Article

Advances in Developing Human Resources
1–23

DOI: 10.1177/1523422318814546
journals.sagepub.com/home/adhr
SAGE

Developing Leadership Competencies for STEM Fields: The Case of Purdue Polytechnic Leadership Academy

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Abstract

The Problem.

Employers view today's science, technology, engineering, and math (STEM) program graduates as deficient in interpersonal skills that are essential for team and organizational performance. However, STEM programs continue to effectively engage in interpersonal skills development in college level, instead placing the responsibility of such development on employers.

The Solution.

A competency modeling framework should inform the design of such education programs, and this article describes such a framework and an educational program that used the framework to identify needed interpersonal skills and successfully develop them in STEM students. The framework will help HRD (human resource development) professionals take an active role in identifying the competencies needed for STEM program graduate success.

The Stakeholders.

The article provides HRD academics with a framework to identify competencies needed for workplace success in a given academic field. As education programs such as described here are developed, STEM organizations may receive workers who are more productive and less in need of leadership development expenditure.

Keywords

leadership development, social skills, STEM, self-efficacy, intercultural competence

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Introduction

Students enrolled in science, technology, engineering, and math (STEM) programs receive a great deal of support from both their college and community, often taking advantage of designated scholarships and substantial campus investments in technology-based fields. The National Association of Colleges and Employers found graduates of STEM programs such as computer science, engineering, and engineering technology can have salaries between 30% and 58% higher than the overall average for bachelor's degree graduates (2017). Once hired, employers are recognizing that although the necessary technical skills are present, interpersonal skills necessary for effective leadership and collaboration are lacking and increasingly becoming a concern. For example, 95% of U.S. employers believe that college students should have experiences that teach them to solve problems with people holding different views than their own, while 80% of employers say colleges and universities should place more emphasis on developing students' oral and written communication skills. Moreover, only 15% of U.S. employers believe that current college graduates are well prepared with regard to awareness of diversity outside the United States, and just 18% believe that graduates are well prepared to work with people from different backgrounds (Hart Research Associates, 2015).

Specifically, employers want more leadership skills including self-directed learning, critical thinking, problem-solving, and interpersonal skills from STEM graduates (Prinsley & Baranyai, 2015; Sarkar, Overton, Thompson, & Rayner, 2016). This article presents a model to assist STEM educators in developing and implementing a competency-based framework of leadership development for STEM students, as HRD scholars and practitioners are best positioned to facilitate such development through connecting with STEM educators and highlighting the importance of focusing on leadership competencies early on. In addition, we present our experience utilizing the model for design of the Purdue Polytechnic Leadership Academy for undergraduate students in STEM fields.

Students enrolled in STEM-degree programs acquire technical competencies necessary to enter their given field and develop skills to successfully perform tasks. However, once in the position, STEM professionals may struggle with working in teams, demonstrating effective communication, and interacting with coworkers from different backgrounds and cultures, key components of contextual performance (Borman & Motowidlo, 1993), which is necessary for effective team and organizational functioning. STEM degree programs have historically emphasized the technical competencies of their fields and rarely prioritized the development of interpersonal skills as a foundation of their academic program, instead relying on employers to develop these skills through organizational leadership development efforts. As companies become increasingly globalized, adapt to changes in the environment, and make technological advancements, these employees are thrust into situations that require them to hold interpersonal skills that help organizations access the diverse skills and knowledge held by team members (Jacobs, 2017).

Significance

Today's graduates are tasked with responsibilities and challenges that require interpersonal skills, attitudes, and behaviors pertaining to leadership much earlier in their careers than in the past, both because of changing organizational dynamics, including flatter organizational hierarchies, and an aging workforce that is nearing retirement age. Interpersonal skills are considered the foundational phase of leadership development for the purpose of this article. Employers are increasingly concerned about the lack of leadership competencies demonstrated by recent STEM graduates (Hart Research Associates, 2008, 2013, 2015). When asked to assess college graduates' level of preparedness in interpersonal skills, such as teamwork, critical thinking, adaptability, and intercultural competency, less than 40% of employers believed their new hires were very well prepared to be successful (Hart Research Associates, 2008). More concerning, for half of the skills included, more than 25% of employers believed recent graduates are not well prepared (2008). The advancement of education in STEM programs is important nationally, for employers, and for educators.

National Significance

To maintain its status as a global leader, the United States depends on the success of its science and technology programs (President's Council of Advisors on Science and Technology, 2012). The President's Council revealed language skills and the ability to think globally are key aspects of effectively collaborating around the world (President's Council of Advisors on Science and Technology, 2012). Employees in STEM fields and across many industries are expected to possess a variety of interpersonal skills. Even if they lack such skills, however, students enrolled in STEM programs often have little difficulty finding employment after graduation because of labor shortages in many STEM fields across the country. The President's Council of Advisors on Science and Technology reported that one million more STEM professionals will be needed over the next decade if the country hopes to maintain its status as a global leader in science and technology (President's Council of Advisors on Science and Technology, 2012). In fact, the United States would have to increase output of STEM graduates by 34% to match job forecasts (President's Council of Advisors on Science and Technology, 2012). The massive number of required graduates creates a sense of urgency for STEM degree providers to ensure they are training candidates who have developed the necessary knowledge, skills, and abilities (KSAs) to be successful in both the short- and long term.

Significance for Employers

Successful job performance in STEM extends beyond having technical knowledge and skills, requiring additional competencies and the ability to perform unfamiliar tasks. For example, employees are expected to contribute to the development of less experienced employees, provide extra effort when needed, and be a supporter

of organizational objectives (Borman & Motowidlo, 1993). These nontask-related dimensions of performance are known as contextual performance. Task performance is becoming ever important and necessary for individual job performance in today's digitalized workplace, but contextual performance contributes to team and organizational performance above and beyond task-relevant actions. Contextual performance has increased in importance as organizations have become flatter, employees are granted more autonomy, and the need for informal learning has increased (Jacobs, 2017). Therefore, interpersonal skills should become an essential, not auxiliary, component of STEM student education because they relate to the contextual behaviors that are essential for effective functioning of the team and organization in the age of machine learning and artificial intelligence.

The role of higher education in developing student leadership competencies is supported by industry professionals. A survey commissioned by the American Association of Colleges and Universities (AAC&U) showed today's graduates are lacking many of the skills that employers consider vitally important and identified several competencies most in need of further development (Hart Research Associates, 2013, 2015); The findings of the AAC&U survey are mirrored in a recent report published by The Chronicle of Higher Education that suggested these competencies are essential for creating graduates who can apply their knowledge across boundaries (Carlson, 2017). To begin aligning STEM degree programs to meet the needs of prospective employers, educators may consider introducing leadership development as a necessary complement to the technical skills currently being developed. Similarly, leadership development programs are increasingly becoming a significant investment for organizations.

An estimated US$50 billion are spent annually on leadership development across the globe, and American companies have invested some US$60 billion on leadership development in recent years (Bersin by Deloitte, 2014; Development Dimensions International, 2014; Zenger, 2012). Organizations should emphasize the development of the skills and competencies in highest demand and needing the most improvement (Hackett, 2015). Leadership development is among the highest—if not the top—training and development priorities. Compared to all other organizational training, management and leadership development receives the most substantial allocation (Bersin by Deloitte, 2014). Even in military settings, leadership development constitutes a significant amount of overall training efforts (Kirchner & Akdere, 2014a, 2014b, 2015, 2016a, 2016b, 2017). Human resource development (HRD) academics and scholars have a unique opportunity to utilize the experience and expertise in the field to help STEM students develop greater communicative, collaborative, and intercultural skills prior to entering the workforce as future STEM leaders.

Effective organizational leaders are often credited with being successful in their positions because of the interpersonal skills they have acquired and they exhibit. Employees who are effective communicators, work well in teams, and have intercultural competence make positive, lasting impressions on organization productivity, investments, and are more likely to be retained. These employees are more likely to be successful in cross-functional teams. Furthermore, cultivating such experiences are critical for the development of leadership competencies.

Significance for STEM Educators

The field of HRD is well-positioned to contribute toward developing leadership competencies of STEM students. For example, in 2016, *Advances in Developing Human Resources (ADHR)* devoted an entire issue reviewing current and new leadership development approaches (Ardichvili, Natt och Dag, & Manderscheid, 2016). This particular issue of ADHR highlights how HRD can utilize its expertise in bridging industry experience and demands with the capabilities and constraints of higher education to successfully develop future STEM workforce. Similarly, academics in HRD programs have the insight and ability to influence the development of leadership competencies for students enrolled in STEM degree programs. And, *Advances in Developing Human Resources*, in particular, have devoted attention to multifaceted phenomenon of leadership developing through HRD. Ensuring the effective development of leadership competencies in STEM fields contributes to organizational competitive advantage and strategic success (Gable, 2010). In this context, Purdue Polytechnic Leadership Academy offers a new approach for designing STEM education that complements the technical competencies acquired in STEM degrees by integrating leadership development as part of student learning in college.

The Purdue Polytechnic Leadership Academy (PPLA) is a potential model for developing leadership competency through its emphasis on developing interpersonal skills in STEM education. Such proactive approach not only supports individual development of STEM students to begin exploring their leadership potential, but also enables the integration of both technical and nontechnical convergence in STEM education. Established by an HRD faculty, PPLA incorporates leadership foundations beyond being an add-on for STEM students and, instead, makes it an integral component of STEM education. Participating students set out on a journey to begin to explore their leadership potentials and develop interpersonal skills that may enhance both their initial employability and long-term career outlook while proceeding through their degree program. Employers benefit from hiring college graduates who have broader skill sets that are necessary for organizational success, while potentially reducing their leadership development program costs (Hart Research Associates, 2015). The competency modeling framework for STEM educators is further described below.

Competency Modeling Framework for STEM Educators

As part of the institutional accreditation process, STEM educators are required to document how they are contributing to the leadership competency necessary for workplace success that go beyond their technical knowledge. As mentioned, developing leadership competency should not be an auxiliary function of STEM education because job performance is more than simply task performance. If STEM students graduate without competencies that contribute to contextual performance, then the organization that hires them will likely suffer in terms of productivity and workplace attitudes.

Competency modeling establishes the collection of KSAs needed to effectively perform in a given role (Campion et al., 2011). The competencies can be important for

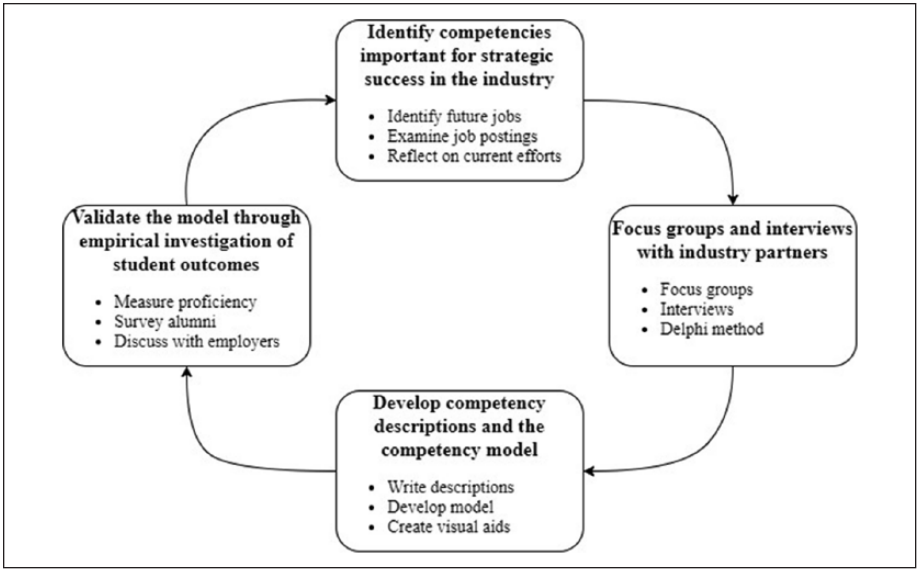

Figure 1. Cyclical competency modeling framework for identifying developmental needs in STEM education.
Note. STEM = science, technology, engineering, and math.

current success, or they can be competencies that are expected to be important in the future. The research on competency modeling provides a foundation for effective competency modeling practice. In our experience, while universities have continued to increase their emphasis on competency-based education, rarely are robust methods in place for identifying, specifying, validating, and revising the competency models that they use. The proposed competency modeling framework for identifying developmental needs in STEM education, as illustrated in Figure 1, outlines the cyclical process of identifying competencies to be developed in a given STEM field. This provides STEM educators a more rigorous approach to ensuring their degree programs result in holistic pedagogical outcomes with regard to skills and competencies necessary for individual and organizational success in their respective STEM disciplines. Specifically, such skills and competencies may differ for an engineer versus an information technology professional. In addition, this approach will help STEM educators document their process of identifying and developing necessary leadership competency. In the remainder of this section, we provide the details of our proposed framework.

Step 1: Identify Competencies Important for Strategic Success in the Industry

Begin by identifying occupations that students are likely to enter upon graduation. Examine tasks, critical incidents, and success factors in these occupations. This can be

achieved through examining job postings to which students are likely to apply. Job analysis and subsequent job descriptions identify competencies required for success (e.g., takes initiative, communicates effectively). These competencies provide a benchmark in which the work can be effectively completed. In other words, job analysis methods can be used to inform competency modeling as well (Campion et al., 2011).

Each field is likely to have a different set of necessary competencies that occupationally represents both technical and nontechnical expertise. After initial identification of the competencies important in a given industry and role, educators should reflect on their current competency-based education efforts. A set of questions for beginning the reflection process include the following:

- Are the competencies we currently emphasize still important?
- Are those competencies being taught effectively?
- How are we and how will we measure these competencies?
- Are entirely new competencies needed, or do we need to modify existing competencies?

These questions act as a conceptual check on the findings prior to the second step of confirming the findings with industry partners.

Step 2: Focus Groups and Interviews With Industry Partners

After identifying the competencies important for success in the students' field, the next step is to utilize the knowledge and expertise that industry partners have to collect more data on needed competencies and to examine the competencies identified in Step 1 to determine whether or not the assessment was accurate. Industry partners are actively involved in the day-to-day realities of the industry and have invaluable first-hand knowledge of the competencies necessary for effective performance in those fields. Three primary methods exist and can be used together or in isolation to collect further data and assess the accuracy of the initial findings: focus groups, interviews, and Delphi techniques. All three can be used to ensure the competencies identified are relevant and useful for the industry in question. Actively involving industry in the process should ensure that their needs are met, rather than graduating students who are lacking in vital skills, as has been suggested by recent surveys of employers (Hart Research Associates, 2013, 2015);

Step 3: Develop Competency Descriptions and the Competency Model

Competency descriptions are important because they provide learners with a better understanding of the competency itself as well as how to judge their proficiency in a given competency. A good competency model includes descriptions of the competencies at various levels of proficiency (Campion et al., 2011). Also, the competency descriptions should be written in a way that makes them easy to use and understand for

the specific audience (Campion et al., 2011). In other words, occupation-specific jargon should be avoided if the field has interdisciplinary foundations (e.g., HRD) or if the students are still relatively inexperienced. Finally, learners will be more likely to remember and refer to the competency model if it is represented in a visual medium (Campion et al., 2011), so presenting a figure of the model would be helpful.

Step 4: Validate the Model Through Empirical Investigation of Student Outcomes

After developing and applying the model, the final step involves determining as to whether or not the competencies identified have been developed effectively in students and whether or not they contribute to job and career success. Begin the validation process by measuring competency proficiency in students prior to graduation. Then collect data from both alumni and employers to determine whether those competencies will help the students succeed in their future jobs.

After Step 4, the competencies must be reviewed for applicability and relevance. A new analysis should begin based on the validation results to address competencies that did not contribute to job and career success and to identify new competencies that may be relevant for the next cohort of students. The pace of change in the world of work continues to increase, and educators must take an active role to ensure that higher education remains a relevant and impactful component of the STEM workforce development. The data from Step 4, then, is the starting point for continuing the competency modeling cycle as shown in Figure 1. The following section of the article illustrates a successful case utilizing this cyclical competency modeling framework to developing leadership competencies in STEM fields.

The Case of Purdue Polytechnic Leadership Academy

The PPLA was created with the ultimate goal of identifying and nurturing future generations of leaders in STEM fields. PPLA helps students gain 21st-century leadership competencies critical for job success and career readiness. The Academy works with students to increase these competencies with the culminating experience of developing an ePortfolio reflecting on their levels of competencies and identifying artifacts that best represent each leadership competency. Through collaboration with industry partners, PPLA helps polytechnic students develop, refine, and strengthen their leadership competencies as they prepare for their future careers.

The leadership academy increases students' awareness of what makes them unique, recognizing that each and every student has a potential million-dollar product to market: themselves! The academy works with students to help them gain awareness of how their coursework, industry/business experiences, and extracurricular activities help them develop leadership competencies needed in the 21st-century workplace. Students develop this awareness and understanding through self-reflection and training programs designed in conjunction with our industry partners. Self-reflection is often forgotten in today's high-speed world, but it is a central component of effective

learning experiences (Kolb, 1984). As part of the academy, students participate in *leadership clinics* and develop an *ePortfolio* in which they demonstrate not only their experiences and education, but also how these experiences apply to leadership competencies through self-reflections and artifacts.

Step 1: Identify Competencies Important for Strategic Success in the Industry

The PPLA was developed and directed by an HRD faculty to support students throughout the Purdue Polytechnic Institute, one of the 10 colleges on Purdue University's main campus, which offers a wide variety of STEM degrees. PPLA was designed to support initiatives in the college, which ensures that the HRD function is aligned with the broader goals of the organization. Whenever HRD functions can be aligned with broader organizational goals, HRD faculty and practitioners have an opportunity to take initiative and contribute value to the organization. The college focuses on applied/use-inspired research because of the college's roots in hands-on learning activities, which PPLA sought to support. Due to the wide variety of programs in the college, a general approach to identifying competencies important for strategic success across STEM industries was deemed necessary, seeking to understand overall workplace trends rather than trends within a specific STEM industry. A general approach provided broadly applicable concepts that guided the remaining steps as we sought to develop interpersonal skills that contribute to success in today's and, especially, tomorrow's organizations.

After determining workplace trends that are critical for identifying relevant interpersonal skills, we examined the literature, especially in the professional realm, to determine the interpersonal skills important for STEM industries. At this stage, we looked to surveys commissioned by the AAC&U and research from The Chronicle of Higher Education (Carlson, 2017; Deming, 2017; Hart Research Associates, 2013, 2015); to identify competencies that employers consider to be both important and lacking in STEM graduates. The competencies emphasized in these surveys are both in high demand and in need of improvement, suggesting their development to be a valuable and impactful activity (Hackett, 2015). In addition, modern workplaces increasingly require employees to demonstrate and manage greater levels of autonomy, self-directed work, and collaboration than ever before (Jacobs, 2017). With advancements in information and communication technologies, large-scale disruptions are becoming more commonplace, which require STEM professionals to be more adaptive, innovative, and agile to remain competitive in a globalized and competitive marketplace.

Step 2: Focus Groups and Interviews With Industry Partners

Recognized today as an invaluable partner for higher education, industry partners provide both insight and resources that are difficult to find elsewhere. The PPLA utilized university-level relationships with industry experts, enabling an understanding of the

needs of employers across a wide variety of STEM industries. Step 1 of the process provided PPLA with quantitative data, and engaging with industry partners provided PPLA with qualitative data, creating a robust mixed-methods approach to program research and development. This enabled us to ensure that competency model development was based on data that are both significant and relevant by including both surveys and in-depth interviews to determine employers' needs and beliefs regarding emerging characteristics and qualities of the STEM workforce.

The process for PPLA included a trip to Silicon Valley to meet with professionals from a variety of well-known, established technology giants as well as several innovative start-ups. Including the voice of both large and small companies ensured the program served a broad cross-section of employers and students, who will have career paths that may include both entrepreneurial activity as well as working for Fortune 500 companies. Many of the global companies in Silicon Valley described the need for employees who can apply their technical knowledge and expertise across a wide variety of situations, especially in companies that are constantly expanding into new business segments, such as Alphabet and PayPal. The internal expertise generated in product and project development is vital when it comes to creating new product lines and establishing autonomous product divisions within the organization.

After meeting with a variety of companies in Silicon Valley, we partnered with an executive recruitment company to gain another perspective on the most sought-after skills needed for business success today. Their insight further reinforced the perception that interpersonal skills are as important, if not more so, than technical skills. As mentioned, if employees do not contribute to contextual components of job performance (Borman & Motowidlo, 1993), then the performance of the team and organization will suffer. A common refrain from the executive recruiters regarding experienced and well-credentialed individuals who were seeking new employers was that when those individuals struggled to find new employers, it was never because they lacked technical skills. Rather, these experienced individuals were not team players. They possessed the skills and knowledge necessary to succeed but lacked the ability to help others in the organization succeed. Employers were never satisfied with a resume that listed impressive accomplishments if the person did not sell themselves as willing to collaborate with and aid the development of their colleagues, which are components of contextual performance. The efforts of the recruiters to coach their clients, then, were focused on coaching them on the same interpersonal skills that employers see as lacking in today's STEM graduates. The importance of interpersonal skills for graduates and executives alike coincides with the workplace trends of flatter organizations and collaborative work, because the problems faced by today's organizations can rarely be solved with the expertise of a single individual.

Step 3: Develop Competency Descriptions and the Competency Model

The third step of PPLA development involved an intentional, data-grounded process of sorting through the information gleaned in the first two steps and developing a competency model for student reflection. The workplace trends we identified led to

identification of a variety of competencies that students need, and our conversations with companies and recruiters confirmed the importance of competencies that contribute to contextual performance.

Nine competencies were adopted that were important for employers. These competencies recognize that success in the modern workplace requires both advanced knowledge of a student's particular field as well as skills and competencies that contribute to contextual performance. These nine competencies are deeper learning, analytical reasoning, effective communication, critical thinking, managing complexity, collaborative work, self-directed learning, cultural awareness, and innovation. The specific needs and characteristics of students in Purdue Polytechnic Institute were taken into account when developing this list as well.

Writing competency descriptions is an iterative process. We used a variety of resources, including academic research and practitioner articles (e.g., Carlson, 2017; Deming, 2017; Hart Research Associates, 2013, 2015; Jacobs, 2017), to inform the competency descriptions. Initial drafts were written, then team members took turns revising and improving the descriptions. The final version of the descriptions that we distributed to students are provided in Table 1. The descriptions are supplemented by examples of the competency as could be demonstrated in a robotics class. Students have reported that they find the descriptions very helpful, because it helps them understand how to connect their experiences to a given competency. In other words, it helps students get started writing their reflections, because it gives them a measuring stick against which they can judge their experiences.

After writing the competency descriptions, we also utilized a visual representation of the competency model (Mili, Alter, Herrick, Frooninckx, & Bertoline, 2014). We utilized the concept of the t-shaped professional (Hansen & Oetinger, 2001). The t-shaped professional has increased in importance as cross-departmental collaboration has increased together with the flattening of organizational hierarchies. Managers and technical professionals alike are now responsible for communicating across traditional organizational silos, which helps organizations access the implicit knowledge and expertise needed to drive innovation in organizations. The model of a t-shaped student adopted for PPLA is provided in Figure 2.

The methods listed in Figure 2 include those that are emphasized by the college for student learning. In addition, the figure highlights that task-related knowledge and expertise are important. The visual representation of the competency model demonstrates a holistic and systematic approach to developing STEM professionals through identifying the depth of technical knowledge required, overarching interpersonal skills and leadership competencies needed, and the methods to be used for acquiring both technical knowledge and 21st-century competencies.

Step 4: Validate the Model Through Empirical Investigation of Student Outcomes

After identifying interpersonal skills and leadership competencies essential for STEM fields through examining existing literature, specifically, the practitioner outlets and

Table 1. PPLA Competency Descriptions (Purdue Polytechnic Leadership Academy, 2016).

Competency	Definition	Example
Deeper learning	The process of becoming an expert on a specific topic. Deeper learning involves the application of expert knowledge to new situations and innovative applications, showing that even though you learned about a certain context, you are able to apply the knowledge to other contexts. Demonstrating your ability to apply the knowledge you have acquired to new situations is critical for professional success and lifelong learning. Deeper learning also requires mapping facts and concepts to help build on prior knowledge, enabling you to connect ideas, apply knowledge across content areas, and solve real-world problems.	In a robotics class, students engage deeply with math and physics as they measure and assess the impact of the changes they are making to control their robots' speed, agility, and water displacement.
Analytical reasoning	The capability to break a problem down into smaller pieces, whether parts of an object or parts of a process. It involves analyzing a problem by making evaluations, developing solutions, considering alternatives, and carrying out plans to address the problem. Activities such as researching, brainstorming, and design thinking help you engage in analytical reasoning.	The robotics students are testing their hypotheses and designing solutions to the unexpected challenges they confront in their robot design.
Effective communication	Listening to and understanding others are the foundation of effective communication. We must listen attentively and be aware of people's emotions, gestures, and cultural identity. Active listening requires reflecting back what the speaker has stated in your own words. This encourages elaboration from the speaker, provides positive feedback, and ensures that your understanding is correct. Active listening requires empathy, which is being open to and sensitive of the values and feelings of other people, understanding the other person's perspective, and being willing to discuss your own thoughts in an open manner. We must, consider our communications from the listener's or reader's point of view; be clear and concise; provide visual cues to support our speech (when appropriate); motivate and support others by giving praise, encouragement, and feedback; and demonstrate tact to those we disagree with.	At the beginning of the project, students must listen to and understand the tasks required of the robot. During the project, students communicate with each other as part of their teamwork. At the end of the project, they present their robot to the class and explain the adjustments they made to the controllers.

(continued)

Table 1. (continued)

Competency	Definition	Example
Managing complexity	First, we must understand what complexity means. Complexity is defined as the information required to describe an entity. Explaining complex entities involves multiple layers of analysis, including breaking entities down into their constituent parts and demonstrating the interactions between the parts. Complexity management can include delayering, decentralizing (or centralizing), streamlining processes, and creating stronger processes that ensure alignment. Big data and advanced analytics are emerging techniques for managing complexity, allowing us to monitor large numbers of variables to see how they develop and interact over time. As you seek to tackle problems, you must be able to analyze those problems, develop solutions, and carry out plans to address them.	Breaking down the concept of a robot into its parts and design considerations (e.g., materials and functionality).
Critical thinking	Philosophers believe that critical thinking should form the basis of our beliefs and help inform our behavior and actions. Critical thinking is objective and is the ideal of science, where evidence, not personal biases and opinions, inform our judgments and actions. It is a way of judging information by analyzing, applying standards (about what constitutes *quality* information), discriminating, seeking new information, logical reasoning, predicting, and transforming knowledge. Critical thinking requires an understanding that there is no single correct way to generate and evaluate arguments, so we must always be aware of our own biases and the biases of others. It is based on logic and objectivity, strategic problem solving, and planning. It entails using judgment, assumptions, and reasoning to come up with innovative solutions to problems or situations.	Evaluating feedback from the instructor and classmates objectively to determine and inform improvements for their robot.

(continued)

Table 1. (continued)

Competency	Definition	Example
Collaborative work	The act of two or more people (or organizations, teams, etc.) working together for a particular purpose. No (wo)man is an island, and this has become increasingly true in recent years. Interdepartmental collaboration in organizations is the norm, and frequently, this is combined with interorganizational collaboration. Information technology has given us the ability to collaborate with hundreds, even thousands, of people around the world on a given day. Success on projects requires considering various viewpoints, working together to find the best plan, and implementing that plan in a coordinated way. The ever-increasing rate of technological advancement makes collaboration even more necessary for success because, increasingly, no individual can possess all the knowledge required to succeed. Collaborative work helps students become better team members in the future as they learn to identify strengths, assign responsibilities, and reflect on successes. By planning thoughtful group activities, creating expectations around group work, and encouraging conversations about open-mindedness, students develop the skills necessary for collaborative work.	In each robotics group, students have created team agreements, identified group leaders, and divided responsibilities equally.
Self-directed learning	Self-directed learning requires, first, identification of what your learning needs are. Then you must formulate learning goals, identify the resources you will use for your learning, select and implement learning strategies, and finally, evaluate the learning outcomes. Self-directed learning demonstrates initiative and drive, which becomes much more important once you begin your career. At work, you are tasked with not only succeeding in your daily job, but also enhancing existing skills and developing new ones. With the explosion of knowledge work and the ever-increasing rate of technological change, the ability to increase your depth of knowledge as well as acquiring new knowledge and skills is increasingly important. Self-directed learning may be achieved through goal setting, progress tracking, reflecting on strengths and weaknesses, and the ability to turn setbacks into opportunities for growth.	In robotics class, students identify daily goals for their robot design in their groups, create challenges for their teams, and surpass the requirements and standards outlined in the project.

(continued)

Table 1. (continued)

Competency	Definition	Example
Cultural awareness	Developing cultural awareness also develops self-awareness, a foundational skill for effective leadership. Without awareness of our own culture, we cannot be aware and accepting other cultures, but we frequently cannot understand our own culture without exposure to and experience with other cultures. Cultural awareness is necessary for effective communication as norms of behavior change from culture to culture. Culture is simply the knowledge people acquire in their daily lives that allows them to interpret experiences and guide their social behavior. Culture is passed down to new generations because they are immersed in the symbols, patterns, and behaviors of the existing culture.	Students learn about the cultural background of their team members and develop an understanding of how cultures relate to values, behaviors, and design decisions in this applied context.
Innovation	Innovation is the process of adapting an existing idea to new uses, improving an existing product or process, or inventing a new product. Innovation should create value, whether that means commercial value or value for society. Successful innovation may require a combination of cognitive, behavioral, and technical skills. New ideas are developed every day, but it takes an innovator to recognize the potential of a new idea to create value for your organization or society. The person who creates an innovation is not always the primary beneficiary—sometimes it takes a person with vision to understand the potential value of an innovation. Innovators must be constantly questioning the status quo, closely observing the details of your products and processes to identify new ways of doing things, networking to gain diverse perspectives from people of different backgrounds, experimenting with new ideas and experiences, and drawing connections between seemingly disparate ideas.	The robots developed through the class project involve innovative approaches to design and technology.

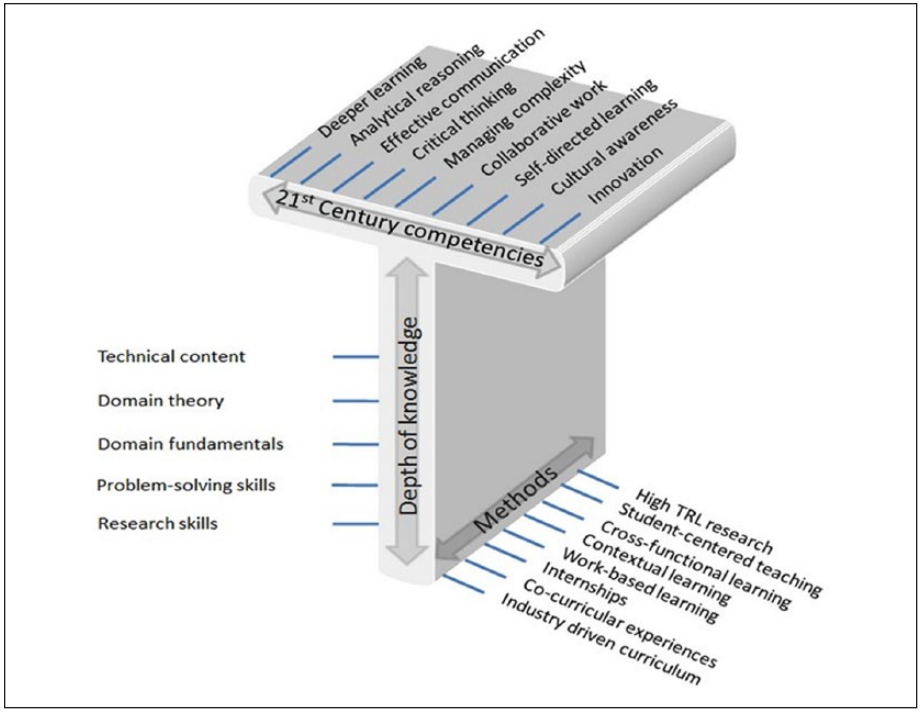

Figure 2. Visual representation of PPLA competency model (Mili & Bertoline, 2014).
Note. PPLA = Purdue Polytechnic Leadership Academy; TRL = technology-readiness level.

interviewing professionals from the field and industry, we developed the competency model for PPLA. Validating the competency model is challenging in an educational context because it is very difficult to examine the traditional validation outcome in industrial-organizational psychology: job performance. Instead, academics can and should measure the change in skills and competencies that have already been validated as contributing to real-world job performance. Measuring student increases in the 21st-century skills and competencies we identified enables an understanding of how PPLA contributes to the students' and their future organizations' success. Further validation efforts include contacting businesses and alumni to gather their perceptions of the importance of these competencies in the workplace.

The model developed for PPLA places a heavy emphasis on communication skills and the ability to solve a wide range of problems in a variety of situations. The increased number of positions in a lifetime that today's graduates are likely to hold compared with past generations suggests that their communication will need to change to fit the different organizational cultures they encounter and to successfully collaborate with a diverse group of fellow employees. In addition, they will need to apply their technical knowledge across a variety of situations that are difficult to predict today. As such, our initial investigation into the impact of PPLA

focused on generalized self-efficacy (Chen, Gully, & Eden, 2001) and intercultural communication (Akdere & Hickman, 2018; Akdere, Hickman, Lowenberg-DeBoer, & Karduss, 2017; Hickman & Akdere, 2018a, 2018b, 2018c) as they relate to several of the competencies in the model. Students demonstrated growth in generalized self-efficacy and intercultural communication (Akdere & Hickman, 2018).

These two constructs coincide with both the general trends observed and the specific competencies identified in surveys of employers, our discussions with Silicon Valley companies, and the experiences executive recruiters shared with us. A widely agreed-upon definition of intercultural competence (Deardorff, 2006) is "the ability to communicate effectively and appropriately in intercultural situations based on one's intercultural knowledge, skills, and attitudes" (Deardorff, 2004, p. 194), suggesting that intercultural communication and intercultural competency are irrevocably intertwined. Cultural diversity occurs along dimensions of gender, race, age, nationality, and even organizational affiliation, and coupled with increased workplace diversity in terms of colleagues, customers, and supply chains due to information and communication technologies, today's employees interact with culturally different others more than ever before. Intercultural communication is relevant for several of the competencies identified in the PPLA model, including *effective communication, collaborative work*, and *cultural awareness*.

Self-efficacy is a perception individuals have regarding their ability to perform by applying their skills to achieve desired outcomes (Bandura, 1977). Studies have generally supported the idea that individuals with higher levels of self-efficacy are likely to persist longer in their efforts because they attribute failures to inexperience and lack of effort, rather than personal shortcomings. Today's workplace is experiencing rapid and disruptive changes that require individuals to function effectively in a greater variety of situations and roles over their lifetime than past generations. Individuals who do not believe that they can succeed may experience negative emotions when encountering difficulty, which can inhibit initiative and innovative behavior by narrowing their focus to whatever is measured (Boyatzis et al., 2012). Self-efficacy is critical to develop for several of the competencies identified in the PPLA model, including *analytical reasoning, critical thinking, deeper learning, managing complexity, self-directed learning*, and *innovation*.

Implications

Students, employers, and faculty within STEM programs stand to benefit from the introduction of leadership development in degree programs. Current STEM students are not learning about leadership, because faculty in their major emphasize the technical skills that have been traditionally expected to be the focus of education. Faculty with an HRD background can complement the development of technical competencies and establish a needed bridge between technical and leadership competencies. Employers will acquire more well-rounded cohort of college graduates who have exposure to the leadership skills and competencies currently lacking. The impact for each of these stakeholders is further addressed below.

HRD Academics

The field of HRD is capable of developing leadership competencies of both students and employees in STEM fields because many HRD faculty have expertise and experience guiding interpersonal skills development. As such, degree programs within STEM colleges are primed to introduce leadership development to incoming students. Purdue University, along with other universities (see University of Texas at Tyler, Indiana State University, and Pittsburg State University) with an HRD or closely related degree programs within a technology college already have the infrastructure to collaborate and develop the leadership competencies sought by STEM employers. These academic departments may be able to break down some of the silos that currently exist to fully develop the required KSAs of STEM graduates. The proposed competency modeling framework gives educators a tool to develop programs that offer students an intentional linkage between developing both the technical and leadership competencies expected of 21st-century employees. However, it should be noted here that, the competency model is just one part of the solution. Breaking down the silos between HRD and STEM and convincing STEM educators of the importance of these competencies is equally important, yet, is beyond the scope of this article.

STEM Students

Students may greatly benefit from including leadership development in their STEM degree programs. Many who enroll in college with the intent to earn a STEM degree leave because of uninspiring introductory courses, an overwhelming amount of math, and an unwelcoming atmosphere from faculty (President's Council of Advisors on Science and Technology, 2012). An estimated 40% of students who enter STEM degree programs drop out prior to completion (President's Council of Advisors on Science and Technology, 2012). By changing majors or dropping out of college entirely, students incur additional costs and lost time that could be avoided. Developing leadership competencies requires very little math and approaches STEM education from an interpersonal skills context, which could potentially offset some of the reasons students transfer out. In addition, students will learn how to use both their technical and interpersonal skills in the classroom prior to transitioning into the workforce. Regardless of an engineer's technical competencies, if they have poor communication skills or are ineffective working in teams, the performance of the employee and team suffers. Learning how to apply technical skills in a controlled classroom setting offers students the chance to engage and reflect on their ability to collaborate and communicate with others. Similar benefits may exist for students when they graduate and are hired by employers.

STEM Professionals and Organizations

Employers hiring STEM degree holders stand to benefit as much as any stakeholder from the development of leadership competencies in STEM programs, which justifies

their prominent voice in the proposed competency modeling framework. Rather than employer-led leadership development being the first exposure to such training for new hires, STEM graduates will already have a base set of competencies, which can be utilized and further developed. Employer involvement in the leadership development process helps ensure organizational needs are being addressed during the students' time in college. The employer perspective offers insight into particular KSA shortages and may introduce innovative development strategies. Employees, teams, and entire organizations each may be affected through the introduction of leadership development in STEM degree programs.

The benefits of having a workforce with leadership competencies can be seen at all levels of the organization. As Hart Research Associates (2015) noted, employees with a broad range of knowledge and skills are better positioned to have long-term career success than those with KSAs limited to a particular industry. Both employers (60%) and college students (63%) believe it is most important for graduates to have both career-specific KSAs and broader skill sets, with many employers placing greatest priority in hiring students who demonstrate proficiency in skills and competencies that are applicable across a range of majors (Hart Research Associates, 2015). At the unit level, the acquired competencies may positively affect team production, workplace communication, and group decision making (Hart Research Associates, 2013, 2015). Extended to the organization, execution of leadership KSAs can also affect workplace satisfaction, leadership pipelines, growth and revenue numbers, and persistence rates of employees (Bersin by Deloitte, 2014; Development Dimensions International, 2014; Hart Research Associates, 2008). As outlined, acquired leadership competencies positively affect multiple layers of an organization; however, the PPLA model presented and general introduction of leadership development presents a series of challenges for faculty and administrators in STEM degree programs, which may be more effectively approached by using the proposed competency modeling framework.

Implementation Challenges

The introduction of interpersonal skills development in STEM degree programs comes with multiple challenges that may inhibit successful implementation. Although with PPLA, we were able to outline nine particular competencies for development, each degree program, industry, and organization has its own culture, values, and priorities. Faculty aspiring to develop student leadership competencies should anticipate varying perspectives from STEM industries on how to best teach and grow leadership among its student population. The introduction of leadership development also requires colleges to allocate resources toward the initiative, including possible degree program requirement revisions, development of certificate programs, and additional student enrollments in HRD courses. Revisions or additional degree program requirements are also unlikely to be received favorably by students. Finally, students may resist or reject the need to develop leadership competencies, instead believing that such education plays a minimal role in their job prospects.

Conclusion

Nontechnical leadership competencies are vital for STEM organizations as employees typically work in collaborative, autonomous teams. As the organizational function that provides employee development, designs teamwork, and assesses organizational effectiveness, HRD has the knowledge and skills to assist in such learning and development initiatives. This article demonstrated how HRD can assist in identifying and developing necessary STEM-student leadership competencies that are essential for success in today's global environment.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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