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Applied Learning at the Graduate Level—Professional Science Master's Programs Lead the Way

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To remain competitive in an increasingly interdisciplinary world, graduate education must produce professionals who can understand both their scientific disciplines and the business environment in which they work. With the addition of applied learning components outside of the traditional scientific laboratory and training in business skills, Professional Science Master's programs (PSMs) help higher education adapt to this changing environment. The current study illustrates some models of PSMs and contains information on how institutions interested in using PSMs as a way to enhance applied learning at the graduate level can get started.

> *"Graduate education in the natural sciences has traditionally emphasized doctoral training for academic or research careers. This training, however, is not meeting the demand for professionals in business, industry, and the public sector, where individuals with a combination of scientific, technical, and managerial skills will be required."*
> (BHEF, 2011, p.1)

The world of science is increasingly interdisciplinary, creating strong demand for professionals who can translate scientific and technical knowledge into policy-making arenas and entrepreneurial ventures. The skills needed to succeed in these endeavors, however, are often lacking. Students typically focus their education and research within narrowly-defined scientific disciplines, particularly at the graduate level. Faculty research drives education and prepares future cohorts of investigators. However, universities train more than just academicians, and to remain competitive and viewed as contributors to a state's economy, faculty designing curricula have to consider the needs of regional employers.

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INNOVATION IN EDUCATION

The National Governor's Association (NGA) released a report in which Sparks and Waits (2011) include key recommendations for institutions of higher education to:

- set clear expectations for higher education's role in economic development;
- emphasize rigorous use of labor market data and other sources to define goals and priorities;
- encourage employers' input in higher education;
- require public higher education institutions to collect and publicly report impacts;
- emphasize performance as an essential factor in funding.

At the graduate level, universities typically base new program development initiatives on the research expertise and interests of faculty, students, and other internal factors. Interactions with prospective graduate employers are limited, and measures of success are based on enrollment and completion statistics, not job placement and other post-graduation parameters. A more recent Council of Graduate Schools (CGS) report (Wendler, et al., 2012) also calls for changes in graduate education, emphasizing the need for stronger linkages between higher education and employer groups. These two reports suggest that universities explore new pathways to program development and monitoring.

Signature research centers, like Oregon's Nanoscience and Microtechnologies Institute, the Built Environment and Sustainable Technologies Center, and the Translational Research and Drug Development Institute, create communities of innovation that facilitate the research and development process and provide students with applied experiences throughout their graduate education. Kamiel Gabriel (2010) describes communities of innovation as links between the research community, business community, social community, and post-secondary institutions. Institutions of higher education can similarly create educational "communities of innovation" focused on development of graduate programs relevant to regional economic needs.

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Research by Tobias (2009) found that as late as 1995, fewer than 3% of all U.S. master's degrees were in the sciences, and many of those were viewed as failed Ph.D.s. Largely in an effort to address the declining percentage of U.S. citizens earning graduate degrees in science, technology, engineering and mathematical (STEM) fields, the Alfred P. Sloan Foundation began supporting development of Professional Science Master's programs (PSMs) at institutions of higher education across the United States. These programs serve as communities of innovation and are rife with examples of ways to incorporate applied learning practices into graduate education. Development of PSM programs require that directors follow the NGA and CGS guidelines described above.

PROFESSIONAL SCIENCE MASTER'S

Professional Science Master's provide students with two years of graduate-level education in a STEM field and cross-training in workplace skills through professional courses and an internship experience. Advisory boards are required for PSMs and include representative employers who provide input on curricular content and desired learning outcomes. Professional course topics may include any combination of business management, communication, ethics, and other workplace skills. An internship project serves as the capstone experience in lieu of thesis research. Many of the approximately 300 PSMs now offered by 127 institutions (http://sciencemasters.com) are in emerging or interdisciplinary fields like *Renewable Energy*, a PSM currently in development at Oregon State University (http://psm.science.oregonstate.edu). With the assistance of the Sloan Foundation, more than fifteen administrative units have been created as collaborations among multiple institutions within a state or university system to facilitate the development of new PSMs (http://www.nash-psm.org/). The chief academic officers of all institutions in the State of Missouri have recently advocated the development of statewide PSMs, and the institutions in the state leading in undergraduate applied learning (Missouri Western State University, Missouri State University, and Truman State University) have taken the lead in developing PSMs.

At the undergraduate level, the sciences have done an excellent job of incorporating applied learning experiences throughout the curriculum. Starting with lab work in general education courses and culminating in faculty-student research, many institutions have adopted the Characteristics of Excellence in Undergraduate Research (COEUR) advocated by the Council on Undergraduate Research (CUR, 2012). At the graduate level, however, training has traditionally consisted of work

on the thesis advisor's own research, which is frequently very basic in nature. Work on applied problems encountered in business or industry is often lacking.

PSMS AT OREGON STATE UNIVERSITY: EXAMPLES IN APPLIED LEARNING

Although many institutions could be used as a model, Oregon State University (OSU) offers five PSMs in biotechnology, applied physics, environmental science, fisheries and wildlife administration, and botany. The program template for PSMs at OSU includes a minimum of 30 quarter-credit hours in a STEM field, 18 credits of professional coursework, and a 3 to 6 month internship (6-12 credits) for a total of 54 credits. This is comparably more than a traditional master's minimum of 45 credits and resulted in the description of PSMs as "science plus" degrees. Students usually still finish within two years, because internships are focused in time and typically start in the summer following the first year of study. At OSU, all students are required to have a major professor and at least two other graduate committee members. In addition to completing the coursework and an internship project, students must present project results in a seminar and pass an oral examination to earn the PSM degree. Other programs, for example those at Missouri Western State University in Chemistry or Human Factors and Usability Testing, have a more traditional Master's requirement of 36 semester hours.

The ability to communicate well with others has been universally touted as the top professional skill preferred by employers across all disciplines (Stevens, 2005). Therefore, virtually all PSMs nationally provide some level of training in communication either as stand-alone courses or embedded in the science curriculum. The professional component of OSU's PSMs is shared across programs and was developed based on feedback from relevant employer groups. Scientists are often called upon to perform "other" tasks, such as guiding development of new policy for agencies, drafting business plans for start-up companies, managing non-profit organizations, and serving in administrative roles as they advance in their careers. To properly prepare PSM graduates for such tasks, OSU developed and requires students to take six professional courses (3 credit hours each):

- Communication and the Practice of Science,
- Research Ethics,
- Professional Skills,
- Accounting and Finance for Scientists,
- Project Management and Marketing Scientific Technologies,
- Innovation Management.

Each class includes students from a variety of STEM fields, so cross-disciplinary communication is an inherent learning outcome. These courses are also offered online as a Graduate Certificate in Management for Science Professionals Program for non-PSM majors. Topics in the Research Ethics course include scientific integrity, conflicts of interest between academic science and commercial science, and social responsibilities in science. A series of three business courses, ending with Innovation Management, prepare students to write their own business plans for a new scientific product or service of their own design. The Professional Skills class requires students to work together on a current scientific problem within the context of an existing business. Company representatives sponsor and mentor the class. Students evaluate different work strategies, draft a project management plan, and then execute the plan. End products usually include a final report and presentation. Lectures cover topics like teamwork, leadership, and working with public media (e.g., how to give effective camera interviews). Students are also asked to participate in a reflective learning exercise at the end of the term in which they evaluate the team, their own leadership and communication skills, and the leadership and communication skills of their classmates. All of these activities provide applied learning experiences for PSM students that may be omitted in a more traditional program.

Prior to the start of fall term, all OSU PSM and Graduate Certificate students participate in a 5-day orientation workshop, which is held at an off-campus location to facilitate social engagement. Costs to deliver the workshop are offset by a differential tuition that these students pay, and no credits are awarded for participation. Individuals get to know their cohort, support staff, and professional course instructors. This familiarity likely translates into greater student success and retention during the first academic year (Ellis-O'Quinn, 2012). Professional development exercises not included elsewhere in the program characterize the workshop and include career development strategies, job search skills, writing effective cover letters and resumes, interview skills, time management skills, working in virtual environments, and dining and networking etiquette. Instructors teach in hands-on, interactive formats that engage students and leave them with skills that enable them to successfully secure internships in the future. For example, students are required to prepare for interviews in both the interviewee and employer roles. As the interviewee, they must research and draft a position description, update their resume, draft a cover letter, and submit their application to prospective "employers." As the interviewer, students must prepare appropriate screening criteria and questions prior to interviewing "applicants." Each student is interviewed twice and must conduct two interviews. A subsequent reflective learning exercise requires students to summarize their interview experience with each individual (as either the interviewer or interviewee), which provides feedback from the other person's perspective.

The internship project is the student's capstone experience, replacing the graduate thesis requirement. It is, therefore, carefully evaluated

by the student's committee. An internship proposal must identify learning outcomes and evaluation criteria, be completed at least three weeks prior to the start of the project, and be approved by the graduate committee, internship supervisor, and PSM program director. Students are expected to maintain a journal throughout the internship experience, and the format will vary depending on the nature of the project. An online internship evaluation form is submitted by the internship supervisor at the conclusion of the project, and a grade is assigned by the major professor based on the internship evaluation, journal, and final report. Every final report must include a scientific as well as a business component, which requires the student to integrate his or her scientific and professional training by framing research conducted in the context of a business. This occurs whether the internship provider was a non-profit organization, for-profit business, or government agency. A seminar describing the internship (science + business) is given by each student just prior to his or her oral examination.

Internships not only provide students with hands-on learning experiences and opportunities to integrate scientific and professional knowledge recently acquired through coursework; they also have opportunities to experience the culture of a particular company. Internship providers are able to hire short-term employees for particular projects, and they can utilize a "try-before-you-buy" approach to fill potential permanent positions. Approximately 38-40% of OSU's 70 PSM students end up accepting full-time employment from their internship providers, and this mirrors what is seen nationally (Bell & Allum, 2011).

Internships and applied research in PSMs also provide students the unique opportunity to perform lab work utilizing equipment actually used in manufacturing-scale operations, and to have experience with many proprietary techniques that cannot be taught in a traditional university lab. These abilities to "scale up" what they have learned make them valuable employees.

NEW OPPORTUNITIES IN EDUCATION

Faculty working with PSM students can capitalize on off-campus connections made through their students' internship searches and projects, supporting educational communities of innovation. Professors with an understanding of current workforce needs are the ones who, together with members of PSM advisory boards, create new PSMs and course offerings to meet those needs. At OSU for example, new professional electives include "Advanced Scientific and Technical Writing" and "Mastering the International Work Environment." Increasingly, science and business are practiced on an international stage, and professionals must develop an ability to convey ideas, make decisions, and develop consensus across cultural boundaries. The Mastering the International Work Environment class begins by defining culture not only in terms of national identity but also social identities

like age, gender, profession, race/ethnicity, and academic discipline. In this class, culture-specific information includes aspects of how both personal and organizational cultures influence workgroups. Intercultural communication theory and practice create frameworks for different communication styles and value dimensions to help individuals adapt to different international work settings. Communication technologies used for collaboration are explored, and discussions address cultural norms and how team dynamics, team effectiveness, and interpersonal relationships are altered in online work groups. Guest speakers provide case studies for discussion, and student term projects blend key culture and communication technology topics.

PSMs also provide an opportunity for faculty to think outside of the limitations of the single course-single skill model. For example, communication skills can be incorporated across the curriculum rather than being taught in a single dedicated communications course. Capstone courses can have students from multiple disciplines work together to develop a business plan. These experiences provide a much more realistic approximation of what will be encountered in the workplace, and provide a rich source of applied experience for the students and faculty.

IT'S WORKING

Oregon State University has graduated over 70 students from its PSM programs over the past 8 years, and approximately 90% of those graduates are employed in their field. Based on a recent national survey completed by the CGS (Bell & Allum, 2011), over 55% of employed PSM graduates earn $50,000 or more in annual salary. The majority of PSM graduates (over 75% of OSU's PSM alumni) secure employment regionally, thereby directly contributing to the growth of local economies. Of the graduates surveyed, more than half worked for businesses, 23% worked in government agencies, 16% in academia, and nearly 8% in non-profit organizations. Employment providers vary by discipline, with government agencies hiring the greatest number of environmental science PSM graduates. Employers asked for testimonials about PSM graduates have been very positive. For example, Linda Amedo, Incubation Lead for Hewlett Packard in Corvallis, Oregon states "The PSM creates individuals who are capable of bridging the worlds of science and business, which is critical for success within the science and technology industries" (personal communication, August 12, 2010).

Several OSU PSM students worked for start-up companies during their internship project or after completing their degree and demonstrate the application of this science *plus* education. For example, one former student earning a PSM in Applied Biotechnology conducted her internship at Intuitive Genomics, Inc., a bioinformatics services start-up company, which engaged her in an entrepreneurial venture and increased her knowledge and skills in the field of genomics and

bioinformatics. She used this experience as a stepping stone to her current position with Sharklet Technologies, another start-up bioscience company, where she works as their Business Development Associate.

Other students use their internship experience as a way to explore future employment opportunities with specific organizations. In the Pacific Northwest, examples of companies that hired their PSM interns after graduation include Microsystems Engineering, Inc., Life Technologies, The Nature Conservancy, Kashi Laboratories, a variety of government agencies, and other organizations.

Many individuals return to graduate school after having worked for several years, and they use their new scientific and managerial skills to move horizontally into a new position or vertically up the career ladder in the same organization. For example, one PSM student worked for the Environmental Protection Agency (EPA) while she was completing her PSM in Environmental Science. After graduating, she accepted a new position in the EPA's Risk Characterization Branch, which utilized her new skills in Geographic Information Systems. Another was able to move to a higher-level managerial assignment within the National Oceanic and Atmospheric Administration after completing his PSM in Environmental Science.

Career opportunities for PSM graduates are generally broader than for those who complete a traditional M.S. program, because PSM graduates can "wear many hats." Students in traditional M.S. programs tend to focus on narrowly defined basic research with complementary coursework to develop depth of knowledge within a specific discipline. Graduates from such programs often pursue a Ph.D. or find work as a technician or research associate. In contrast, PSM graduates are comfortable communicating with individuals in science and business, and they understand how to apply research results to new start-up ventures or policy development initiatives. Examples include a former PSM student in Environmental Science, who completed her internship with the Washington Department of Fish and Wildlife where she created new technology-based ways to communicate information about marine recreational fishing regulations with fishermen. She is currently working in Washington, D.C. on marine policy issues.

A few PSM graduates have continued their education to earn Ph.D.s, MBAs, or law degrees. One student completed his PSM in Applied Biotechnology with an internship focused on production of biofuels. He is currently pursuing his Ph.D. in the same field at Colorado State University. A PSM student in Human Factors and Usability Testing from Missouri Western State University went on to pursue a Ph.D. in the MIT Media Lab.

Myhrvold (2010) indicated that just 1% to 3% of patents generate a profit for their inventors. PSM graduates have the potential to increase the number of profitable patents and initiate successful business ventures because they have depth of training in science plus breadth of training in business management and entrepreneurism. Individuals in other science-related disciplines can also benefit from the professional education that characterizes PSM programs. For example, veterinarians

are trained as doctors yet many end up running their own medical practices—typically with no training in accounting, management, or marketing.

Although it is hard to estimate the actual impact educational programs like PSMs have on local and regional economies, directors and state education leaders are optimistic. Realizing how well PSMs can help meet workforce needs, state and university systems have started investing in PSM program development initiatives.

CHALLENGES

Directors of PSMs are pioneers, blazing new graduate program development pathways to create educational communities of innovation. Pioneers typically face many challenges, and the PSM movement certainly has its share. Traditional faculty members often view higher education's contribution to economic development as a secondary by-product of the education process, not as a primary goal. However, increasing pressure from state and federal government agencies as well as student "consumers" will continue to push institutions to use labor market data and employers' input when exploring new program development initiatives. Measures of success will have to include job placement and other post-graduation parameters in addition to enrollment and completion statistics. Many institutions receive faculty buy-in, and those institutions that remain entrenched in the more traditional ways of thinking risk being relegated to obscurity.

Administration of PSM programs at an institution is often coordinated centrally by a full-time director and part-time assistant who are responsible for overall student recruitment and orientation, advising, professional course coordination, website maintenance, outreach and advisory board interactions, alumni tracking, and other activities. Individual PSM program directors are based in the department offering the program, provide some student advising, are responsible for the science curriculum, and facilitate the marketing and recruitment efforts of the central office. Advisory boards identify new program development opportunities, generally promote programs to prospective students and employer groups, give seminars, and sponsor special projects or events. Professional curriculum and costs of delivery can be shared across different programs. Borbye, Bechert, Lawton, King, and Ambos (2012) recently identified five key strategies to support and sustain PSM programs. They include:

- connect leadership silos and sustain centralized management,
- nurture robust external partnerships,
- automate numerous administrative and educational processes across and within institutions,
- develop and promote graduate degree business models, and
- connect and share ideas and resources nationally.

State- or system-level PSM advisory boards can make recommendations for new program development opportunities based on state and regional workforce trends, which universities can pursue based on complementary research or educational strengths and interests.

Breaking traditional boundaries to collaborate on educational program development projects beyond the Ivory Tower has not been easy, particularly in research-intensive universities, but is something that PSM directors have had to do. As Boyer stated in 1990 (p. 77), "Now is the time, we conclude, to build bridges across the disciplines, and connect the campus to the larger world. Society itself has a great stake in how scholarship is defined." As the applied learning movement continues to gain momentum in undergraduate studies, it will likely complement the efforts of those who are dedicated to creating similar learning experiences at the graduate level through PSMs. Existing M.S. programs should consider re-inventing themselves as PSMs, and as research drives the creation of new fields of study (frequently through the merger of existing disciplines), new educational programs need to follow.

Given numerous examples of the integration of applied learning and business skills into graduate STEM curriculum, the success of pioneering programs, and the needs of the business community, expansion of PSM opportunities just makes sense. Institutions wanting to learn more about developing PSMs have numerous resources available to them. Some of those resources include:

http://sciencemasters.com/

http://oregonpsm.org/resources

http://www.npsma.org/

http://www.nash-psm.org/

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