Background:
This workshop was designed to bring together a set of high-level stakeholders in technological advancement from across industry, government, and academia, with the following overall objectives:

- to develop a robust understanding of the current status of the pipeline from graduate degree programs in science, technology, engineering and mathematics (STEM) into professional research environments; and,
- to promote innovation in U.S. academic-industry partnership around advanced research and graduate studies.

Due to the pandemic, the Workshop’s format had to be changed from one comprehensive in-person meeting to multiple events in phases focused on specific issues and spread throughout the year, with a concluding event in a year’s time on June 24-25, 2021.

This Workshop series is part of an NSF-supported Innovation in Graduate Education program at Lehigh University, “Partnership with Researchers in Industry for Doctoral Education.” It was motivated by a comment that we often heard from colleagues in industry, “you have very smart students coming out of Lehigh but they don’t think like us in industry.” Its goal is to address this disconnect between the current training of STEM PhDs and the expectations of their most likely employers - a national malady of graduate education, which has been described in detail in the 2018 report of National Academies, *Graduate STEM Education for the 21st Century*.1

This report summarizes the outcome of Phase 1 meeting held via Zoom on July 9, 2020, which focused on identifying the challenges of the current doctoral training, especially concerning Industry-University partnerships. Proposed solutions to such challenges will be sought through subsequent meetings.

Overview:

The event:

The kickoff event had 78 registered participants (66 participated in the morning session; 64 participated in the afternoon session) comprised of 28% industry leaders, 55% academicians (administrators + faculty) and 17% from nonprofits, US funding agencies and representatives of international institutions engaged in the management of doctoral training. Considering the intense nature of interactions on Zoom and the 9-hour spread of time zones, the event was scheduled to run from 11:00 AM through 2:15 PM EDT. To seed the discussion, the program started with a brief introduction of the topic by Workshop host, John Simon (President, Lehigh University), followed by 25-minute oral presentations on industry and university perspectives on challenges in STEM graduate education by Gary Calabrese (Senior Vice President and Director, Corning Global Research) and Julia Kent (Vice President, Best Practices and Strategic Initiatives, Council of Graduate Schools), respectively. Al Romig, (Executive Officer, National Academy of Engineering) provided introductory remarks for the afternoon session which was
designed to ensure active participation of all attendees through 13 small group discussions of up to six participants, followed by 4 large group discussions of up to 20 participants each.

When within a small group, each participant was asked to share, in advance or upon hearing the industry and academic perspectives, one or two individual priority issue(s) with the group, which should be pursued at the follow-up meetings. The group then collectively identified 1-3 consensus opportunities for innovation in STEM doctoral education. This information was then carried over to the large group to compare, discuss, and identify key next questions that need to be addressed in and across sectors to move forward opportunities for industry-university partnership for innovation in STEM doctoral education.

Finally, the four large groups summarized the discussion at the final session where all the participants assembled again in a panel discussion mode moderated by Al Romig and Alan Snyder (Vice President and Associate Provost, Research and Graduate Studies, Lehigh University). This segment, moderated by Beth Dolan (Deputy Provost, Graduate Education, Lehigh University), provided opportunity for the audience to ask questions and clarify from the speakers any issues raised earlier in the day. The event ended with closing remarks by Lehigh Provost Nathan Urban. A post-workshop survey by an independent evaluator, Lynn Columba, with a response rate of 34% showed that, with the exception of one participant, all participants were very satisfied or satisfied with the event.

The Outcomes:

The key outcomes of small and large group discussions, and resulting identification of topics needing most attention for successful industry-university partnerships, are succinctly listed below:

1. Although not discussed explicitly, the participants agreed implicitly that the current doctoral training in STEM subjects is inadequate to meet the needs of majority of employers who are largely outside the academy.

2. The current training regimen, while strong and rigorous in disciplinary, in-depth investigation of a problem, does not prepare the doctoral students in core competencies or essential skills that are necessary for consistent success in industry (including national labs). The participants identified the following skillsets that should be included in doctoral training:
   a. Effective communication
   b. Learning agility, openness to collaboration, cross-discipline interest, broad perspective
   c. People skills, teamwork
   d. Time management, rapid and practical problem solving, innovating in real time
   e. Ethics, lab safety, research integrity
   f. Analytics, data science/statistics
   g. Business acumen
   h. Project management, government regulations
   i. Intellectual property issues
   j. Economic analysis
   k. Critical, independent thinking

The above listed essential skills have been identified previously, but their relative importance, which may very well be company dependent, remains undetermined. In future
sessions we will explore the crucial skills that must be acquired by all doctoral students, with the others offered as elective depending on the student’s career plan.

3. Three major categories of challenges were identified in order to prepare doctoral students for successful careers in professions besides academia.
   a. Identification and implementation of the mechanisms for providing skills
      i. Establish if the current doctorate model is agile and adaptive enough to impart the required skillsets, or would it be prudent to establish an alternative doctorate that assures these skills? For the latter option, how can we reduce perceived risk of ‘industrial’ doctorate?
      ii. How to get doctoral students trained in appropriate core competencies; those needed to thrive in industry or other professions?
      iii. How to facilitate core competency training more consistently across STEM doctoral education?
      iv. How to help all participants recognize the differences across various industry, university, nonprofit and government entities?
   b. Faculty buy-in. Need for core competencies has been recognized for some years, but there has been lack of enthusiasm, even resistance from faculty, especially those who have excelled in the current system, raising following questions:
      i. How to engage faculty mentors in supporting professional competencies?
      ii. How can the faculty be encouraged to allow their doctoral students to participate in more experiential learning?
      iii. How to incentivize the faculty and industry researchers to collaborate and find solutions to these problems?
   c. Development of industry-university partnerships.
      i. How to identify best-fit industry partners?
      ii. How to facilitate more back and forth movement of faculty/students/industry scientists?
      iii. How to incorporate incentives that bring value and increase diversity in the academy and in industry?

4. Various mechanisms were proposed as opportunities to impart essential skills, but their relative effectiveness could not be considered within the allotted time. Industry-university partnership appeared as necessary for developing these mechanisms. However, the suggested role of the partners and their responsibility for implementation varied significantly. The suggestions included:
   a. Long-term professor-industry relationships
   b. Broaden definitions of “career success”; make students aware of non-academic career paths
   c. Experiential learning beyond internships
   d. Adopt best practices from other countries’ industrial PhDs. Develop a US industrial PhD track
   e. Block grants to universities to educate STEM doctoral students beyond technical expertise
   f. Celebrate alumni outside academia who are making a difference in the world
   g. Centers of excellence for engaging students
h. Support networks for underrepresented students
i. Doctoral analog to undergraduate capstone collaboration to solve current problems
j. Co-advisors / mentors from industry
k. Industry involvement in developing classes, programs
l. Refer undergraduate interns in industry to relevant graduate programs depending on their interests and skills
m. Engage industry researchers to teach the skillsets needed, and to establish robust mentoring
n. Collaborate with humanities and business faculty in the academy

Conclusions:
Based on above summarized discussions, the following next steps are identified as needing further consideration and resolution for overcoming the gap in the training of STEM doctoral students:

a. Identify and rank order the skillsets that every STEM doctoral student must acquire vs. others that are desirable for the completion of doctorate degree. Recommend mechanism(s) for providing these skills.
b. Collect and analyze information about the faculty and university administration’s take on (a), and use it to develop and recommend strategies, in consultation with industry stakeholders, for successfully providing the identified skillsets to doctoral students.
c. Identify best practices and options that interested companies and universities may adopt to build industry-university partnership for the training of the doctoral workforce.
d. Establish whether a new track of doctorate is needed in US that is commensurate with the needs of industry, such as those adopted by Germany and UK, or instead whether we should continue improving/optimizing the existing traditional version of STEM doctoral training.

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