Perceptions of Strengths and Deficiencies: Disconnects between Graduate Students and Prospective Employers

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The US Botanical Capacity Assessment Project (BCAP) was initiated as a first step to gauge the nation's collective ability to meet the environmental challenges of the 21st century. The project, in which the authors of this article are involved, specifically aimed to identify multisector contributions to and gaps in botanical capacity in order to develop growth opportunities to address research and management problems. One of the primary gaps revealed by the BCAP surveys was that the skills graduate students identified as their greatest strengths closely matched the areas future employers (government and private sectors) identified as needing greatest improvement. Although our survey focused on only one discipline (botany), we suspect that the results are applicable throughout the science, technology, engineering, and mathematics disciplines. We suggest that it is critical for university faculty and administrators to team with professionals from government, nonprofit, and for-profit organizations to identify critical and desired knowledge and skill sets and implement the necessary curriculum changes to provide graduates with the tools they need.

Keywords: botanical capacity, student perceptions, employer expectations, skill sets, education

For the past year the Botanical Capacity Assessment Project (BCAP; Kramer et al. 2010) has evaluated the human, scientific, technological, organization, institutional, and resource capabilities that support botanical education, research, and management in the United States. The BCAP was initiated as a first step to gauge the nation's performance of the skills necessary to meet the environmental challenges of the 21st century. The authors are the steering committee of the project and include botanists representing the academic, government, nonprofit, and for-profit private sectors. Our particular concern for this article is the capacity of universities to prepare plant scientists to address national needs for protecting biodiversity, especially in light of the complex global environmental challenges facing our society.

A startling revelation as we began data analysis, particularly for those of us in the higher education sector, was that the skills and general knowledge that graduate students viewed as their greatest strengths were seen by potential employers as the areas needing the greatest improvement. This was surprising because of the sustained focus on improving college science education in the United States during the past three decades. Beginning with the Neal report (NSB 1987) and continuing to the present, university scientist educators have been encouraged to develop inquiry-based laboratories, update instrumentation, provide faculty development, implement new pedagogies, develop innovative courses and curricula, provide students with research opportunities, and increase student diversity (DeHaan 2005, Hyde and Linn 2006, Russell et al. 2007, Miller et al. 2008, Pfund et al. 2009). Furthermore, the National Science Foundation report Shaping the Future (NSF 1996) recommended specific roles for other stakeholders in the educational process, including mission-oriented federal agencies, business and industry, private-sector organizations, and state and local governments. These stakeholders were charged to “make clear to educational institutions their expectations about graduates.” The faculty members in our group assumed, as we suspect most faculty do, that we educators were doing a reasonable job of preparing our students, particularly graduate students, for employment in the government and private sectors. The results we present below suggest that more needs to be done.

Training the next generation of scientists and environmental problem solvers to be competent in both technical and interpersonal skills is particularly important today.
as the United States and other countries urgently address the effects of humans on the environment. The public is beginning to understand that climate change is a real and significant threat to human and ecosystem well-being (Lorenzoni and Pidgeon 2006), but it’s not the only serious threat facing humanity. Recently, Rockström and colleagues (2009) identified nine “planetary boundaries,” biophysical thresholds that define the limits of ecological sustainability. They suggested climate change is one of three processes whose threshold already has been exceeded, but they consider loss of biodiversity (species extinction) to be even more critical (biogeochemical nitrogen cycling is the third process exceeding threshold). Human activities have resulted in an extinction rate “100 to 1,000 times more than what could be considered natural,” according to Rockström and colleagues (2009). The loss of biodiversity has pervasive effects on the entire biosphere, and our survey supports recent suggestions that just as the need to catalog, study, manage, and protect species in their environments has never been greater, the pipeline of adequately trained professionals is trickling dry (Brito 2004, Prather et al. 2004, Wheeler 2004, Crisci 2006, BCAP 2010). New goals and strategies are being set for protecting critical habitat, maintaining species diversity, and moderating climate change (SCBD 2002). New professional scientists, trained in basic field skills, able to apply modern methods, and with well-developed interpersonal skills, are needed to implement these strategies.

The Botanical Capacity Assessment Project

We designed a series of sector-specific surveys to evaluate the current state of botanical training in US colleges and universities and the current expertise and needs for trained personnel in government agencies (federal, state, and local governments) and public-sector organizations (both non-governmental organizations [NGOs] and for-profit organizations). We designed the BCAP questionnaires to identify limiting factors, resources, and perceived trends in the near future. Survey questionnaires are appended to the full BCAP report (Kramer et al. 2010). Among the questions common to student, faculty, government, and private sector surveys were (a) select the top five areas that represent your greatest strengths, and (b) select the five areas needing the most improvement. The response options included 24 general content areas (e.g., botany and ecology) or specific skill sets (e.g., plant identification ability, geographic information systems [GIS]).

We invited approximately 10,000 people involved in plant science research, education, or natural resource management in the United States to participate by completing the appropriate electronic survey. We received more than 1500 responses, from more than 400 academic faculty; 195 graduate students; nearly 650 federal, state, county, or city government employees; and more than 330 employees of NGOs and for-profit consulting firms (table 1). A more detailed breakdown of respondents within sectors is available in the full report (Kramer et al. 2010).

**Critical need for botanically trained professionals**

An immediate concern raised by the full survey is that 91% of respondents, employed at all levels of government, indicated that their agency does not have enough botanically trained staff to meet its current management or research needs (Kramer et al. 2010). This result underscores the urgent need for a focused effort to increase botanical capacity. The shortfall in person power may be due in part to the fact that federal botanist positions (classified as series 430 by the US Office of Personnel Management) require a minimum of 24 semester units of botany coursework, such as plant anatomy or morphology, plant taxonomy, plant physiology, and courses dealing with specific problems of a botanical nature or with specific groups of plants. Yet the number of universities that offer this curriculum is decreasing (Sundberg 2004). As botany departments are merged into large biology departments, specialty organizational courses tend to be lost with the retirement of the senior faculty who teach them. At the same time, more than 45% of current botanists in federal agencies who responded to

### Table 1. Responses to two survey questions asked of four different sectors (shown as percent response by skill set, with rank in parentheses). Bolded responses indicate inclusion among the top five skill sets (strengths or need for improvement) selected by each sector.

<table>
<thead>
<tr>
<th>Skill set</th>
<th>Graduate students (percentage, n = 195)</th>
<th>Faculty (percentage, n = 407)</th>
<th>Government agency staff (percentage, n = 642)</th>
<th>Private sector (percentage, n = 331)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written communication skills</td>
<td>49.7 (1)</td>
<td>53.4 (1)</td>
<td>41.6 (1)</td>
<td>44.8 (2)</td>
</tr>
<tr>
<td>Ecology</td>
<td>48.5 (2)</td>
<td>7.4 (17)</td>
<td>32.7 (5)</td>
<td>31.7 (5)</td>
</tr>
<tr>
<td>Field skills</td>
<td>47.4 (3)</td>
<td>29.3 (8)</td>
<td>36.4 (3)</td>
<td>28.3 (6)</td>
</tr>
<tr>
<td>Plant identification ability</td>
<td>40.4 (4)</td>
<td>38.6 (2)</td>
<td>38.4 (2)</td>
<td>50.3 (1)</td>
</tr>
<tr>
<td>Botany</td>
<td>37.4 (5)</td>
<td>19.8 (10)</td>
<td>35.9 (4)</td>
<td>40.0 (3)</td>
</tr>
<tr>
<td>Problem-solving skills</td>
<td>35.7 (6)</td>
<td>37.7 (3)</td>
<td>32.2 (6)</td>
<td>25.5 (7)</td>
</tr>
<tr>
<td>Verbal communication skills</td>
<td>31.0 (7)</td>
<td>29.9 (7)</td>
<td>23.9 (11)</td>
<td>32.4 (4)</td>
</tr>
</tbody>
</table>

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our questionnaire plan to retire within the next decade, and nearly 60% plan to retire during the next 15 years (Kramer et al. 2010). These retirements will occur at a time when the need for trained botanists to address the needs of biological diversity conservation has never been greater. Plant scientists are in particularly high demand given the scope and nature of the environmental problems we face. More native plants than animals are listed under the US Endangered Species Act. Plants are (a) the ecological foundation of every ecosystem, making it is essential to understand what is happening to the plant life in any system where loss of biodiversity is examined; (b) fundamental to providing food and habitat to support animal wildlife; (c) the basis for habitat restoration and control of invasive species; and (d) the model organisms for monitoring and modeling the effects of climate change on ecosystems.

** Disconnects between student and employer perceptions**

Here, we report the survey results relating to the skills that students perceived as among their top five strengths, and compare them with the top five skills needing most improvement, as reported by faculty, government, and private-sector staff. We were stunned by each sector’s responses of their top five strengths and top five areas for improvement; the results are summarized in table 1.

**Written communication skills.** Nearly half of the students perceived written communication skills to be among their top five strengths—the highest rated of any skill. Faculty members did not share this opinion: More than half (53.4%) scored written communication skills as an area of weakness in student preparation. More significant, according to potential employers in both the public and private sectors, written communication skills are in great need of improvement. Government staff ranked written communication skills as new employees’ top deficiency. In the private sector, insufficient written communication abilities ranked just behind inadequate plant identification skills. To address this deficiency, some newly hired botanists, biologists, and ecologists in the US Forest Service are sent for additional training in technical writing to improve their skills to a minimal level.

**Ecological knowledge.** Ecological knowledge was the next-highest-rated strength reported by graduate students (48.5%), a perception supported by its low ranking by faculty members as an area in need of improvement (7.4%). However, this perception of strength was not shared by potential employers in either the public (32.7%) or private (31.7%) sectors, who rated it the area fifth most in need of improvement. The discrepancy between faculty and employers probably reflects the difference between the theoretical emphasis of the academic setting versus the need for practical application in the nonacademic public and private sector arenas.

**Field skills, plant identification ability, and general botanical knowledge.** Field skills, plant identification ability, and general botanical knowledge were the next three areas rated as strongest by students. Given the traditional university emphasis on content preparation, and in light of the science education reform efforts of the past several decades, the university faculty members on our committee expected that students would highly rate their discipline-based skills, but they again were surprised that both government and private-sector professionals identified field skills and botany as high on the lists of areas needing improvement. This may be a result of the shift in emphasis on core course requirements being offered to graduate students today. Traditional training in botany, as in many of the biological sciences, strongly emphasized organismal diversity—the “-ology” courses, such as mycology, phycology, bryology, lichenology, and so on—and this feeling for the organism was deeply rooted in the curriculum. Coursework frequently involved field study and familiarization with techniques specific to the study of particular groups. But today fewer of these courses are being offered, even at the largest universities, in order to accommodate the increasing emphasis on molecular and developmental courses (Sundberg 2004, Kramer et al. 2010). We were not surprised by the deficiency in plant identification ability; it is well documented that many colleges and universities, even those retaining botany or plant science degree programs, are reducing or eliminating plant taxonomy and flora courses that emphasize plant identification (Lammers 1999, Landrum 2001, Sundberg 2004, Crisci 2006). Our findings add urgency to the task of preserving and reinvigorating organismal botany courses in departments where they are still offered, and we argue for the reintroduction of such botanical courses into the curriculum as part of the educational reform to prepare future scientists to meet the next centuries’ environmental challenges.

**Problem-solving skills.** Students ranked problem-solving skills sixth highest among their strengths, and it appeared on the top five list of more than one-third of the student respondents. This was a surprise to the educators on our team, who rated problem solving as the fourth-most deficient skill. It was especially disconcerting that this skill also ranked highly on the “needs improvement” scale of prospective employers: number six (32.2%) for government agencies and number seven (25.5%) in the private sector. A major focus of science curriculum reform for the past two decades has been teaching students how to “do science,” the process of critical thinking and problem solving. Yet college and university faculty and staff at government agencies and private organizations agree that much remains to be done.

This survey revealed striking discrepancies between students’ perceived preparation and needed skills. Plotting the need for improvement, as evaluated by the different sectors against students’ perception of their strengths shows a striking trend (figure 1). Students’ top 10 strengths are rated
in order, with the lowest number indicating what students perceive to be their greatest strength (i.e., 1 is the greatest strength). The corresponding value for that skill for each of the other sectors is the rank order value indicating need for improvement (number 1 indicates the greatest need for improvement). The y axis is inverted to indicate the inverse relationship between strengths and needs for improvement. For instance, the students’ perceived greatest strength, written communication skills (1), was the skill deemed in greatest need of improvement by government workers (1). In general, the faculty and employer sectors feel that graduates need the most improvement in those areas the students consider their strengths. This trend is particularly evident with potential employers in the government and private sectors, where the values of the regression coefficients are high, 0.84 and 0.67, respectively.

Top 10 results yield areas of agreement mixed with sector-specific disagreement

The results of the surveys were more uniform among respondents (when comparing students with prospective employers) in their assessment of perceived weaknesses (Kramer et al. 2010). Each of the four greatest weaknesses perceived by graduate students, statistics (60%), GIS (47.1%), experimental design (35.9%), and plant identification (34.7%), also were among the 10 skills rated most in need of improvement by employers both in government agencies and in the private sector. However, students tended to overemphasize their weaknesses in these four areas relative to employers’ perceptions. For instance, both government workers and private-sector respondents rated GIS as the greatest strength of recently graduated new employees. Nearly 57% of respondents from the government sector identified GIS as among students’ greatest strengths (the next-highest-rated category was environmental issues, at 35.4%) and 45.2% of the private sector rated GIS as a strength. However, both graduate students and faculty rated GIS proficiency far down their lists of strengths, with less than 10% among each group considering it a strength. Moreover, as mentioned above, graduate students considered GIS to be their second-greatest weakness at 47.1%. Educators are aware of the utility of this technology and schools are willing to expend the funds required to provide the hardware and software, but perhaps students and faculty feel the training provided is inadequate because there is so much additional potential inherent in the technology. Nevertheless, students have the proficiency that potential employers seek.

In other areas, survey results within a single sector of prospective employers seemed contradictory. Although field skills was rated third by government workers as an area needing improvement (36.4%), just as many of these professionals (35.1%) rated it as the third-greatest strength. This category was probably too broadly defined for the range of field skills required by the diverse fields of applied plant biology. Many students are well prepared with the field skills required for the position in which they were hired. The field skills of others may be comparable, but not as appropriate for their area of work. Similarly, the plant identification skills category may have been too broad. Plant identification ability was the highest-scoring weakness among private-sector respondents (50.3%); it was rated fourth highest among recognized strengths by 35% of the same group. This result could reflect a disconnect between students’ knowledge of the plants of the area in which they were trained relative to the plants of the area where they were employed.

Broader implications for all of the sciences

Our surveys focused on botanical capacity in the form of education and training at the university level as a pipeline for filling critical and immediate needs in government and private sectors, but we believe the results have broader implications for all of the sciences. First, the discordances between student and employer perceptions of strengths suggest that college and university faculty, consciously or subconsciously, may be fostering an exaggerated sense of preparation in students, while failing to provide necessary training in some of the skills that students recognize they will need. Although this may be the result of overemphasized and compartmentalized courses, rather than the needed broadly integrated subject areas across a curriculum of study, as suggested by Moslemi and colleagues (2009), we are concerned that it is equally the function of the decline of organismal courses in the college curriculum.

Second, skill sets, for which there was cross-sector agreement on needs for improvement, should be given special priority by colleges and universities to enhance the content
of academic training for in-need areas. Looking at the top five responses to the surveys (as indicated in bold in table 1), all sectors agreed that written communication skills and plant identification ability need improvement. Similarly, prospective employers from the public and private sectors also agreed that students need additional botany and ecology training (both ranking them as areas for improvement). Strengthening academic training in these areas would transcend the strict needs of the botanical sciences because, as pointed out by the government and NGO members of our team, these skill sets are important in other scientific fields, such as soil ecology, wildlife biology, and natural resource management.

Third, future generations of professional scientists (regardless of their field of expertise) must be able to communicate effectively with business leaders and government agencies to solve the nation’s current environmental challenges and make future scientific advances. Again, it was the government and NGO members of our team who stressed that scientists employed in their sectors must be able to effectively communicate within a team, across disciplines, with decisionmakers, and with the public. They must be able to collect and interpret relevant data but also be collaborators, policy facilitators, and negotiators across a spectrum of stakeholders. Where multiple stakeholders and organizations are involved, landscape-level management requires interpersonal skills that bridge disciplines and cross boundaries, among what are sometimes competing constituencies (Schusler et al. 2003, Bouwen and Tailleau 2004). Communication skills have become as important as technical discipline-based skills. This has critical implications for education and training because traditional academic training in the sciences focuses on acquisition and communication of disciplinary-based knowledge to peers, not the ability to communicate effectively with an array of audiences.

Collaborations among scientists, land managers, decision-makers, and field workers require the negotiation of diverse ideas and potential approaches to solve complex problems. Resource management problems are generally less well defined than purely scientific problems, and the diversity of views may be much broader. In fact, new employees, trained to identify hypotheses and design rigorous experiments, may find it frustrating to deal with managerial problems in which information is incomplete and rigorous experimental controls are impossible or impractical. The collaborative scientist must be attentive to the needs of each of the partners and able to emphasize common ground and shared interests; he or she must be flexible, adaptive, creative, and able to think creatively while exploring the implications and practical consequences of solutions. This involves communicating effectively within webs of relationships to facilitate multiorganizational problem-solving arrangements. Curricula must include and require more opportunities for students to speak and present information. Seminar courses, in which students become familiar with research or biological concepts and then lead discussions with their classes to include broader impacts, are the perfect vehicle for developing communication skills in the next generation of professional scientists.

Fourth, and arguably most important, our analysis of the surveys and discussions among this writing team suggest that universities and potential employers have not been communicating with each other effectively. For instance, employers in government and the private sector rank botany and ecology broadly among the five most serious knowledge deficiencies of potential employees. These are far down the list of weaknesses perceived by faculty; faculty view ecology as students’ second-greatest strength. The gap between the training that universities and colleges provide and the skills that government and private-sector employers seek is disturbing. That gap will only widen as taxonomy and other traditional botanical courses are dropped from college curricula (Sundberg 2004). At the very least, our data suggest that students are not receiving a clear and accurate assessment of their skill sets, and that faculty are ill informed about the needs of public and private-sector plant scientists. Therefore, universities and colleges are not providing graduates with the skills required by nonacademic employers.

Meeting the inherent challenges of STEM education

The specialization of science encourages disciplinary isolation and fragmentation of knowledge, particularly with respect to the botanical and social sciences. Yet effective resource management requires consideration of ethics, values, economics, and political constraints that can be gained only through effective dialogue among all interested parties. Our analysis indicates that today, 14 years after the publication of Shaping the Future, cross-sector needs and expectations continue to be poorly translated into scientific curricula for the botanical field, and very likely in other scientific arenas, as well. If science, technology, engineering, and mathematics (STEM) education in the United States is to prepare the next generation of scientists for the critical challenges that face us, university faculty and administrators must join arms with leaders of government, nonprofit, and for-profit organizations to identify the skills future scientists will need and to design the curricula necessary to train them.

Federal initiatives such as the Integrative Graduate Education and Research Traineeship program are a step in the right direction, concentrating on integration and communication among disciplines on college campuses (Moslemi et al. 2009), but inclusion of agencies and NGOs throughout the process continues to be a critical need. The STEM Education Coalition (www.stemedcoalition.org/Default.aspx) is an advocacy group with broad representation in each of the four sectors we surveyed whose purpose is to support federal programs for teachers and students in STEM courses at all levels. Although it does include the employer sectors in its advocacy, the group does not provide guidance or a mechanism for assessing curricula.
The BCAP was a necessary first step toward establishing a baseline against which to measure the disparities that continue to exist between current botanical capacity and our anticipated needs to meet the challenges of the 21st century. We suggest that these multisector surveys could be used as a tool for the ongoing assessment of botanical capacity to measure progress toward resolving these disparities. Furthermore, they could be modified for use in other disciplinary fields and serve as a barometer for success throughout all STEM fields.

Our analysis suggests that if STEM education in the United States is to prepare the next generation of scientists for the critical challenges that face us, university faculty and administrators will have to collaborate with leaders of government, nonprofit, and for-profit organizations to identify the skills future scientists will need and to design the curriculum necessary to train them.

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