE) worked with business and industry stakeholders to identify knowledge, skills, and abilities (KSAs) required for engineering graduates. Attendees at the May 2013 workshop identified 36 KSAs as most important, 15 of which were designated as high priority for engineering education. Noted in the high priority category were:

> …good communication skills; physical sciences and engineering science fundamentals; ability to identify, formulate, and solve engineering problems; systems integration; curiosity and persistent desire for continuous learning; self-drive and motivation; cultural

> awareness in the broad sense (nationality, ethnicity, linguistic, gender, sexual orientation); economics and business acumen; high ethical standards, integrity, and global, social, intellectual, and technological responsibility; critical thinking; willingness to take calculated risk; ability to prioritize efficiently; project management (supervising, planning, scheduling, budgeting, etc.); teamwork skills and ability to function on multidisciplinary teams; entrepreneurship and intrapreneurship. (TUEE, p. 11-12)[1]

These competencies reflect the nature of today's workplaces. Organizations need more than a product developer or design engineer; they need more than people who are trained in STEM fields. Employers need technical professionals who are what participants in the National Academies of Sciences, Engineering, and Medicine National STEM Workforce Strategy Workshop referred to as a "STEM-capable workforce." These workers have STEM capabilities along with employability skills (teamwork, interpersonal communication) and workforce-ready skills (problem-solving, data analysis, creativity, innovation).[2] Looking to higher education to meet these workforce needs, the messages from business, industry, and program accreditors are clear—change is necessary to train the STEM workforce of the future.

Transformation at Purdue

With the national call to improve STEM education and better equip the STEM workforce of the future, colleges and universities have been and are changing their curriculum, their approaches to teaching, and the learning environments. Purdue University is no exception; the College of Technology, one of the academic colleges at Purdue, embarked on a transformational journey in October 2013. Understanding the changing landscape of the economy, world of work, and students entering higher education, the College of Technology developed an educational incubator, the Purdue Polytechnic Institute. The first Polytechnic program began in the Fall 2014, "offering integrated curricula, state-of-the-art learning methods and redesigned learning spaces" to 35 new students along with an expanded "industry-sponsored senior capstone initiative…providing real-world challenges to more than 100 School of Engineering Technology students" (Milestones).[3] In May 2015, the College of Technology was officially renamed Purdue Polytechnic Institute.

The Purdue Polytechnic Institute includes seven academic schools, departments, and divisions: Aviation and Transportation Technology, Engineering Technology, Computer and Information Technology, Computer Graphics Technology, Construction Management Technology, Military Science & Technology, and Technology Leadership & Innovation. These opportunities are also offered to Purdue Polytechnic students at one or more of the nine locations across the state.

The Purdue Polytechnic Institute Statewide is a unique partnership between education and business, industry and government. Polytechnic Statewide was created to extend Purdue's existing technology programs across the state where highly skilled workers with problem-solving skills are in great demand. All courses and programs have the same high quality, follow the curricula and learning outcomes as West Lafayette, and are taught by Purdue faculty members.

Our Statewide location has been in Richmond for 50 years. Purdue Polytechnic Richmond is connected to the community through our advisory board, our business and industry stakeholders,

and our students—most of whom work while attending classes. The immediacy of workforce needs and the skills required of our technology-related science and engineering program graduates are important aspects of our community's economic vitality.

Being situated in a community-based Purdue Polytechnic location, we, the faculty who teach in technology-related engineering and leadership/supervision programs embraced the transformation initiative. We shared ideas, collaborated on revising learning activities, and created campus visit presentations for high school students. What became apparent to us was that prospective students lack an understanding of our programs, courses, and learning outcomes, and how these facets connect with future employment opportunities. Other authors have noted that, being careful not to overgeneralize, applied engineering fields such as industrial engineering technology and technology management, tend to focus less on the traditional design engineering and more on the process engineering.[4] This focus leads to more process-oriented roles in the workforce. In these programs, learning experiences are geared toward developing some product design, a good deal of process and system improvement, and significant team management and communication—the people aspect.

Our Preliminary Work on Product-Process-People Model

Our working model to describe the interrelationships in thinking-focus of STEM programs consists of three primary constructs: product-process-people. We have developed and refined this model to facilitate our students' understanding of the relationships between products, processes, and people in applied engineering, technology, and leadership fields. Across the majority of engineering disciplines, focus is directed upon the product (e.g., design, composition, structure, sustainability and life cycle; discovery, theory, application). Much of the development of students in K-12 STEM lay a foundation for this product-orientation. Our areas of industrial engineering and leadership focus on the development and improvement of processes and people.

In conceptualizing the product-process-people model, we have found that the primary modes of or approaches to thinking differ. This has become an important aspect of our model. Identifying the diverse types of thinking—polytechnic thinking—required for a STEM-capable, employable, and workforce-ready graduate has been a foundational step in impacting our learning environment. Polytechnic thinking is the umbrella term we use to describe the diverse types of thinking required for the areas of product-process-people. Thinking, and learning how to think, is an important skill across educational levels and disciplines. Lawson stressed that all students need to "learn 'how to learn,' and not simply 'what to learn'" (p. 177).[5] Thinking is part of learning how to learn. And the ability to think should improve, resulting in lifelong learners who think. Nelson Lair, Seifert, Pascarella, Mayhew, and Blaich summarized, "Put simply, students should become better thinkers as they proceed through college. They should leave their institutions inclined to learn more, and they should be ready to take up the intellectual challenges imbedded in their lives" (p. 402).[6]

In transforming the teaching and learning in introductory courses, we incorporate the product-process-people model and address the need for polytechnic thinking as well as ensure course content in foundational theories and concepts. The polytechnic thinking concept includes design and scientific thinking primarily utilized in the product area as well as systems, process, relational, reflective, and metacognitive thinking necessary for process and people work. In

approaching the course revisions, we have been intentional in creating learning environments that meet the learning needs of both traditional and nontraditional students and build upon their existing knowledge and experiences.

Transforming First-Year Courses

Essential to getting the distinction of product, process, and people across is developing the underlying types of thinking and building students' understanding of and experiences with the interrelationships between product, process, people, and polytechnic thinking. The foundational course required for all students at Purdue Polytechnic Richmond is TECH 12000, Design Thinking in Technology. TECH 12000 introduces students to design thinking, contrasts design thinking with scientific thinking, highlights team-based problem solving, facilitates learning-by-doing, and situates learning in the context of product. Incorporating our conceptual model, we needed to formally introduce people and process in the curriculum.

Two first year courses required for students in Industrial Engineering Technology and Organizational Leadership programs fit the conceptual model areas: TLI 11100 Introduction to Manufacturing and Supply Chain Systems and TLI 11200 Foundations of Organizational Leadership. The 11100 course is where we explore the concepts of industrial engineering technology and supply chain management, what process is and involves, and the types of thinking needed. Then the 11200 course is when we analyze the theories and concepts of organizational behavior and leadership, explore people and relationships in organizations, and apply the thinking required for this people-oriented area. See Table 1 for a summary of these courses, learning outcomes, content approach, thinking competencies, and paradigms.

In designing learning within each course and enabling connections between and through the courses, we have asked ourselves how to best get our students to think in multiple ways. We continually question:

- What tools will assist students in developing connections between product-process-people and polytechnic thinking?
- What strategies do we use to integrate the conceptual areas and diverse thinking in a seamless way through the first year courses?
- How do we create opportunities for students to solve problems using the skills just taught and retain the skills, knowledge, and understandings gained from the experience?
- When are students ready to do projects with bigger problems in "real world" context, with ill-defined or undefined steps?
- How can we create opportunities for self-reflection and meta-cognition?

In the Fall of 2016 we implemented the transformed TLI 111000 in an online format via Blackboard. Students from the Richmond location as well as from several Statewide campuses registered for the course. TLI 11200 will be offered online in Spring 2017 and is still undergoing development as of this writing.

Table 1. Summary of Transformed First Year Courses at Purdue Polytechnic Richmond

Course	**TECH 12000 Design Thinking in Technology**	**TLI 11100 Introduction to Manufacturing & Supply Chain Systems**	**TLI 11200 Foundations of Organizational Leadership**
Learning Outcomes	Apply strategies of ideation to develop novel and innovative solutions. Prototype solutions for purposes of design, testing and communication. Apply ethnographic methods to understand technological problems. Describe how problems are nested in a complex system with technological, political, economic and cultural implications.	Explain the purpose and function of various organizational units within an enterprise. Describe how the enterprise is a system of interrelated parts. Explain the impact of risk on the enterprise system. Critically analyze current processes to identify areas of improvement. Predict how a suggested change impacts the system.	Define the foundational theories, concepts and practices of organizational behavior and technology leadership. Use self-assessment for identifying behaviors and skills of technology leadership. Define and implement reflective practice for leadership growth. Explain the systematic study of organizational behavior. Describe dimensions of technology as they relate to organizational behavior and leadership.
Content Approach	Design thinking approach. Multiple small application projects. Prototyping.	Systems and process thinking foundations. Manufacturing, supply chain applications.	Systems and process thinking applied to organizational behavior and leadership theory foundations and applications. Leadership mindset applications.
Thinking Competencies	Design thinking. Ideation.	Systems thinking. Process thinking.	Relational thinking. Reflective thinking. Metacognitive thinking.
Paradigms/ Worldviews	Human centered. Empathy.	Interconnectedness. Flow.	Other-centeredness. Reflective thought.

Early Results and Work Planned

As is frequently done in transformed courses, we incorporate projects. In this case, the focus of the projects is to get the students engaged in the course material using polytechnic thinking, especially systems thinking, reflection, and metacognition. In our TLI 11000 course, we utilize open ended questions such as:

- Explain the connections that you see – make the company's systems approach or process improvement approach clear for me.
- What did you learn from doing this research on best practices? What was particularly interesting for you based on the organizational area of the initiative/best practice? Share your thoughts and reflections as a result of analyzing this company and connecting it with what you learned in the readings.

The incorporation of journaling in to these STEM classes surprised us with the initial depth of polytechnic thinking by the students. Here are two examples of results that we have received from students to journal prompts in the TLI 11000 course:

- "I would say that my mind is more open different possibilities both of problem causes and opportunities/solutions. Now I find myself wondering why things happen the way they do and what are the driving factors behind them. I find myself taking a step back and trying to see the whole picture to get a feel for what is happening. I believe there has been a shift from linear to more nonlinear thinking."
- "I think that systems thinking has a profound effect in the area of supply chain management. Although this is not my major, I took a supply chain class last fall. I found myself wishing I had taken this class - or at least read the Meadows book - before I took this class as I think it would have broadened my understanding of a supply chain as a complex system with relatively simple elements. Supply, demand, logistics, price, location, placement...these are just a few of the variables that define the dynamic present within a supply chain. None of them is overly complex by itself, but when combined together they can form an incredibly complex system."

Both of these demonstrate a variety of levels of polytechnic thinking by the students. We are currently working to determine what guidelines we can use to design journal prompts that encourage the level of thinking shown here. We are also working to determine how to assess such qualitative and developmental thinking.

We plan to take the early anecdotal results and determine ways to get measurable and repeatable results at Purdue and then craft a model transferable to other universities. Also, we are working to answer the questions: How do we show success? And, how do we go beyond typical "metric"? We realize that there is potential for significant impact to the STEM postsecondary learning environment and the community's workforce. Ultimately, the product-process-people and polytechnic thinking competencies our students develop will be essential to their futures as STEM-capable, employable, and workforce-ready graduates and contributors to the region's economic vitality.

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Biographical Information

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Jan Tyler taught part-time for Purdue's Polytechnic Institute in Richmond prior to becoming full-time faculty in the department of Technology Leadership & Innovation. She holds an Ed.D. with a specialization in Higher Education. Jan is an experienced college and university administrator in both student and academic affairs as well as undergraduate-level instructor in business and organizational leadership and graduate-level education faculty. Her research interests are in the scholarship of teaching and learning in applied sciences and technologies areas.

Dr. James G. Maley, P.E.

After completing his masters and doctorate in Industrial Engineering at Purdue, Jim Maley researched and applied solutions in the automotive, electronics and defense industries. As a technical specialist, Jim led production process design, improvement and implementation projects in North America, Europe, and Asia. More recently, Jim joined the faculty of Purdue's Polytechnic Institute at their Richmond location in the Technology Leadership & Innovation department.