LESSONS FROM FIRST-GENERATION CLIMATE SCIENCE INTEGRATORS

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Climate science integrators use specific skill sets to further the development of usable climate science.

Decision-makers at scales ranging from agricultural producers making decisions for individual enterprises to public land managers concerned about massive tracts of publicly owned land are increasingly finding it necessary to address impacts created by both climate variability and climate change. To do this, they will need the best available climate science in a form they can readily use. To be usable, the science must be relevant to their context and the complex management challenges they face and credible and legitimate in their eyes (Cash et al. 2003). In recognition of this growing need, the federal government has recently created several networks of regionally based organizations that share an overarching goal of facilitating connections between scientists and decision-makers in order to promote the development of usable science. These networks include the Department of the Interior (DOI) Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs) and the U.S. Department of Agriculture (USDA) Climate Hubs. These new organizations follow the example provided by the USDA Cooperative Extension System (CES), state climatology offices, and the National Oceanic and Atmospheric Administration's (NOAA) Sea Grant and Regional Integrated and Sciences and Assessments (RISA) Programs, which have been involved in the effort to develop usable science for decades and, in the case of the CES, for over a hundred years.

Accompanying this growing demand is a growing literature that seeks to increase the supply of usable climate science by identifying guiding principles for its development (Dilling and Lemos 2011; McNie 2007), often through the process of coproduction of knowledge (Lemos and Morehouse 2005) or provision of decision support (NRC 2009). However, this literature does not address questions about how to increase the supply of climate scientists who want to participate in the process of developing usable science, what specific skills are needed to put these guidelines into practice, and how to provide scientists with these skills. In this article we address these questions by presenting insights from highly respected "first generation" climate science integrators from

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across the United States, who collectively have more than 200 years of experience bridging the gap between scientists and decision-makers. We use the term "climate science integrator," following Jacobs et al. (2005), to refer to climate scientists who specialize in helping decision-makers across a broad spectrum of sectors to integrate the best available climate science into their decision-making processes. There may be similar techniques used in fields such as translational medicine, but what we feel sets climate science integration apart is the emphasis on coproduction. In the medical field, translational research has been defined as bringing the results of research to the public (Woolf 2008), which implies a unidirectional model rather than the bidirectional model of coproduction. Science integration work encompasses a range of activities, from responding to individual inquiries over the telephone to collaborating with stakeholders over an extended period of time. The cadre of scientists who participated in our research has largely developed their methods for working successfully with stakeholders on their own, without formal training. The collective wisdom of this group illuminates the kinds of skills needed in order to be a successful science integrator, suggests the types of training that would cultivate these skills, and indicates ways to change academic training and institutions to better encourage aspiring climate science integrators and to support this kind of work. Their insights both supplement and reinforce the literature on developing usable science.

In this literature, the foremost principle is that efforts to develop usable science require two-way flows of information between and among scientists and diverse decision-makers (Hirsch Hadorn et al. 2006; Jahn et al. 2012; Lemos et al. 2012), rather than the one-way flow of information—from science to society—assumed in the traditional, "linear," or "loading dock" model of science (Cash et al. 2006; McNie 2007). Another key principle is that scientists from a variety of physical, natural, and social sciences, as well as decision-makers from different sectors, will have to work together to address the complex social and ecological issues related to climate variability and change (Jacobs et al. 2005; Lemos and Morehouse 2005). Third, in order for science to be usable by decision-makers, they must perceive it as salient—relevant to their context and needs, credible—scientifically sound and accurate, and legitimate—unbiased, produced in a transparent manner, and respectful of their beliefs and values (Cash et al. 2003). Scientists must acquire a firm grasp of the context for decision-making in order to produce science that has these characteristics (Dilling and Lemos 2011; Jacobs et al. 2005; Kirchhoff et al. 2013; Lemos et al. 2012; McNie 2007). In addition, research shows that users' perceptions of information are highly influenced by the quality of their interactions with information providers. Thus, a fourth principle is the need for relationships between scientists and decision-makers that are characterized by mutual understanding, respect, and trust (Cash et al. 2003; Dilling and Lemos 2011; Ferguson et al. 2014; Jacobs et al. 2005, 2010; Kirchhoff et al. 2013; Lemos and Morehouse 2005; Lemos et al. 2012; McNie 2007). Lemos and Morehouse (2005) suggest that the level of fit between the knowledge being produced and the information stakeholders believe they need is enhanced by relationships that are long term and iterative. The literature also notes that developing and maintaining these relationships is time and resource intensive and often not regarded as legitimate scientific activity (Dilling and Lemos 2011; Jacobs et al. 2010; Kirchhoff 2013; McNie 2007).

From this brief review of guiding principles for developing usable science, it becomes apparent that climate scientists who want to participate in the process of developing usable science need skills, in addition to their traditional disciplinary training, that facilitate communicating, interacting, and developing and sustaining relationships with scientists from other disciplines, practitioners, decision-makers, and technical experts. However, training in basic science approaches is still the norm for most scientists—education focuses on the methods, approaches, and tools necessary to succeed in a particular scientific field of inquiry, with little attention paid to how the knowledge might be used outside of academia (Shanley and López 2009). Stokes (1997) traces the split between basic and applied research as far back as the Greek natural philosophers, who consciously separated inquiry from use. When technological innovation outpaced basic science inquiry, basic research became the domain of universities, leaving industry to pursue usable technology. In the United States the split was codified after World War II by President Roosevelt's science advisor, Vannevar Bush, who formalized the distinction between basic and applied research and separated their federal funding mechanisms (Stokes 1997). With the external boundaries in place, they are often reinforced from within scientific communities through a process Gieryn (1983) refers to as "boundary work," in which scientists seek to separate themselves from society in order to protect the perception of their purity of purpose and action—they are not influenced by or seek to influence society. Universities remain the home of basic research, which is reflected in their reward systems, such as the prioritization of peer-reviewed journal articles over work that is used by people outside of the research community (NRC 2004; Shanley and López 2009; Dilling and Lemos 2011). Given the need to encourage, support, and train the next generation of climate science integrators, the goal of this article is to contribute to ongoing efforts to develop guidance and training resources for scientists interested in working with stakeholders to develop usable science and to improve institutional support for this type of work.

METHODS. The results presented in this paper are from two separate research projects that both seek to understand how scientists work with stakeholders, their methods for doing so, and challenges they have faced doing this type of work. One project focused on understanding the challenges that novice climate science integrators face and how to overcome them. The other focused on how experienced climate science integrators evaluate their own work and their recommendations for developing evaluative metrics for the field of climate science integration and coproduction of climate science more broadly. While the interview guides were different, there was a significant amount of overlap. Together, the two research teams conducted 15 in-depth semistructured interviews with experienced climate science integrators (defined as at least five years of experience). Most of these researchers are, or were, in the NOAA RISA system, but the group also includes researchers in DOI CSCs, current or former state climatologists, and extension faculty. The sample is not intended to be representative of all science integrators; rather, participants were selected based on years of experience and positive reputation in the field. Interviews took place in 2014, either in person or over the telephone, and lasted approximately 60–90 minutes each. Interview questions were designed to elicit information about 1) the types of science integration activities in which interviewees engage, 2) their background and the career path that led them to their current position, 3) what they see as the challenges of doing science integration and how to address them, and 4) what advice they would give to aspiring science integrators. The interviews were transcribed and were analyzed using a mixed inductive/deductive grounded theory approach (Bernard and Ryan 2010; Strauss and Corbin 1998) to identify key themes and emerging trends both within and across datasets. In this article we also use preliminary results from interviews with four stakeholders who work with an early career climate science integrator to triangulate our results. Because the sample size is small, we discuss the results qualitatively. We use quotes from the interviews to illustrate themes and to better convey interviewees' meanings. In what follows, quoted phrases and extended indented passages are excerpts from these interviews.

FINDINGS. *How do the scientists interact with decision-makers?* The scientists in this study described a wide spectrum of ways in which they interact with decision-makers, from answering individual telephone inquiries to working collaboratively with small, interdisciplinary groups over an extended period of time to develop information or decision support tools specific to decision-makers' needs. Several used the metaphor of "matchmaker" to describe the work they do. The job of a matchmaker is to understand what types of data are available; to understand the context, the needs, and the values of the stakeholder; and then to make a match between them. We found that the ways of interacting that the scientists described fit into a model developed by Ferguson et al. (2016) to conceptualize the ways in which stakeholders interact with the NOAA RISA for the Southwest. The four primary ways are 1) as an information broker communicating climate information, 2) as an informal consultant, 3) as a short-term partner, and 4) as a collaborator. Ferguson et al. found that most interactions were in the first category with percentages decreasing in each succeeding category. Our study participants also described a potential fifth category: as a liaison or networker, someone who makes connections among individuals or organizations with common needs and facilitates cooperation among them.

Some examples of information broker interactions from our interviews include providing information over the phone on a one-time basis or in newsletters, websites, podcasts, and conference presentations and giving public talks in which they are "translating and synthesizing, or value-adding to climate information." Interactions in the informal consultant category include providing expert advice on project development or data interpretation. For example: "It's not at all unusual to get calls from agency partners related to something: they want to do a new project, or where we are on a project, or what do you think about this. So basically I will get used as a subject matter expert." This category was the most frequently mentioned in our research. Examples of short-term partnerships include helping to organize and/or participating in workshops and webinars to address a specific weather-/climate-related issue. Interviewees also described being involved in long-term collaborations with stakeholders: for example, working with tribes to develop a drought plan for a reservation or using climate projections to help city planners understand the city's vulnerabilities. Finally, the types of interactions that fall into the networker category include those of an investigator with one of the CSCs who was connecting with other agencies in the region that worked with stakeholders to learn about and provide for their climate science needs. For all of these types of interactions, the scientists felt that certain skills and attributes, described below, were key to successful engagement with individuals, groups, and organizations.

What motivates them to do this kind of work? Despite increasing emphasis on funding research that benefits society and contributes to the achievement of desired societal outcomes (e.g., NSF 2013), as well as the efforts of the boundary-spanning organizations mentioned at the beginning of this paper, the scientists in our study note that in academia incentives for engaging directly with stakeholders are still limited, even in applied research projects. Many of them perceive significant challenges for science integrators working in the academic system, which we discuss in greater detail below. They are motivated to do engaged work in spite of these challenges by personal incentives: a desire to do scientific work that is useful, helps someone, or helps society. Many interviewees expressed a sense of deep satisfaction in producing research that responded to a specific problem or issue and "had an impact." Just publishing papers was not nearly motivation enough for them—they wanted to see their research "out there" in the world, potentially "having something to do with maybe a paradigm shift for management" and "making the world a better place."

The scientists we interviewed were also motivated by the diversity of opportunities for different types of research that their work offered. They were intrigued by the type of creativity and ingenuity required to respond to a stakeholder's question or need, which differed from the problem-solving skills ordinarily applied in their discipline. Several noted that working with stakeholders allowed them to look at a problem in new ways, leading to novel insights. For example, some water managers working with a climate scientist to understand streamflow reconstructions from tree-ring data reported that the process opened their eyes to a range of variability, and a level of vulnerability, far greater than what the historical data they based their planning on revealed. Finally, one of the scientists we interviewed enthused that he had "a job that I look forward to coming to each day." The personal satisfaction these scientists derive from doing this type of work seems to far outweigh the lack of external incentives.

How did they learn their craft? The scientists we interviewed were trained in meteorology, atmospheric science, climatology, or another physical science. Some also had social science training in undergraduate or graduate school. However, when the majority of them began their careers, there was little informal or formal interdisciplinary training or training in science integration available. Most just "fell into" working with stakeholders while in graduate school or in an early job and discovered they liked it. They described their learning process as "learning by doing," "trial and error," or "sink or swim." For example, "It really was just trial and error. Just going out with the information you had and, for me, really being as good a listener and watcher of people's expressions and body language." One scientist compared learning how to provide climate services to learning a craft: "It's like any trade; you have to learn it by doing it. And you discover whether you have a facility for it along the way."

Many of our interviewees mentioned that they had informal mentors, such as academic advisors, job supervisors, or coworkers who were doing applied climatology or translational science work and who encouraged and supported them or served as role models. One scientist recalled that "So much of what I learned I learned by quietly working behind the scenes under the guidance of an excellent mentor, the former State Climatologist, who let me learn slowly without throwing me in the deep end of the pool too early." Although no one reported that their first introduction to science integration work came from the nascent literature on the subject, several people reported that finding the literature later in their careers elucidated and reaffirmed what they were doing.

Many also cited experiences in their personal backgrounds that they felt helped prepare them for doing science integration work: for example, growing up in a farming community prepared them to be able to communicate with growers; being a union steward or a lay congregation leader prepared them for organizing meetings, speaking to large groups, and developing programs; congressional fellowships prepared them for working with policymakers. Overall, their learning process was experiential and their suggestions for training the next generation of climate science integrators, which we discuss below, also focus on providing experiential learning opportunities.

What are the key lessons they have learned about working with decision-makers? Many of the interviewees felt that being a good science integrator was not something that everyone could learn, that it takes a certain kind of personality, or that some people just have a "knack" for it. For example,

> Partly we're talking about personality. And I don't know if it's fair to say that there's something genetic, you know, it's that old saying, "You either have it or you don't." [Laughs] And to me it's a really good question, is that really the case, or can a person really change something so that they do have it?…I do not know if you can be trained for this. I know a lot of people that there's just no way they could do this and some will openly admit it, they're not comfortable going out and talking to people.

However, when asked about the most important things they have learned about doing science integration work or about the advice they would give to aspiring science integrators, their responses revealed some specific personal characteristics and practices that they felt made them successful. Whether acquired by nature or nurture, the experienced integrators articulated specific guidance for the next generation. We discuss nine practices, beginning with the most commonly mentioned. Although we discuss them separately, they tend to be interrelated and to build on and reinforce one another.

Be a good listener. The most prominent characteristic that emerged is the need to be a good listener and to ask questions. According to one interviewee,

> One of the things that I learned, or I guess just maybe picked up early on…just kind of to let them talk. They may call up asking for, you know, "I need this rainfall data from this place"…So I'd ask them, "What do you need this for? Can you describe the kind of project?" Because oftentimes there'd be other data that might be more appropriate for their study that they didn't know existed…I learned to listen, to get them to tell their stories.

By responding initially in this way, the scientist initiates two-way communication and sets the tone of the relationship. He signals that it is one of mutual respect and understanding between peers who are experts in different fields and that the he is "*genuinely* there to learn." By engaging decision-makers in conversation, the scientist also begins to learn about the decision-making context. In addition, two interviewees pointed out that "what [users initially] asked was usually not what they needed," so that engaging them in conversation made it possible to identify their actual needs.

Understand and respect the people you work with. Scientists in the study emphasized that it is also essential to understand decision-makers' perspectives and what they value. This makes it possible to couch communications and to interact with them in ways sensitive to their perspectives and respectful of their values, which gives you "credibility" and makes you trustworthy in their eyes. This interviewee emphasizes the importance of sincerity in this endeavor:

> When you are working with users, you gain a lot more traction with them if you are viewed as credible in their camp. And this takes some extra work on the part of the translators: you can't just sit in your office and kind of come at it from one way; you've got to put yourself in other people's minds. This is the whole issue of empathy. It's the primary way you can work with people is by being empathetic, and by that I don't mean painted on, but you actually really understand their situation.

The scientists also found that when stakeholders and scientists can make a personal connection, such as sharing a similar upbringing, hobby, or interest, it enhances this type of credibility. Our interviewees mentioned specific commonalities like being raised in a farming community or on a military base as good foundations for a relationship.

Using the same language as stakeholders and speaking conversationally rather than "coming across as an academic" or lecturing has a similar effect. One scientist related an experience he had after giving a talk to wildfire managers that illustrates this: "At the end of [the talk], one of them comes up to me and asks, 'You have a Ph.D., right?' And I go, 'Yes.' And she goes, 'Well, that's so odd. Because you were actually talking *to* us, not at us. So you're using our language.' And that's the day that I knew what I was trying to do was working."

Understand the decision-making context. Listening begins to set the tone of the relationship and to bring the decision-making context into focus, but for deeper understanding the scientist may undertake activities that resemble the participant observation of anthropological fieldwork: for example, shadowing a stakeholder, which one interviewee described as the "terribly fascinating job of driving around with somebody, and doing their job. And then having discussions about weather and climate and those kinds of things, with them" at their workplace. Gaining experiential understanding of the context can shortcut a lengthy question-and-answer process in which the scientist may not yet have enough grasp of the context to ask the right questions. Another interviewee who is working with government agencies that manage wildfire went "through the training that firefighters go through so I could see how that worked. And then I embedded myself with as many managers as would put up with me so I could understand their decision-making process." This made it possible to coproduce fire-climate, fire-weather, and operational products that have become essential to agency decision-making processes.

Coming to understand the decision-maker's context is a prerequisite for the scientist to be able to develop science that is salient to that context, but the process also contributes to decision-makers' trust in the scientist and their perceptions that the science is legitimate—two characteristics of usable science that Cash et al. (2003) identified. A thorough understanding of the context for decision-making also makes it possible for the scientist to recognize that science sometimes plays a very small role in the decision-making process because decision-makers have many other factors to consider, including policy, politics, economics, and resource availability. Even the best available, most actionable science does not guarantee its eventual use in decision-making, as several of our interviewees noted.

Be humble. A science integrator needs to have humility. Aspects of humility are illustrated by the preceding three characteristics: the humility to realize that she needs to listen rather than talk; to learn from stakeholders about their context, needs, and values; and to respect their perspectives and values, rather than to try to change them. This can be challenging for scientists who sincerely believe in the value of science, as this scientist explains:

> I think with scientists…finding out that what they know how to do is not actually what people need has been a real challenge. I think for the climate science community as a whole we do…science that, it's clearly important, but it doesn't often fit as largely in people's portfolios as we'd like it to. And so, you have to just sort of accept that. And you can't cram into their worldview and sort of lever it open and make it bigger, even though maybe it should be. Maybe the risk is huge and maybe you do need to worry about it, but you've got to sort of meet people where they're at.

In addition, interviewees pointed out the need to have "the right amount of humility about how much we think we know about this stuff, and not coming off as too cocksure about anything," the humility "not to be defensive when someone questions some aspect of your science," and "being humble enough to know that you may not be able to give them anything." Being humble, as well as the three preceding characteristics and practices, contribute to earning the trust of the decision-makers the scientist is working with.

Maintain credibility in both the scientific and stakeholder communities. Interviewees pointed out that the science integrator must maintain credibility in both the scientific and stakeholder communities, which one scientist described as a "tough trick," which "if you take it seriously, puts a lot of onus on you to go the extra mile to try to be good in both arenas." To maintain credibility in the scientific community, she needs to be well-grounded in a climate science-related discipline, as this interviewee emphasizes:

> I always encourage people to at least get through their Masters, get a degree in a discipline, maybe some interdisciplinary work but make sure that you're well-grounded in the discipline…So have something that gives you the credentials, it gives you the depth of knowledge in that field, and then try to weave in the interdisciplinary from there.

To maintain credibility in the scientific community, she also needs to remain unbiased, to "offer an independent opinion on things," and not become an advocate for a particular stakeholder group or solution, or a "stoolie for some agency."

We have already discussed how understanding and respecting the people you work with gives you credibility in the user community. To maintain credibility in that community, the science integrator needs to be seen as unbiased by that community as well. She should not try to "advocate any one thing," because "people are always on the lookout for hidden agendas," and she would lose the trust she has built up in the user community by coming across as "just another vested interest." At the same time, she would reflect poorly on "the [scientific] enterprise by having the spokesman for it come out as being seen as having a hidden agenda." When the climate scientist herself has credibility with the user community, its members are more likely to perceive the science as credible and legitimate (Lemos et al. 2012).

Enjoy interacting with people. In general, the scientists described themselves as people who enjoyed interacting with other people. However, they noted that one need not be an extrovert or gregarious to be successful at science integration work; in fact, several described themselves as introverts. But these scientists also found it "difficult and isolating [to work alone for] hours on end." They welcomed the opportunity for interaction and they really enjoyed "the one-on-one stuff."

Be curious/interested in a variety of things. Because learning about the context and understanding other people's perspectives takes time and effort, it helps to be the type of person who likes to learn about new and different things. Many of the interviewees described themselves in this way. For example, one scientist described himself as a "generalist" and found it "rewarding…learning about another world." When he worked with the National Aeronautics and Space Administration (NASA) on climate adaptation, he talked with "the people who work on the launches of the space shuttle" and "the people who work on making flushing the toilets work," and "learned all these things about infrastructure that [he] never would have learned otherwise."

Be patient. The scientist needs to be patient because the processes of listening, learning, and developing trustful relationships takes time. The scientist needs to be patient with stakeholders as they learn more about his domain and with himself as he learns more about theirs. Here, an interviewee describes the patience it takes to make the "match" between what he knows and what stakeholders need:

> For the most part when it is about information use and applications, it's trying to find that little nugget of intersection between something that you know is out there or something that you can do and a need that they have, and sort of being very patient about finding that. And not overwhelming the person with a thousand different potential things they could do. But sort of trying to figure out where they're at and then making that match.

Reflect on what you are doing. To be able to learn from experience and to put all of the pieces we have discussed so far together, the scientist needs to take time to reflect on what he is doing. One interviewee explained that when he was trying to figure out how to work with stakeholders, he found "just reflecting and trying to study the immersion process" and all the things he was "learning about people and what they do and how they do it" helped him to know when he was "really sort of hitting the mark on meeting a potential user need." In contrast, another scientist felt that his lack of time to reflect negatively affected his work. He felt that he and his colleagues were often "flying by the seat of our pants" and doing things "ad hoc all the time. And you know there's a certain amount of that that has to be because the situations are unique." But he felt that it would be beneficial to reflect on their experience in order to develop a more systematic approach to working with stakeholders and to developing and managing science integration projects.

Preliminary analysis of interviews with stakeholders working with a climate science integrator reinforced the importance of some of the personal characteristics and practices listed here. For example, what one stakeholder found most helpful in interacting with the science integrator is that "He has always been very interested in joining meetings that talk about the specifics of the project, whether it's ecological response models or the social science part of it… He's easy to talk to, he's interested, he has the validity to actually talk at a level that we can understand, but he's a very good listener."

Challenges of pursuing science translation as a career. Interviewees identified several challenges associated with doing science integration work. The most prominent among them were time, academic culture, and the lack of well-defined career paths.

Time. The biggest challenge for the scientists in our study is the time it takes to develop and maintain relationships with stakeholders and to understand their decision-making context, which echoes previous findings (see, e.g., Dilling and Lemos 2011; Jacobs et al. 2010; Kirchhoff et al. 2013; McNie 2007; Shanley and López 2009). In the words of one interviewee,

> Each one of these relationships with stakeholders is like a marriage, especially if you're going to do a multiyear process with them. And, you know, a marriage requires a whole lot of relationship building and care and feeding, and the relationship evolves and you have to be sensitive to that too, and needs change, and understanding of the science changes, understanding of the relationship changes, the state of the science changes, the events come and go.

The time demand is compounded for science integrators who have faculty positions and the time-intensive activities associated with them. One scientist brought up the "burnout factor": "I'm publishing papers, trying to be an administrator, and then also running [an organization] and maintaining the current connections with stakeholders: it is a *lo*t of time, a lot of work, and a lot of travel. And it takes its toll." In addition, as science integrators advance in their careers they tend to take on more project management duties, which are also time intensive, and for which they often have little training.

Academic culture. A second challenge for science integrators is an academic culture that does not value the type of work that they do. Some of those we interviewed had experienced this challenge in their own careers; others identified it as a challenge for aspiring science integrators. In the following quote, the interviewee reflects the contention that many scientists may see participating in this type of research as "at best uncomfortable and at worst inconsistent with real scholarship" (Cash et al. 2003, p. 8090):

> [In academia] it's about research. So especially in the earlier years, and there's still a fair amount of this now, there is not as much receptivity—in some people's minds this is doing sort of second-rate stuff, you're dealing with the unwashed, and you're not using the most of your talent because you're out talking to all these folks—and it is really hard to fund it…Some colleagues might view you as being second-tier because you're not out in the forefront of the science side…Especially with the funding atmosphere and so forth, people are so preoccupied with "Where's my next grant going to come from. How am I going to keep myself going?" that this kind of stuff we're talking about here is viewed as kind of a luxury.

Others noted that the reward system in academia, which is based primarily on the peer-reviewed journal article (McNie 2007; Shanley and López 2009), is not a good metric for the success of science integrator stakeholder engagement. For example, "If you are rated based on your number of peer-reviewed publications then that is a very different outcome than if you are allowed to be rated in part with your interactions with the community." Because of the mismatch between academic and engagement metrics, some interviewees had struggled with the tenure process, even at institutions where they had achieved recognition as successful science integrators. Others expressed concern about how the predominant academic culture will impact the ability to train and employ the next generation of science integrators:

> I'm not saying everybody has to fill this role, but I feel like there really needs to be more value in the academic system for people that want to engage in this kind of work.... And so for the few people that want to engage in it, it's like there's no opportunity to learn the skills, number one, you have to do it on your own, and number two, once you emerge there might not be a job for you.

Lack of well-defined career paths. Interviewees pointed out that while recognition of the importance of the role of science integrators and demand for their services are growing, as well as interest in doing this type of work among undergraduate and graduate students, there is a lack of awareness in academia of job opportunities and of a career path to follow. For example, an interviewee who is a university professor felt that

> There's still a problem, or challenge out there with jobs. If you want to go into this field…there are limited opportunities that really do this bridging. I think over time people will create more private sector engagement, some of the things, especially engineering firms are doing with climate change now, and adaptation. There it's starting to open up…But sometimes students will come by and ask, "What is out there?" And to be honest it's not clear right now. It's a transitional kind of thing.

On the other hand, a state climatologist pointed out that

> There are quite a few applied climate jobs in private industry, but they're not widely promoted. You have to go search them out, anywhere from the climatologist working behind the scenes at the Chicago Stock Exchange, to the folks that do reinsurance and, there's quite a batch of climate work that goes on behind the scenes in the insurance and reinsurance businesses, I mean there's a lot of places and there aren't very many universities teaching how to do this.

And within the federal organizations designed to facilitate science-stakeholder interactions, such as the NOAA RISA system, there is limited funding for integrator positions, as this RISA scientist pointed out:

> I think that there's a *need* for more jobs like this, there's clearly the demand from the stakeholder community for more people doing RISA-like work, but where do we employ those people? [It's not

possible] with the base funding available [in the RISA system] that's been flat for 15 years.

Thus, scientists introduced to science integration work through graduate assistantships or postdocs in these organizations often have to look elsewhere to pursue this type of work.

Recommendations for developing and supporting the next generation of science integrators. The scientists we interviewed offered a number of suggestions for overcoming these challenges and for developing and supporting the next generation of science integrators. They see the next generation as the key to overcoming the time challenge because increasing the supply of science translators to meet the increasing demand for this kind of work will reduce the burden on those who are already engaged in it. One scientist put it this way: "That's why we need new college graduates to be hired all of the time. They've got more time on their hands in terms of the ability to go out and really spend time talking to the stakeholders. And they're young and enthusiastic; they multitask [laughs] better than those of us who are getting older do." And even though interviewees indicated overwhelmingly that the best way to learn science integration work is to "just do it," they provided insights into appropriate training for the next generation—particularly involving experiential learning opportunities similar to those from which they learned the "craft" of science integration. Their suggestions are summarized in Table 1.

Regarding the challenges posed by academic culture, the science integrators we interviewed saw it changing already, albeit slowly. One example of changes they were seeing is that there is more interest in interdisciplinary applications among students and more interdisciplinary courses being offered in meteorology departments. A second example is the attainment of upper-level administrative positions in academia by proponents of this type of work where they can "nurture" programs that support the types of bridging activities needed to connect climate science and decision-makers. A third

Table 1. Suggestions for training climate science integrators.

Type of training	Example
Job shadowing or apprenticing experienced science integrators	A graduate student who is shadowing the regional climatologist at a regional climate center
Internships with climate service providers	Internships for high-school, undergraduate, and graduate students at state climatology offices
Exchange programs with stakeholders	A climatologist who "embedded" in land management agencies and took firefighter training to learn about fire management; at the same time, an agency person embedded in his group
Working with extension faculty	Working with extension faculty as a graduate student; learning from their experience working with clientele; benefiting from extension's social capital for building relationships and trust
Support or professional networks of science integrators	From extension: Association of Natural Resource Extension Professionals; National Association of Community Development Extension Professionals
Service learning components in academic courses	Applied Climatology course (University of Oklahoma)
Postdoctoral fellowships that encourage work with stakeholders	American Association for the Advancement of Science (AAAS) policy fellowship; NOAA Postdocs Applying Climate Expertise (PACE) program; Sea Grant Knauss fellowship
Science integrator training programs	Certificate for Science and Decision Making (The University of Arizona); Graduate Certificate in Science and Technology Policy (University of Colorado Boulder)
Training in social science research methods	Social science methods for nonsocial scientists: to raise understanding of methods, ethics, and cultural differences
Training in science communication	A series of workshops on science communication through the Cooperative Institute for Research in Environmental Sciences (University of Colorado Boulder)

example is increased interest in supporting these activities by university administrators when they are seen to be able to bring in large grants, such as those for NOAA RISAs and the DOI CSCs. These scientists also see the proliferation of federal initiatives to connect scientists and decision-makers as an indication that prospects for employment are improving and career paths are beginning to emerge. They also anticipate that more employment will become available in the private sector as the need for adaptation to climate change becomes more widely recognized.

CONCLUSIONS. In this article we have called on some of the most respected first-generation climate science integrators to provide insights about how to train the next generations. Their pioneering efforts have demonstrated the value of science integration work, as we have seen, in improved drought planning for tribes, and risk assessment and planning for city planners, water managers, and government land management agencies, and contributed to the rapid increase in demand for usable climate science. Their enthusiasm for their work demonstrates that they have found it personally rewarding. Some of those we interviewed are now retired or about to retire. Before this generation leaves the work force, we need to draw on their collective wisdom to ensure that their shoes will be filled and the ranks of science integrators expanded.

Many of their suggestions concur with those of proponents of science integration work who have suggested principles for developing usable science and have been calling for training programs for science integrators, changes in academic culture to encourage and support science integration work, and incentives from funding agencies for including science integrators in research projects for some time (e.g., Averyt 2010; Jacobs 2002; Jacobs et al. 2005; McNeeley et al. 2012; NRC 2009). The voice of experience should lend weight to these appeals and momentum to the changes in science policy and academic culture beginning to take place.

However, our interviewees have also provided details and put a human face on the general principles for developing usable science through their practical guidance on the personal characteristics and practices that aspiring integrators should cultivate in order to work successfully with decision-makers. They have offered tangible ideas for the types of training that will help cultivate new climate science integrators. They have described the rewards of this type of work, as well as the demands and the challenges, and their personal stories are stories of overcoming those challenges to find personal growth in their work. We hope these stories will provide mentorship and inspiration to future generations of climate science integrators.

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