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Solutions to Challenges of Forming Industry-University Partnerships for Doctoral Training

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Abstract

Partnerships between industry and universities are a vital first step in addressing persistent shortcomings of the U.S. STEM doctoral education system. Although often difficult to establish, these collaborations are essential for preparing a doctoral workforce that meets the evolving expectations of most employers. Students trained through such partnerships will gain a research mindset oriented towards solving real-world problems, an outcome not usually delivered by the current system.

Three key challenges have been identified for forming desired industry-university partnerships: (i) limited corporate capacity to commit support for the duration of PhD projects; (ii) complexities surrounding intellectual property (IP) and publication agreements; and (iii) misaligned timelines for research pursued by universities and industry. To find solutions to these challenges, seventy-seven leaders from academia, industry, funding agencies, nonprofit organizations, professional societies, and international institutions convened in Washington, D.C. last August. They identified four key takeaways for systemic change: (a) approach partnerships strategically, not transactionally; (b) introduce flexibility into PhD requirements; (c) develop standardized agreement templates related to IP and publications; and (d) explore alternatives to the traditional PhD model. Participants also highlighted practices needed to put these ideas into action, specifically: adopting collective approaches to forming partnerships, maintaining consistent and transparent communication, and prioritizing follow-up actions with sustained attention.

From these insights, nine potential solutions were developed, ranked in order of increasing implementation complexity: (1) Involve graduate students in shaping their programs; (2) Increase flexibility in project start dates to allow for timely outcomes that benefit the industry partner; (3) Improve the process for forming partnerships; (4) Shorten the duration of PhD programs by re-examining coursework and other milestones; (5) Revise faculty reward criteria to include engagement with industry; (6) Establish upfront alignment between academic and industry researchers; (7) Build strategic industry-university partnerships at the institutional level; (8) Create standardized national templates for agreements; and (9) Establish university consortia to collectively address common STEM graduate education issues. While solutions 1–5 can be pursued independently by universities, the remaining more complex reforms will require coordination with industry partners and leadership from funding agencies. Note that such coordinated models are already standard in several countries (e.g., Germany, the UK, and Belgium) where industry-university partnerships are central to doctoral training.

Finally, actionable recommendations were provided for four stakeholder groups: academia, industry, government, and doctoral students. Post-workshop survey results indicated optimism about adoption, with most respondents affirming a strong likelihood of implementing key recommendations at their institutions. Collectively, these outcomes represent an important first roadmap for strengthening STEM doctoral training in the United States. The implementation of this roadmap is expected to prepare universities to meet the challenge of training the necessary

STEM PhDs, especially as federal policies are being intensely revised and funding for research is reduced.

1. Background

There has been growing recognition of the need for major changes in doctoral education worldwide [1]. Indeed, shortcomings of STEM doctoral training in the U.S. have been known for decades [2], [3]. For instance, Roach and Sauermann demonstrated that a significant portion of STEM students lose interest in academic careers as they progress through their training — a shift driven more by changing preferences than by research productivity [4]. According to the most recent statistics collected by the National Center for Science and Engineering Statistics (NCSES), for each STEM PhD with definitive employment in academia, 1.6 accepted jobs in industry [5]. Over 90% of engineering and 88% of physical sciences doctorates who do not pursue postdoctoral studies for further training opt for careers outside academia [6]. This shift in trend of employment of PhD graduates away from academia toward industry and other professions has continued for decades, but graduate training has not kept pace with this evolving reality.

Within the graduate education community, the relevance of the current PhD model has become a "hot topic" of discussion, as indicated by the occurrence of three national level events within a span of two months during the summer of 2025, including (i) The "National Workshop on the Formation of Industry-University Partnerships for Doctoral Training" held under the auspices of an NSF-IGE project [7]; (ii) "Reimagining STEMM (Science, Technology, Engineering, Mathematics, and Medicine) Graduate Education and Postdoctoral Career Development: A Summit", hosted by National Academies [8], and (iii) The "Expanding STEM Ph.D. Funding Streams" workshop, hosted by University-Industry Demonstration Partnership (UIDP) organization [9]. The latter two events provided valuable insight into the challenges facing doctoral education, but did not go far enough to offer implementable solutions and action plans on how to achieve them. By comparison, the National Workshop progressed to the next stage and succeeded in developing a roadmap of precise steps for fixing the problems. These steps are reported here.

While targeted improvements have been implemented in a few select departments and institutions, the current system generally falls short in preparing students for careers outside academia, despite most graduates being employed in industry (private corporations, national laboratories, regulatory agencies, healthcare organizations, etc.) [1], [10]. Traditional PhD programs provide strong subject-matter expertise, but often fail to equip students with the skills and mindsets required to solve real-world problems. In particular, PhD students frequently lack the following: meaningful exposure to industrial R&D challenges, an understanding of how industry conducts research to drive innovation, and the non-technical professional competencies essential for career success.

To address these gaps, over one hundred leaders from academia, private corporations, national labs, government funding agencies, and professional societies convened for three workshops in 2020-2021 [11]. The group recommended creating student-centered doctoral training focused on use-inspired research through industry-university partnerships. This led to the development of a pilot program: the **Pasteur Partnership PhD (P3)** [12]. There are four distinctive features of the P3 program: (1) A pre-program summer internship for the student to gain a broad perspective of the research topic of interest; (2) Co-advising of the student by a university faculty member and an industry researcher, which aligns with evidence-based practices for effective mentorship in STEMM and recognizes the value of diverse mentoring networks [13]; (3) Instructions in developing essential professional skills; and (4) An industry residency for the student to conduct part of their dissertation at a partner industry location. These features are incorporated within traditional programs while maintaining their rigor. Prospective PhD applicants expressed overwhelming interest in the P3 program, and faculty were eager to collaborate with industry [14]. However, the limited availability of industry-university partnerships restricted student enrollment.

Through extensive discussions, **three key challenges** to forming such partnerships were identified [10], [12], [15], [16]:

I. Difficulty for corporations to commit resources for the duration of a PhD.
II. Complexities surrounding intellectual property (IP) and publication agreements.
III. Misaligned timelines of research pursued by universities and industry.

Despite these obstacles, several international models have demonstrated that such partnerships can be established to successfully train STEM PhDs. They provide motivation to seek solutions within the US graduate training structure by modifying their models to incorporate our laws and norms. With this mindset, the National Workshop on the Formation of Industry-University Partnerships for Doctoral Training convened in August 2025, gathering graduate education stakeholders to develop solutions to the three key challenges noted above. They were encouraged to share their experiences and discuss them in an intentionally crafted workshop format [7]. In this article, we communicate the recommendations of this workshop. We begin with a description of its organization and execution (Section 2), followed by its key outcomes that provide valuable guidance to address the challenges facing the training of STEM PhDs (Sections 3-8).

2. National Workshop on the Formation of Industry-University Partnerships for Doctoral Training

The goal of the National workshop was to move beyond the previously completed analysis of problems facing doctoral training. The structure of the Workshop needed to be such that it would stimulate discussion and constructive debate, while disallowing the dominance of either industry or academic viewpoint. The presented information and new ideas were analyzed and synthesized, as described below, to yield the outcomes of the Workshop.

2.1 Workshop structure

To facilitate the participation of relevant stakeholders, the Workshop was held at the National Academies building in Washington, D.C., on August 4-6, 2025. It was attended by 77 participants, including leaders from industry, academia, funding agencies, professional societies, nonprofit organizations like the National Academies and the Council of Graduate Schools, and international institutions already engaged in graduate training through industry-university collaborations. The workshop was deliberately limited in size to enable meaningful engagement while ensuring representation of a complete spectrum of perspectives. Altogether, 59 organizations were represented, including 36 academic institutions and 23 non-academic organizations (10 private corporations, 4 international organizations, 3 professional societies, 3 nonprofit organizations, 2 funding agencies, and 1 National Lab).

The workshop program was divided into five parts, starting with an introductory session to provide an overview of the state of STEM doctoral training in the U.S. and its shortcomings relative to the expectations of major employers of PhDs. At the center of the Workshop were the three half-day sessions, one for each of the three key challenges previously identified. The last part of the program focused on integrating the outcome of these three sessions and any new information from unstructured discussions.

Each of the three main sessions started with one longer (30 min) and two shorter (20 min each) invited presentations. To maintain a balance, one short-presentation speaker was from industry while the other was from academia. The longer presentation provided an assessment of the challenge to be addressed, and the speaker was asked to inform the audience of specific problems and/or questions that they should consider. This speaker was neither from industry nor academia, thereby providing an additional perspective on the 'problems' to be solved. The shorter keynote presentations provided examples of solutions to the issues raised by the longer talk. The three speakers were encouraged to consult with each other prior to the workshop. Thus, after listening to the three keynote talks, the audience became well aware of specific issues and some possible solutions, and they were ready to tackle the challenge of the session. A 20-minute coffee break provided an opportunity for the participants to informally share their reaction to what they had just heard.

After the break, the participants were divided into four parallel breakout sessions of approximately 16-19 people each to continue in-depth discussions of the already identified issues. Based on their personal experiences, all participants were encouraged to raise new issues connected with the overall challenge of the session. Each breakout session was led by a Discussion Leader who started with a 5-minute presentation prepared in advance to induce discussion. Thereafter, the points raised by the participants were addressed. The Discussion Leader was charged with keeping a balance of different perspectives and focusing on the goal of finding implementable solutions to the issues raised during their session. In addition, a Reporter-Panelist took notes and kept track of the issues discussed and their likely solutions.

At the end of the breakout session, the four Reporter-Panelists shared their message with the full audience. Thereafter, they served as panelists to help prioritize the issues connected with the overarching challenge under discussion. A moderator managed the panel discussion, who was charged with extracting practical solutions to the issues, and avoiding discussions of hypothetical situations with no clear solution.

All the presentations and discussions were audio-recorded. The participants were made aware in advance that the sole purpose of the recording was to build a consensus report without tracking the identity of individuals. At the end, the speakers were given a choice of sharing their slides with the participants. Most, but not all, speakers complied with such requests from the audience.

2.2 Analysis of discussions and ideas presented at the Workshop

The audio recordings were the primary record of the information presented and discussed, as well as the new ideas generated, at the Workshop. In addition, some Discussion Leaders and Panel Moderators took notes on chart paper. The authors also took notes of the conversations they had with the participants. In order to construct a logical report of the key points discussed in various sessions, help was taken from AI platforms to prepare an extensive summary of each session, identifying the most important concepts discussed. From these summaries and the authors' own notes, it became clear that overall, the information could be classified into the following categories: points of agreement; points needing further discussion; takeaways; solutions; and actionable recommendations. AI then helped reorganize all the information into these categories. The resulting document was edited manually for comprehensiveness, filling missing points, giving appropriate weight to ideas according to live discussions rather than the frequency of related phrases in the recording, and ensuring a smooth flow of information and prevalent thinking. The resulting document served as the first draft of the outcomes report, which was then shared with the participants for their feedback. The draft was revised and updated to incorporate the feedback received.

The resulting outcomes report was provided to the participants for future use and sharing with others interested in improving the state of doctoral training. A concise message of the report is published in ASEE's Prism magazine as a Letter to the Editor [17]. Details of the Workshop and how the report was generated are presented here for interested readers. The key outcomes are presented next.

3. Points of Agreement

3.1 State of doctoral training in the U.S.

The workshop revealed a strong consensus that the traditional model of doctoral education requires significant updates to reflect the evolving needs of students and the nation [2], [3]. Two key factors drive this urgency: the increasing diversity of career paths for PhD students, and the national demand for talent to fuel economic growth, as exemplified by the high compensation packages for leaders in emerging technologies such as Generative AI. There is a substantial opportunity for mutual benefit by connecting universities and industry; however, success depends on acknowledging and respecting the differing objectives of each sector. The core principle of any reform must be keeping students at the center, as universities have a fundamental responsibility to prepare them for diverse career trajectories in addition to training them with disciplinary, in-depth expertise. Bridging the gap between academia and industry will require clear, data-driven arguments that demonstrate the benefits for companies as well as the broader societal and economic returns of aligning doctoral training with industry needs [18].

3.2 Required skills and experiences for STEM doctoral training

Participants agreed that PhD trainees preparing for careers in industry should develop four core competencies: 1) technical subject-matter knowledge; 2) professional skills; 3) practical experience in developing viable solutions; and 4) a research mindset oriented toward real-world problem-solving. The current system effectively delivers 1) and, to a varying degree, 3), while 2) has been offered to a limited number of students in recent years through programs like the NSF Research Traineeship (NRT). However, 4) remains largely absent from most programs, a gap that has been identified as a systemic failure in recent national assessments [3].

3.3 Learnings from European models

The workshop highlighted international models that successfully integrate all four core competencies through industry-university partnerships. For example:

- **German model of science and innovation:** Germany is investing over €500 billion in research and development over ten years, driven by both federal and state governments, and the private sector. The Fraunhofer model fosters collaboration between universities and industry, where master's and doctoral students work on specific projects supported by companies with a significant infusion of government support.
- **Belgian model:** Funded by the federal government, a consortium of five universities facilitates the transfer of PhD talent into the non-academic labor market. This program includes a successful job-shadowing initiative, guided by an advisory board of ten companies and recognized by university chancellors, illustrating how a collective, government-supported approach can overcome systemic challenges in industry-university collaborations.

Workshop participants agreed that these models demonstrate the success of structured partnerships for effectively equipping doctoral students with technical expertise, professional skills, practical experience, and real-world research mindsets, providing instructive examples for U.S. reform efforts.

4. Points Needing Further Discussion

While participants agreed on the need for reform, several challenges remain, particularly regarding financial support. The participants acknowledged that industry cannot be viewed as an unlimited source of funding for university research. Instead, universities must recognize industry as an equal partner, bringing expertise and resources that complement academic capabilities.

Financial investment in partnerships should be directly linked to the benefits for each stakeholder—universities, companies, government, and students alike. A key point of contention was the recognition that universities must exercise strategic flexibility in how they allocate resources. This may involve redirecting funds from other areas, at least in the short term, to invest in developing new models of industry-university collaboration.

The financial commitment from all parties must be grounded in a clear return on investment, both in terms of tangible outcomes (e.g., research outputs, patents) and broader impacts (e.g., workforce readiness, societal benefit). Addressing this issue is critical to establishing sustainable industry-university partnerships that can effectively prepare doctoral students for diverse career paths.

5. Overall Takeaways

To address the three key challenges noted in Section 1, the workshop structured separate half-day sessions dedicated to each topic as described in Section 2.1. However, discussions frequently overlapped, as many solutions applied across multiple challenges. Therefore, key takeaways and proposed solutions are presented collectively.

Participants identified several overarching takeaways that highlight how academia, industry, and government can collaborate to reimagine STEM doctoral training and better align it with the evolving research and innovation landscape.

- **Consider partnerships with strategic vision, not just transactions**
  Industry-university relationships should be treated as long-term, strategic partnerships rather than short-term transactions. Graduate student success should remain the central goal, with academic integrity preserved. Participants emphasized that developing transferable problem-solving and critical thinking skills are more important than strict alignment with industry-specific tasks.
- **Add flexibility to PhD requirements**
  Flexible, student-centered PhD pathways are essential for delivering the four core competencies highlighted in Section 3.2, particularly the research mindset oriented toward real-world problem-solving, while aligning with industry goals. Participants recommended differentiated tracks, restructured curricula, and updated program models that balance academic rigor and practical application, echoing global calls for a reform of PhD structures that have remained largely unchanged for many decades [1].
- **Develop standard templates**
  Standardized national templates are critical in streamlining agreements for intellectual property, publications, and student engagement. Master templates can be adapted with addenda to account for institutional and disciplinary differences, reducing administrative burden and facilitating partnerships.
- **Consider alternatives to the traditional PhD**
  The workshop highlighted the potential to evolve the traditional PhD to incorporate new approaches and technologies. Participants also suggested reconsidering alternative doctoral degrees, such as the Doctor of Engineering, to better meet industry needs.
- **Develop collective approaches to forming partnerships**
  Moving beyond individual agreements, forming consortia of universities aligned with industry sectors can drive systemic change. This effort will require the engagement of funding agencies and innovative collaboration models to ensure that doctoral education remains relevant, equitable, and career aligned.
- **Pursue consistent communication**
  To overcome cultural differences and misaligned timelines between academia and industry, participants emphasized the need for clear and consistent communication. This expectation includes identifying shared goals, and understanding sector-specific priorities that may vary with the area of technology.
- **Consider the relative importance of follow-up actions**
  - Participants prioritized initiatives tied to funding and research. Encouraging funding agencies to create graduate fellowships linked to industry-university collaboration and supporting student research through partnerships received the strongest support.

- Establishing consortia of universities to partner with companies in specific technology areas was also valued, though responses reflected recognition of implementation challenges.

These takeaways underscore a persistent “readiness gap,” driven by traditional academic curricula, cultural differences, and the absence of structured collaboration. Addressing this gap is an ecosystem-wide challenge requiring coordinated effort and shared responsibility, as well as an area for further research to improve STEM graduate education. To be successful in industry, a PhD should cultivate highly sought-after transferable skills and a problem-solving mindset in addition to technical expertise.

6. Solutions to the Three Key Challenges

Building on the overall takeaways, the workshop generated concrete solutions to advance industry-university partnerships. Some solutions are considered “small steps” that can be implemented immediately. Examples of immediate, ‘small step’ solutions include developing individualized coursework tailored to the student’s background and their dissertation needs; creating more flexible academic calendars; and encouraging, even requiring, industry partners to serve on student dissertation committees to integrate real-world perspectives into research projects.

By comparison, “big steps” would require strategic, long-term planning, greater understanding of industry needs, and the support of governmental agencies. Examples are: implementing Individual Development Plans (IDPs) for students’ dissertations, creating consortia, and developing standardized contract templates. These approaches provide clarity, efficiency, and uniformity, while also making a stronger case with national agencies.

6.1 Potential solutions (in order of increasing complexity)

i. **Involve students:** Engage students in developing their educational plans and in understanding partnership agreements, licensing, and related processes. Creative approaches, such as flexible fellowship structures, can support this involvement.

ii. **Add flexibility to project start dates:** Adjust project start dates to accommodate industry timelines, reducing delays from months to weeks. This is increasingly important in rapidly evolving technological areas and for engaging students in startups and translational research.

iii. **Improve the partnership forming process:** Streamline processes using templates and automated tools. Institutions should share knowledge and resources, and designate a central office to handle industry inquiries, reducing the administrative burden on potential partners.

iv. **Shorten PhD duration:** Reduce the duration of the PhD to approximately four years beyond the bachelor’s degree (may be longer for students with insufficient background knowledge), aligning with European models. This may be achieved by replacing traditional coursework with coursework informed by the student’s background and their dissertation needs, reducing credit requirements where appropriate, or recognizing prior knowledge through exams. Shortened programs may also attract more industry partners by aligning the 'opportunity cost' of a PhD with the rapid pace of industrial innovation [1], [15].

v. **Develop alternative faculty rewards criteria:** Revise promotion and tenure criteria to formally recognize industry collaboration, addressing a primary barrier identified by faculty in recent surveys [14]. For example, some institutions accept letters of support from industry partners as part of faculty evaluation under “publicly engaged research” options.

vi. **Establish upfront alignment:** Align expectations among academic and industry researchers before pursuing formal agreements. Simplified non-disclosure agreements (NDAs) can outline essential points and determine collaboration feasibility.

vii. **Develop strategic, institution-to-institution relationships:** Create institution-level agreements rather than relying on individual faculty-led arrangements, fostering sustainable and scalable partnerships.

viii. **Develop standardized national templates:** National contract templates for financial, IP, and publication agreements can simplify and standardize interactions. These templates, like the UK’s Lambert agreements [19], may be incorporated into government solicitations, with project-specific details handled via annexes.

ix. **Establish consortia:** Form consortia based on the P3 model to provide comprehensive doctoral training and engage a wide range of partners, including small and non-traditional organizations. Government, industry, and philanthropic resources can support these consortia, following European examples such as Germany’s Fraunhofer Institutes. Additional measures include centralized databases of industrial opportunities, templates, case studies, and combining structures of existing programs (e.g., North Carolina State’s A2i and Lehigh’s P3). Scalability, accessibility, and sustainability should guide national-level initiatives.

7. Actionable Recommendations by Stakeholder

The workshop generated detailed recommendations tailored for the four key stakeholder groups: academia, industry, policymakers, and PhD candidates.

7.1 For academia (graduate schools, universities)

- **Curriculum redesign:** Develop individualized coursework based on each student’s background and dissertation needs. Shorten the duration of the degree program through a more efficient engagement of the student in research. Embed transferable skills, professional development, and an interdisciplinary mindset into curricula.
- **Industry liaisons:** Establish dedicated offices for industry engagement and well-resourced collaboration programs. This ensures that students develop a problem-solving mindset aligned with industry expectations.
- **Faculty incentives:** Revise promotion and tenure criteria to formally recognize and reward applied research and industry collaborations. Increase faculty awareness of PhD competencies.
- **Career development:** Invest in robust career development services tailored for PhD students and leverage alumni networks for mentorship opportunities.

7.2 For industry (companies, national labs, defense organizations, etc.)

- **Direct engagement:** Participate in curriculum design, deliver guest lectures, and mentor PhD students. Establish exchange programs for researchers in industry as well as university faculty.
- **Joint research and sponsorship:** Increase investment in collaborative research projects and consider creating industry-sponsored PhD positions.
- **Internship pathways:** Offer structured internships and postdoctoral opportunities specifically tailored for PhD students and graduates.
- **Value PhD skills:** Recognize and leverage the problem-solving capabilities of PhD graduates, as industry mentors increasingly emphasize the value of 'use-inspired' research training [16].

7.3 For policymakers (government and funding agencies)

- **Incentivize collaborations:** Implement funding schemes that explicitly support industry-academia research partnerships and PhD placements, for example, by broadening programs like NSF's GRFP, NRT-IPP and SFS, or DoD's NDSEG and SMART.
- **Establish national platforms:** Develop platforms or consortia to facilitate alignment between academic research groups and industry needs.
- **Incorporate IP regulations:** Integrate appropriate intellectual property expectations into funding structures to foster collaborative innovation.

7.4 For PhD candidates

- **Engage proactively:** Seek industry internships, networking opportunities, and professional development experiences during doctoral studies.
- **Broaden horizons:** Develop awareness of diverse career paths and tailor development of skills accordingly, considering options beyond traditional academic trajectories.

8. Concluding Remarks

The workshop proved highly informative and engaging for all participants. Its structure, particularly small-group discussions, provided ample opportunity to share diverse perspectives and experiences. Subsequent panel discussions and plenary debates enabled participants to synthesize solutions and recommendations by consensus. Overall, there was a unanimous agreement that the workshop successfully accomplished its goals.

To assess potential long-term impact, participants were surveyed on the likelihood that their organizations would adopt workshop outcomes. Most respondents indicated they were 'extremely' to 'somewhat likely' to implement key recommendations. Partnership agreements and timelines for addressing research challenges received strong support, though some neutral or cautious responses reflected the complexity of adoption. Financial models received the most measured responses, indicating uncertainty around the implementation of more resource-intensive approaches.

Notably, 85% of respondents reported that their institutions were extremely or highly likely to collaborate with others to form consortia, suggesting a broad willingness among universities to pursue collective approaches. These findings indicate optimism that the workshop has established a foundational roadmap for improving STEM doctoral training in the United States. Implementation of the Workshop's recommendations is expected to prepare academia better for its charge of training an appropriate doctoral workforce while federal funding for research is reduced and policies are intensely revised [18].

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