In contrast to the narrowing of options in academic careers, the bioscience industry offers robust employment opportunities for STEM-trained workers, especially those who display both scientific and business talent. Unfortunately, traditional science programs typically lack curricular features that develop this type of worker. The North Carolina State University Master of Microbial Biotechnology (MMB) program facilitates industry-specific experiential learning to fill this training gap. Similar programs often rely on a single industry internship to provide students relevant work experience, but completion of one internship might not suffice to position students for employment in a highly competitive job market. The MMB program requires students to complete an internship and three practicum projects in an industry setting, to promote development of key skills in a variety of areas, to build confidence in the ability to perform initial job duties, and to establish a more extensive work history in industry. In this Perspective we discuss an unmet need in undergraduate and graduate STEM education that can be filled by incorporating a similar set of industry-specific work experiences for students who desire to transition from academe into the life science industry.

INTRODUCTION

The National Science Board (NSB) and the Bureau of Labor Statistics predict significant growth for overall science and engineering (S&E) employment in the United States through 2022 (1 – Chapter 3, Figure 3-A, Table 3-A), but this optimistic outlook looks less sanguine for S&E doctorate holders who seek academic employment, especially when one considers the increasing number of new doctorates awarded each year. The bleak job landscape in academe is further complicated for new S&E doctoral graduates by continued decline in overall academic employment, which fell by nearly six percent between 2005 and 2015; the life sciences and mathematics and computer sciences represent the academic areas hardest hit by the overall decline, showing 7.7% and 22.2% employment decreases respectively (2 – Table 46).

While overall unemployment for the holders of S&E bachelor’s and master’s degrees remains slightly higher than for doctoral recipients (1 – Chapter 3, Appendix Table 3-8), the latter are more likely to suffer the apparent narrowing of job opportunities in academe. According to the NSB, the percentage of S&E doctoral recipients who held tenure and tenure-track positions declined from about 21% in 2003 to approximately 16% in 2013 (1 – Chapter 3, Table 3-16). Although the National Association of Colleges and Employers (NACE) reported employment for 89% of all doctorate holders in 2015 (3 – Figure 7), the National Science Foundation (NSF) shows that the percentage of S&E doctoral recipients who reported definite employment commitments (i.e., signed a contract or received definite notification of employment) or post-doctoral study decreased from about 71% to approximately 63% between 2005 and 2015 (2 – Table 42); during this period, definite commitments for those with life science degrees decreased from approximately 71% to 58% and commitments for the physical sciences and earth sciences decreased from about 72% to 61%. Alarmingly, the same NSF data also show that the percentage of life science doctorate holders who reported no definite commitments for employment or post-doctoral study rose from approximately 29% in 2005 to nearly 37% in 2015; more than 40% of doctoral recipients indicate no commitments for both the life sciences and engineering.

As enrollment in S&E degree programs continues to rise in the United States (1 – Appendix Table 2-24)—and despite an increase in the number of doctorate recipients with definite academic post-doctoral S&E appointments (2 – Table 42—
which count as full-time employment—little assurance exists for degree holders, undergraduate or advanced, that the outlook for traditional tenure-track employment will improve. As one might imagine, many scientists and engineers have started to consider non-traditional career routes over traditional, academic paths. Unlike the stark academic S&E career landscape, many viable career paths can be found in industry.

With approximately 1.62 million workers employed by more than 73,000 companies nationally (Battelle/BIO State Bioscience Jobs, Investments, and Innovation 2014 report [https://www.bio.org/articles/battellebio-state-bio science-jobs-investments-and-innovation-2014]), the life science industry serves as an important economic driver in the United States. Bioscience companies rely heavily on cross-disciplinary workers with cross-functional skills to serve on interdisciplinary teams (4, 5); these individuals and teams bolster individual company vitality, and by extension, they also strengthen the industry’s continued growth (6). While technical proficiency in S&E areas often serves as a prerequisite for industry positions, companies also need workers who can link technical knowledge to business concepts associated with product and technology development and commercialization (e.g., intellectual property, regulatory pathways, finance, marketing) (4, 7). This aspect of the industry can especially burden doctoral recipients seeking employment since academic training often promotes specialization over cross-disciplinarity early in the process.

Industry employers also desire experienced employees who apply key professional skills, including leadership, effective spoken and written communication, adaptability, time management, critical thinking, teamwork and project management proficiency, and an ability to build positive interpersonal relationships (4–7; The Coalition of State Bioscience Institutes - 2016 Life Science Workforce Trends Report [http://www.csbioinstitutes.org/workforce-development]). Without such knowledge, skills, and abilities (KSA) desired by industry employers, transitioning from academe to industry can be very difficult. Unfortunately, traditional baccalaureate and graduate programs rarely offer the business and professional skill development, or relevant work experiences, demanded by industry, despite serving as a primary talent source for bioscience companies (4). Instead, traditional science curricula usually emphasize a combination of lecture-based coursework and laboratory experiences, but these learning strategies alone are insufficient to promote career readiness in industry or academe without coupling those strategies to development of the aforementioned professional skills (5, 8–10). Thus, these conventional approaches do not adequately serve the career needs of students who seek industry jobs.

To fill this training gap and establish a pipeline of scientists and mathematicians who possess valuable business and professional skills, the first Professional Science Master’s (PSM) programs were launched in 1997. These non-thesis programs train students in a variety of fields of study, although biotechnology, environmental sciences, and biological sciences represent the predominant fields represented by active PSM programs. In response to the aforementioned training gap—and given the strong bioscience industry presence in the Research Triangle Park (RTP) area—Microbiology faculty at North Carolina State University launched a PSM in 2003: the Master of Microbial Biotechnology (MMB) (9).

Like their counterparts in many other PSM programs, MMB students pursue advanced STEM training in a variety of areas (e.g., biomanufacturing, molecular biology, and statistics) while simultaneously developing business and professional KSA highly valued by the bioscience industry. Also like other PSMs, our program exposes students to an environment that emphasizes active and cooperative learning through team-based project work. Most PSM programs require completion of a single internship in a business or public sector institution while a few also require a final team or project experience; these features replace the master’s thesis and allow students to acquire industry-specific work experience. Unlike those in other PSM programs, our students complete additional work in industry to enhance their ability to land jobs with bioscience companies.

We discuss here how these curricular features improve employment opportunities, increase job readiness, and better prepare students in general for industry careers than a strategy emphasizing completion of a single internship or more traditional approaches. This approach might serve as a useful model for conventional STEM and other PSM programs to better position undergraduate and graduate students for industry careers.

**DISCUSSION**

Work experience is a key feature offered to employers by job seekers, and companies will undoubtedly favor applicants with a robust and relevant set of job experiences over those without. College students are often at a disadvantage in this regard since financial, academic, and other constraints can impair or preclude their ability to gain work experience while simultaneously completing degree requirements. In response to this gap, some applied programs offer course credit for completion of internships to increase student participation in career opportunities that might not otherwise be feasible.

The efficacy of internships is often debated in popular media but peer-reviewed empirical evidence is scarce. Nevertheless, internships offer undeniable benefits. They allow students to evaluate host companies as future employment prospects, and vice versa. In a broader sense, internships can also allow students to identify if a particular job role or industry sector represents a strong fit for their career needs. Internships can further provide an opportunity to transfer learning from the classroom to the professional world. Additionally, well-structured internship programs can position students for full-time employment.
after graduation, either with the host company or with another employer.

Broad development in both technical and collaborative skills (e.g., communication and teamwork) will strongly transfer into a variety of industry positions; ideal internships will offer training in both. Conversely, narrowly focused internships that emphasize only technical skills development might not provide an experience that translates well outside of the respective technical area or company. Ideal experiences will also directly connect to a student's academic training, but as with direct conversion into employment, ideal outcomes cannot be guaranteed. Several PSMs, including the MMB program, require completion of separate capstone projects to fill this potential gap, but students might nevertheless need more extensive work histories to elevate their candidacy in an increasingly competitive job market.

For these reasons, MMB students complete not only an internship and a capstone project, but also three semester-long, team-based practicum projects in collaboration with local bioscience companies. Practicum projects essentially serve as team-based internships that present students with actual problems faced by bioscience companies. As a result, students collect not one or two, but five industry-specific work experiences during their graduate training. The projects and other activities associated with the project course afford students added industry exposure while further developing important KSA, and these can be structured to include specific features that are often difficult to ensure for internships, including teamwork, oral presentations, written deliverables, and direct application of instructional content.

As described in detail elsewhere (9, 10), each practicum project spans a fifteen-week semester, during which students are placed into teams paired with a local bioscience company. Host companies change each semester to expose students to different firms, to the various real-world problems engaged by different bioscience companies, and to industry-specific functional areas. Students perform project work mostly outside of class since instructional time is devoted primarily to guest presentations and additional professional skill development. Multiple opportunities occur throughout each semester to evaluate student performance through alternative assessment forms (e.g., observation of performance tasks, interviews, peer evaluations).

The percentage of MMB graduates since 2010 who are currently employed (86%; our unpublished data) is higher than national employment levels for undergraduate and master's recipients (64.5% and 79.2% employment, respectively) (3 – Figures 4, 6). National PSM employment data is scarce, but in 2014, the PSM National Office reported 86% employment for PSM graduates nationally (11 – page 17). Unfortunately, data that allow for more direct comparisons between the MMB program and other similar PSM programs has not been made available.

Also since 2010, 40% percent of MMB alumni gained employment prior to graduation, while 53% of those who sought employment immediately following graduation found it within six months and approximately 7% of alumni required longer than six months to do so; to our knowledge, national PSM data has not been reported for this dimension of employment. Nearly 90% of MMB graduates transition into industry careers; a small proportion pursue other degrees and outcomes in academe. The PSM National Office reported in its 2014 survey that only 50% of PSM graduates were working in industry (11 – Table 18).

Approximately 30% of all MMB graduates hold laboratory-based positions in industry that require technical skills, including KSA pertaining to current good manufacturing and laboratory practices (our unpublished data). As described in detail elsewhere (9, 10), MMB practicum projects often emphasize evaluation of industry market segments, commercialization strategies, and technology features rather than direct performance of technical skills. MMB students acquire technical skills through completion of laboratory-based coursework, and some MMB students also choose to complete internships that favor development of laboratory-based or manufacturing technical skill. For alumni who started in laboratory-based positions, individual alumni survey responses (not presented here) suggest that internships, rather than MMB project work, directly impact acquisition of laboratory or manufacturing technical skills, but project work does significantly enhance development of other professional skills important for technical positions (e.g., teamwork, communication).

Information collected from life science professionals in the Research Triangle Park region (Appendix I) showed us that team collaboration skills are highly important for employment. Adaptability followed teamwork as the next most important skill identified, followed by spoken communication, critical analysis, written communication, building positive interpersonal relationships, time management, project management proficiency, and leadership capability, respectively. Moreover, RTP professionals largely reported that these “soft” skills are as important as technical skills for job selection and career advancement. Students who effectively demonstrate these skills will more likely land industry jobs and experience career success than those who do not. We thus incorporate and assess skill development in these areas at the end of the internship period and at numerous points in the practicum project process during each semester of the project class.

Students also need exposure to a variety of industry areas and companies to better understand the culture and infrastructure of industry companies; MMB practicum projects provide this by incorporating a variety of industry sectors and companies (9, 10). Most MMB alumni report that they were asked about KSA associated with their practicum projects during interviews for both the internship and the first post-graduation job held (Appendix 2), which establishes that project experience was considered for those positions. Alumni largely agree that KSA from projects enhanced their ability to secure an internship, to land their
first job, and to perform their initial job duties. Indeed, a majority of alumni reported that project KSA, in general, eased their transition to industry. We also routinely ask alumni to consider the impact of the internship experience on landing the first post-graduation job; nearly half indicated that the internship played a more significant role than practicum projects, and almost all alumni respondents reported that the internship, in general, eased their transition into industry. Alumni responses largely indicate that practicum projects and the internship both directly enhanced their ability to gain employment after graduating from the MMB program. Taken together, information collected from MMB alumni indicates to us that the MMB experience produces strong employment outcomes and we attribute those outcomes largely to the increased number of industry-specific work experiences offered to our students.

CONCLUSION

Change must occur at all academic levels to better serve the needs of STEM students who desire industry careers. These changes should involve actions that not only improve likelihood of employment but also increase confidence, enable new hires to become fully functional employees soon after the job start, and enhance career advancement. Completing several industry work experiences, including an internship, during the course of an academic program will more likely result in these outcomes than other approaches that emphasize a single work experience will, and certainly more so than traditional approaches to STEM education do.

Of course, academic programs must do more than merely require completion of these exercises. Program faculty and administrators must ensure that students indeed develop and strengthen the KSA desired by industry professionals during each experience. Some companies lack sufficient resources to develop internships that meet such demands; embedding these features in the experience can prove difficult. Practicum project work, however, can be structured to address gaps left open by an internship. This approach also provides administrators and instructors more control over student evaluation as it pertains to job readiness.

Doctoral S&E recipients may be most likely to benefit from such an approach. While undergraduate and master’s degree holders remain somewhat insulated from the challenging academic job market, the starker academic career landscape for doctorate holders is unlikely to improve. Despite NSF data that show increasing interest by doctoral recipients in industry careers, they are woefully underprepared by traditional academic curricula for industry jobs. Opportunities for professional development outside their area of specialization but specific to industry will undoubtedly improve industry employment outcomes for doctoral recipients.

Although additional studies, in the RTP and other areas, are needed to determine the impact of local and regional bioscience economies on employment, we have nevertheless observed that practicum projects and internships influence initial employment and job-related confidence in a positive manner. From our perspective, an internship alone will not develop the KSA desired by industry companies. A process combining an internship with completion of several practicum projects appears to exert the strongest impact on these outcomes, and we intentionally structure the practicum project process, along with other features of our program, to ensure that the aforementioned training gaps are filled. We strongly urge other STEM-training programs to gather data and publish employment information for their graduates so that more comprehensive analysis of employment outcomes can be performed. We further encourage other STEM-training institutions to offer students not only industry-specific internships but also team-based project work completed in an industry environment to build desired KSA and work experience.

SUPPLEMENTAL MATERIALS

Appendix 1: Bioscience industry professionals survey responses
Appendix 2: MMB alumni survey responses

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