Scholar Development: A Conceptual Guide for Outreach and Teaching[1]

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Abstract

External funding opportunities are often associated with "broader impact" activities aimed at improving public scientific literacy and helping to build the future scientific workforce. Increased outreach by agricultural science professionals has the potential to assist the public in building the competencies needed to pursue a range of careers in agricultural sciences. However, engaging in high quality science outreach often requires faculty scholars to cross complex social and institutional boundaries. This paper presents concepts that are critical for helping graduate students better understand and enact effective and efficient science outreach and teaching. Science outreach and teaching best practices include: a) professional development focusing on strategic planning, time management, relationship building and the appreciation of alternative viewpoints; b) the employment of teaching and learning resource professionals to assist in the development of competencies; and c) the expansion of opportunities to build outreach activities into graduate student training, assisting in expanding a culture of scientific outreach.

Introduction

Graduate education draws heavily on an apprenticeship model of adult learning which views the graduate student experience as a process of professional socialization into academia (Buck et al., 2006; Christodoulou et al., 2009; Collins, 2011; Crone et al., 2011). Preparation for entry into scholarly professional communities is facilitated through authentic experience with all aspects of future work, including outreach, teaching and research for developing university faculty (Austin, 2002). Within the process of socialization into academia it is likely that different programs of study will place varying degrees of emphasis on the outreach and teaching aspects of the authentic experience process (Blickenstaff et al., 2015). While it is likely that the competencies associated with outreach and teaching will be valued by faculty guiding the scholarly development of graduate students, it is commonly the case that those aspects receive less attention and are outside of the guiding faculty's primary skillset (Smith et al., 2014). Currently, there is a dearth of literature that describes or assesses the design or implementation of an outreach program geared towards assisting graduate students to develop outreach and teaching competencies through an experiential learning process. It will be useful, therefore, to offer a conceptual description of how an outreach program could be utilized to build the outreach and teaching knowledge and skills of graduate students through just-in-time instruction and authentic outreach experience.

Just as the public has become increasingly more disconnected from agriculture, its connection to science seems to be thinning as well. It is critical that budding faculty scholars build outreach and teaching competencies so that they can effectively and efficiently share new knowledge in ways that are conducive for building the public's understanding and support for science (Blickenstaff et al., 2015). In fact, as Wellnitz et al. (2002) point out, programs of study should help graduate students recognize that part of their professional practice will include communicating to people outside of the science and academic enterprise system their understandings, discoveries and new directions for inquiry. As an extension, it then follows that, graduate students should be engaged in outreach and teaching experiences with the hope of instilling within them competencies such as effective cooperation, communication and pedagogical expertise early in their budding careers (Bruce et al., 1997; Burrows et al., 2009; Collins, 2011; Crone et al., 2011; Montano, 2012; Nilsen, 2013).

However, one of the central challenges for science based graduate programs of study is authoring and enacting experiential opportunities which guide graduate students through a process of constructing understandings and meanings around high quality outreach and teaching. Further, if authentic guided experience doing science serves to build the research and scientific problem solving capacity of graduate students, then

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authentic experiences with communicating and teaching about science are critical for developing their thinking about and ability to enact high quality outreach and teaching. When working to engage graduate students in a process of developing their outreach and teaching abilities, there is merit in working with faculty and resource persons with expertise in those areas (Smith et al., 2014; Stedman and Adams, 2012). Faculty with expertise in teaching and learning can be engaged in order to help graduate programs of study design and enact efficient pathways that can guide graduate students through an experiential process of developing their outreach and teaching abilities. It is the expert guidance from knowledgeable teaching and learning faculty and resource persons and the time to engage in actual practice, just as in learning about the process of science, that can help graduate students construct a deeper understanding of goal setting, instructional planning, and assessment through ongoing expert feedback and self-reflection (Fenwick, 2003; Kolb, 1984).

The purpose of this paper is to tie together the related research and theoretical perspectives in order to describe a conceptual level guide for using K-12 outreach teaching experiences to build the capacity of graduate students to: a) connect research with value adding diffusion strategies that contribute to the public's understanding of science; and b) employ research based instructional strategies to construct and enact high quality science based learning experiences. The guiding conceptual framework is constructed by tying together constructivist, situated learning and activity theory perspectives in concert with research related to the need for agricultural and scientific literacy and the challenges associated with building outreach and teaching competencies. The value in illustrating a conceptual level guide is that it will easily transpose to a wide variety of contexts which may have different parameters, resources and limitations.

Constructivist Perspective

Fenwick (2003) notes that all instructional strategies, including experiential methods, can be viewed from multiple theoretical perspectives. In the constructivist perspective, learning is grounded in experience, sociocultural beliefs and prior knowledge (Black, 2003; Klassen, 2006). Knowledge is acquired through constant reflection on new experiences within the context of what was already known by the learner and how it was known. Within the constructivist perspective learning is "contextualized" because of how novel experiences dovetail with previous understandings about the world which resulted from the physical and social experience of daily life (Fenwick, 2003; Klassen, 2006).

The idea of experiential education is frequently attributed to the early 20th century educational philosopher John Dewey, who popularized learning through real-life contexts in his Laboratory School (Clark et al., 2010; Enfield, 2001; Fenwick, 2003; Knobloch, 2003; Kolb, 1984; Phipps et al., 2008; G. Smith and Sobel, 2010). The constructivist conception of experiential learning is based on the Dewey's work, along with other major theorists Vygotsky, Lewin and Piaget (Fenwick, 2003). These constructivists considered concrete experience to be the fundamental basis for learning in a continuous process of reflection, assimilation and further observation to connect conflicting concrete and abstract conceptualizations of the world (Fenwick, 2003; Kolb, 1984).

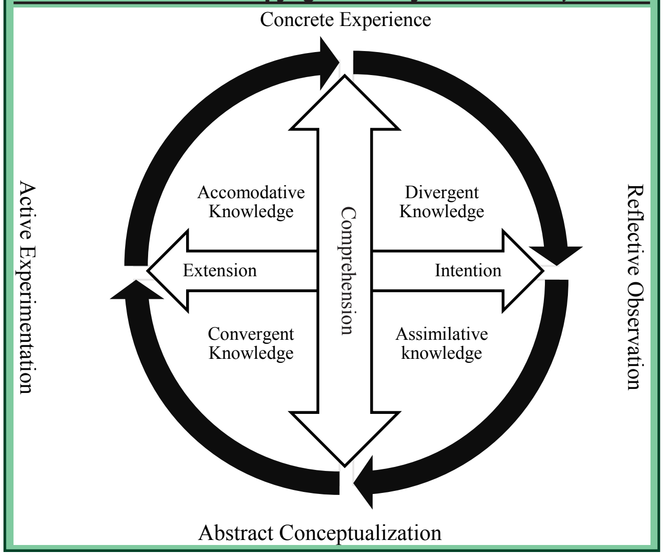
Clark et al. (2010) note that experiential learning can occur via application of knowledge in immediately relevant settings or through connection of daily life experience to abstract concepts. Regardless of the mode, the process is grounded in real-life experience and consists of a holistic combination of action, perception, cognition and reflection (Fenwick, 2003; Kolb, 1984). The extent to which a learner is prepared for an experience will influence his or her ability to interpret and connect new learning to prior knowledge as well as to transfer or apply it in new contexts (Abdulwahed and Nagy, 2009; Fenwick, 2003). Before, during and after an experience, learners are encouraged to reflect on the content, process and premises - asking what happened, how and why – and to consider their underlying assumptions about the phenomenon (Baker et al., 2014; Clark et al., 2010; Fenwick, 2003).

Dewey referred to the principle of "interaction and continuity" to describe the idea that the learning process is inherently social, builds upon prior experience and should provide a platform upon which to build through successive, structured experience connected to content (Dewey, 1986; Enfield, 2001). The iterative nature of learning is emphasized throughout the constructivist approach, but was particularly popularized by Kolb in his 1984 work, The Process of Experiential Learning (Abdulwahed and Nagy, 2009; Baker et al., 2012; Clark et al., 2010; Knobloch, 2003; Kolb, 1984; Mowen and Harder, 2005).

Figure 1 illustrates that Kolb's experiential learning cycle consists of continuous movement through phases of concrete experience, reflective observation, abstract conceptualization and active experimentation (Abdulwahed and Nagy, 2009; Clark et al., 2010; Kolb, 1984). Learning can begin at any stage and consists of the combination of apprehension and comprehension, by which knowledge is grasped, along with intention and extension, through which knowledge is constructed (Abdulwahed and Nagy, 2009; Clark et al., 2010). Acquisition of knowledge most commonly occurs through concrete experience or abstract conceptualization and is also referred to as prehension. In Kolb's view, reflection and experimentation result in knowledge construction or "transformation" (Abdulwahed and Nagy, 2009).

Constructivist experiential learning theory strongly informs the pedagogical standpoint of most science outreach education efforts (Bruce et al., 1997; Burrows et al., 2009; Collins, 2011). It also strongly informs the philosophies of 4-H and K-12 Agricultural Education, which espouse "learning by doing" and "hands-on" learning in their respective programs (Carmichael et

Figure 1: Structural Dimensions Underlying the Process of Experiential Learning and the Resulting Basic Knowledge Areas. Adapted from Experience as the Source of Learning and Development (p. 42) by D.A. Kolb, 1984, Englewood Cliffs, NJ: Prentice Hall. Copyright 1984 by Prentice Hall, Inc.



al., 2010; Clark et al., 2010; Mowen and Harder, 2005; Phipps et al., 2008). Many STEM outreach programs, including 4-H, incorporate inquiry-based or problem-based approaches to learning science content – a modification of the experiential approach. Common to all of these approaches is the back-and-forth flow between experience/exploration and reflection/conceptualization, resulting in application (Clark et al., 2010). In a program designed to build outreach and teaching capacity through "learning by experience," there should therefore be a strong focus on helping developing scholars to incorporate constructivist experiential approaches into their outreach curriculum activities (Dolan, 2008). Therefore, the constructivist perspective on experiential learning should not only be used as a model to describe the developing scholars' experiences – it also has the potential to influence their conceptions of themselves as outreach and teaching professionals.

Situated Perspective

Situated learning offers an additional theoretical perspective that has value within the context of graduate student training. From a situated learning perspective, one could view graduate students as peripheral scholarly participants who are being socialized into an academic community of practice (Austin, 2002; Collins, 2011). Situated learning draws on the social constructivist school of thought, however, one of Lave and Wenger's critiques of the constructivist perspective is an over-emphasis on the individual, internalized view of learning (Engeström et al., 1999; Lave and Wenger, 1991). Informed by activity theory, situated learning extends the perspective on learning to include the ways in which the learner's "social world" affects learning. This includes the ways in which the learner might influence that world, as exemplified in the interaction between newcomers and established members in a community of practice (Lave and Wenger, 1991; Wenger, 1998).

Situated learning is most commonly applied to the apprenticeship perspective on adult learning, according to Pratt (1998). A fundamental assumption which arises from the situated learning framework is that outreach and teaching work cannot be learned outside of the context of practicing it (Pratt, 1998). Some fundamental aspects of apprenticeship include increasing participation in the ongoing work of the community, a direct relevance of the learning setting to future work and the predominance of practically focused, performance-related goals (Lave and Wenger, 1991). The ultimate goal of situated learning is for learners to achieve full participation in the community of practice in which they are apprenticing. A community of practice is defined as a group of people connected by mutual engagement in an activity. This is their only common feature – it does not, therefore, imply homogeneity or harmony in any way other than that of the standards of practice dictated by the field (Wenger, 1998).

Activity Theory Perspective

The constructivist and situated perspectives describe the ways in which the graduate student scholars might incorporate pedagogical expertise and philosophical perspectives into their identities and practice. Activity theory views learning from the perspective of interacting cultures, groups, or "activity systems," and therefore offers an additional perspective on learning experiences. Engeström (2001) conceptualizes a "third generation activity theory" in which two interacting systems – referring to individuals or groups - are the unit of analysis. These systems work together to co-create a new meaning, product, or process referred to as the "object of study". Interacting individuals or groups carry with them influences of their "home" community - its organizational history, knowledge base, norms, rules, division of labor, etc. These underlying influences cause "contradictions" (aka boundaries) between and within activity systems. Third generation activity introduces the possibility of "expansive transformation" by which the two systems transcend their contradictions and move toward collective change or collaborative vision (Daniels, 2004; Engeström, 2001; McMillan, 2011).

From the perspective of activity theory, "boundary spanning" refers to the process by which individuals enter unfamiliar territory beyond their qualifications to accomplish "expansive transformation" (Akkerman and Bakker, 2011). Boundary spanning is the driving mechanism for inter-organizational collaboration. Star and Griesemer (1989) refer to it as the flow of objects and concepts through the collaborative network. Boundary-spanning interaction is two-sided and embraces differences of all types, to include those of culture, discipline, knowledge, or language (Akkerman and Bakker, 2011; Lamont and Molnár, 2002; Long et al., 2013). It also requires "crafting, diplomacy and choice" (Star, 1989, p. 389) to manage processes across social worlds (p.389). McMillan (2011) summarizes boundary spanning as forming an "expanded community" which reaches beyond the home institution to engage in new ways that challenge the existing activity system.

The development of new partnership projects such as a program for developing the outreach and teaching capacity of graduate students inevitably necessitates boundary spanning. In Wenger's (1998) conception of this process, three things mediate the interaction. Encounters, meetings and conversations across communities of practice likely emerge first. These are followed by the development of objects or tools used to negotiate across these communities and facilitate interaction. Boundary "brokers" (or workers) serve as "key agents" of facilitation, usually legitimized by their multi-membership in the collaborating communities (McMillan, 2011; Wenger, 1998). The job of a boundary-worker is to bring people together, identify shared goals, support transfer of knowledge, increase cooperation and improve communication by translating differences in organizational culture or language (Abrutyn, 2012; Akkerman and Bakker, 2011; Linden, 2002; Long et al., 2013). Because of their unique situation, boundary workers must take multiple perspectives and mediate conflict when necessary (Akkerman and Bakker, 2011; Long et al., 2013). The result of boundary work is the transfer of best practices and the synthesis of information to create new practices in the "third space" between groups (Siegel, 2010).

A wide variety of challenges to collaboration exist at the boundaries which separate people and organizations. Participating parties may enter collaborations with conflicting missions, interests, or viewpoints, as well as differences in resources, power, or status (Cordeiro and Kolek, 1996; Linden, 2002; Sandholtz and Finan, 1998). Broadly, the related literature indicates that the presence of a "boundary-worker" enhances the ability of developing scientists to successfully navigate boundary challenges and attain more favorable results. Burrows et al. (2009), conceptualize graduate student participants in a science outreach program as boundary-workers functioning as a "pivot point among high school and university educators, high school students and the university research environment" (p. 5). The coordinating faculty of such programs could certainly also be considered boundary-workers, as McMillan (2011) notes in her discussion of service-learning coordinators. These individuals have a critical influence on participants' experiences.

In addition to boundary-workers, "boundary objects" such as a collaborative vision statement, program expectations and standard operating procedures, prove helpful in easing communication across the boundary (Akkerman and Bakker, 2011; Clark et al., 2011; Dolan et al., 2004; Kimble et al., 2010; Star and Griesemer, 1989). Some examples of boundary objects employed in science education outreach programs include but are not limited to jointly produced curricula, evaluation plans, program descriptions, collaborative planning documents and research documents (Burrows et al., 2009; Crone et al., 2011). Sometimes boundary objects can simply be a set meeting schedule and agenda. As one collaborator notes, "*it helped that we had structured activities that put us in close contact to share responses*" (Leone, 1998 in Kezar, 2007, p. 29). Both organizational and individual learning can be facilitated by boundary objects (Daniels, 2004).

The remaining sections of the paper apply the concepts of experiential learning, legitimate peripheral participation, and activity theory to the description of an outreach program that could be utilized to build the outreach and teaching knowledge and skills of graduate students through just-in-time instruction and authentic outreach experiences. These efforts are situated within the cultural contexts of science education reform and the mission of land grant institutions of higher education. Cooperation invites a number of boundary-crossing processes between members of the higher education and K-12 or informal education communities. When graduate students become involved in such efforts, they become legitimate peripheral participants in this larger activity system. A review of the contexts, challenges, and "map for success" in science education partnership efforts is provided in the subsequent sections.

The Need for Agricultural and Scientific Literacy

The turn of the 21st century has been characterized by mounting calls for increased public literacy in science and agriculture as well as education reform to improve student outcomes and increase the future STEM and agriculture work-force. We are approaching the 30-year anniversary of the publication of "A Nation at Risk," the first major public call for education reform since the Sputnik era. This report highlighted disappointing performances of U.S. youth and adults in areas of basic literacy, numeracy and scientific understanding as compared to our global competitors (Gardner et al., 1983). This publication is credited with the dawn of high stakes testing, but also spurred reform in the formation of the National Science Education Standards, which increased the emphasis on science as a process of inquiry as opposed to a collection of fact (Buxton and Provenzo Jr, 2011; National Research Council, 1996).

The cry was mounted again in 2007 with "Rising above the Gathering Storm," which highlights the rising prevalence of European Union and Asian Pacific Economic Cooperation nations in science and technology as well as growing trade imbalances, stagnating public funding for science and the disappointing performance by American students as compared to students from other developed nations on national and international math and science performance assessments. In the 2005 National Assessment of Educational Progress (NEAP) science assessment, only 32% of 8th graders and only 18% of 12th graders scored at or above the "proficient" level. The performance of American 12th graders on the 1999 TIMSS and 2006 PISA were particularly discouraging (National Academy of Sciences, 2007). PISA averages for American 15 year-olds in 2012 were not measurably different than in previous years, which beg the question – if the U.S. spends 39%

more per student than the average member nation in the Organization for Economic Co-operation and Development (OECD), the pool from which PISA scores are taken, why are our students consistently scoring at or below average? (Kelly et al., 2013).

Relative deficits at the K-12 level translate to the adult population. Though science literacy among American adults showed an increasing trend in 2007, with 28% of adults demonstrating basic science knowledge, a 2014 report from the National Science Foundation (NSF) indicated that science literacy had stabilized (National Science Foundation, 2014). Though the majority of adults who responded to the 2012 NSF survey held positive views about science, many struggled to respond to elementary science questions, showed an incomplete understanding of the nature of scientific knowledge and showed declining interest in socio-scientific issues such as stem cell research, climate change and environmental quality (National Science Foundation, 2014).

Interest in science careers is also a concern. Though it is widely recognized that the need for a highly-trained scientific workforce is on the rise, data presented in Rising above the Gathering Storm indicated that the number of undergraduate and graduate students enrolling in STEM fields had remained relatively stable over the last several decades and was predicted to level off in the coming years (Bybee and Fuchs, 2006; National Academy of Sciences, 2007). Over the past decade, graduation rates in STEM have improved, but recruitment and retention – especially of women and minorities – remain a high priority for the field (Gonzalez and Kuenzi, 2012). The 21st century push for science education reform has resulted in the recent release of a new set of standards for science education. The Next Generation Science Standards incorporate increased emphasis on engineering design and the relevance of science to social issues, thus increasing the relevance of the applied sciences in the hopes of preparing students for a wide variety of 21st century careers (Achieve, 2013).

The call to action in the agricultural sector mirrors that of the science community, with a rising call to integrate STEM competencies into the K-12 career and technical agriculture classroom (Myers and Washburn, 2008; Spindler, 2015; Warnick et al., 2004; Williams and Dollisso, 1998). Like Rising above the Gathering Storm, the 2009 National Academy of Sciences report Transforming Agricultural Education for a Changing World emphasizes the need to recruit students into the agricultural sciences, especially women and minorities. It highlights the need to integrate high-quality agricultural and STEM education to address critical challenges in the field – particularly the globalizing economy, the rise of "scientific agriculture," and the increase in systems-based thinking to address pressing issues such as food security, climate change and environmental quality. However, with less than 20% of the U.S. population growing up in rural communities, agricultural literacy and workforce development is even more pressing an issue than science literacy and recruitment into STEM fields (National Academy of Sciences, 2009). In support of the Academy's report, Kovar and Ball (2013) reviewed the research on agricultural literacy over the last 20 years and found that 17 out of 23 studies across a variety of populations identified deficiencies, the greatest of which were among K-12 students and teachers.

With the wealth of possibilities for application and experiential learning of scientific concepts, the K-12 agricultural classroom is increasingly seen as complimentary to the science classroom in advancing science literacy goals. (Myers and Washburn, 2008; Parr and Edwards, 2004; Young et al., 2012). Common themes among reports outlining the need for science and agricultural literacy include (1) the complexity of current socio-scientific issues requiring 21st century professionals to possess the higher-order thinking and scientific reasoning skills to address them, (2) the prevalence of science, technology, and agriculture in daily life, demanding an appreciation for and understanding of these fields for informed citizenship and (3) the importance of public and policy-maker understanding of science and agriculture to create a cadre of advocates to enhance public funding and political support for research and development (Crone et al., 2011; Doerfert, 2011). Enhancing education at all levels is broadly embraced as a "systematic way" (Dolan, 2008) to address the issues of scientific and agricultural literacy and is reflected in the most recent strategic plans of the Virginia Cooperative Extension System and the American Association of Agricultural Educators, among others (Doerfert, 2011; Virginia Cooperative Extension, 2010). Though training a technologically capable work force to secure the nation's economic prominence is still a significant driving force behind science literacy initiatives and education reform, the need to build an informed, caring citizenry with the critical thinking skills to address 21st century socio-scientific issues is increasingly emerging as a motivating factor (McFarlane, 2013; Partnership for 21st Century Skills, 2011; Williams and Dollisso, 1998).

The Case for Agricultural and Science Education Outreach

The National Science Foundation responded to the call for increased science literacy by revising their grant proposal guidelines in 2000 to include "broader impacts" criterion; requiring NSF funded projects to indicate direct societal impact or to share discoveries with the wider public through *"improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others"* (National Science Foundation, 2013). Around this same time, the NSF initiated their two signature outreach projects - the Graduate STEM Fellows in K-12 Education Program (GK-12), which was founded in 1999 and the Math and Science Partnership (MSP) program, which funded its first projects in 2002.

The former connects STEM graduate students with K-12 teachers to develop and deliver curriculum relevant to both the graduate students' research and state learning standards. The latter connects scientists with teachers for a wide variety of projects; including "scientist-in-the-classroom" programs and professional development workshops for teachers by scientists (National Science Foundation, 2015a, 2015b).

As mentioned in the introduction, the renewed push to connect the university to the public is not unique to the STEM fields, but spans all academic sectors (Cordeiro and Kolek, 1996; Kinpaisby, 2008; McMillan, 2011; Siegel, 2010). Public forces that influenced this resurgence include the 1999 Kellogg Commission on the Future of State and Land-Grant Universities report, Returning to our Roots: The Engaged Institution, the American Association of State Colleges and Universities Tools and Insights for Universities Called to Regional Stewardship report published in 2006 and the 2007 Carnegie Community Engagement Classification System (Siegel, 2010). Notable discussions around this time included the Committee on Institutional Cooperation and the National Forum on Higher Education for the Public Good meetings in 2002 which resulted in an agenda to reduce the alienation between higher education and society (Bagdonis and Dodd, 2010). These discussions brought up the need to return to the original land-grant mission of service to the public and created ranking and incentive systems to reward institutions for public service (Siegel, 2010). Kindon et al.(2008) note that the role of university faculty is increasingly being re-envisioned from a one-way creator of knowledge to a working community partner engaged in two-way learning with professionals and citizens outside the institution.

Given that renewed calls for science education reform and public scholarship converged at the turn of the 21st century, the shift toward supporting higher education science outreach is not surprising. As a result, the past decade and a half has seen an explosion of science outreach and engagement projects across a variety of settings, from museums and nature centers to K-12 schools, universities and national research laboratories (Foster et al., 2010; Montano, 2012). As Figure 2 illustrates, Dolan (2008) places outreach activities on a spectrum from "awareness" to "partnership," and advocates for a high level of teacher involvement (i.e. partnership) to maximize benefits for all parties involved. Typical outreach formats include: "scientist in the classroom" initiatives; technology programs, field trips, citizen science projects, summer science internships or camps, "Saturday science" programs and teacher professional development.

There are a variety of purposes for science outreach, but the most predominantly cited goal is to impact K-12 students' understanding of and interest in science through "authentic" learning (Bruce et al., 1997; Burrows et al., 2009). Predominant agendas for science outreach include the recruitment of the next generation into STEM fields and addressing public misconceptions about science (Besley et al., 2015; Bruce et al., 1997; Burrows et al., 2009; Pecen et al., 2012). Constructivist philosophy dominates the pedagogy of science outreach education, as the majority of programs emphasize "hands-on" or "inquiry-based" strategies for communicating scientific content, working from the standpoint that students learn best by experience (Bruce et al., 1997; Burrows et al., 2009; Collins, 2011). A secondary agenda for outreach, mentioned by Wellnitz et al. (2002) and Dolan (2008) is the obligation of universities to serve their communities. Broadly speaking, outreach presents a compelling way for colleges of science to live up to their public service mission while assisting with the advancement of science education reform efforts and addressing public science literacy issues that are of concern to them as professionals (Crone et al., 2011; Kinpaisby, 2008; Montano, 2012).

In the realm of agriculture, science outreach has become a strong focus of the Cooperative Extension Youth Development (4-H) program and some of 4-H's national "signature" programs connect students to scientists vis à vis citizen science projects and science fairs (National 4-H Council, 2014a; Virginia Cooperative Extension, 2010). However, formal, funded programs that directly connect agricultural scientists to youth through partnerships such as GK-12 and MSP are rare in the literature, as compared to engineering, physical science, earth science, or biological science-based projects. Within Colleges of Agriculture, the majority of K-12 outreach activities tend to be concentrated within social science departments: agricultural education, leadership, communication and economics (Bagdonis and Dodd, 2010). The apparent lack of "scientist-in-the-classroom" engagement in the agricultural sciences relative to other areas presents a significant missed opportunity for Colleges of Agriculture to capitalize on the "outreach imperative" in science education.

Successes and Challenges of Outreach

Science outreach programs have shown measurable success in achieving their stated goals of improving science education (Bruce et al., 1997; Kirwan and Seiler, 2005). In particular, Foster et al. (2010) and Zhang et al. (2011) evaluated the NSF-MSP program and found that science outreach activities by scientists improved

Figure 2: The continuum of university-based K-12 education outreach and engagement activities. Reprinted from Education, Outreach, and Public Engagement by E. L. Dolan, 2008, p. 2, Copyright 2008 by Springer Science and Business Media, LLC.

Outreach Activities	Awareness	Involvement	Support	Sponsorship	Strategic Partnership
	providing materials	guest lectures	teacher professional development workshops	research experience for teachers	ongoing collaborations
	providing information	ask-a-scientist	loan equipment	research experiences for students	teacher/scientist exchange programs
	judging science fairs	materials for science fairs	mentoring students in science fairs	support for teachers making conference presentations	outreach training for scientists (e.g., GK-12)

teachers' understanding of science content and processes as well as their confidence in teaching science via inquiry-based methods. They also found that student achievement in science improved for classes involved in MSP sponsored programs. Generally, teachers are welcoming of the content expertise, enthusiasm and positive role-modeling that scientists bring into their classrooms (Bruce et al., 1997; Collins, 2011). Outreach also presents a singular opportunity for scientists to accrue new ideas about teaching and learning and to rekindle personal excitement about their own work (Dolan et al., 2004; Foster et al., 2010; Zhang et al., 2011). In their study of a teacher-scientist collaboration project, Munson et al. (2013) extensively reviewed the literature on the benefits for both teachers and scientist of outreach projects and found similar results.

The prevalence and success of many science outreach programs might lead one to believe that the process of connecting scientists to schools is simple. Because there is the common focus on education, the collaboration between universities and schools or non-formal educational institutions should be natural. However, regardless of the sector – even in relationships between collegiate-level departments of education and K-12 schools – differences in institutional culture can become a significant barrier (Bouwma-Gearhart et al., 2014; Dolan et al., 2004; Kezar, 2007; McMillan, 2011; Restine, 1996; Tsui and Law, 2007). Some of these cultural differences include the pace of school vs. university life; limitations to time and resources, and differing priorities for student learning. Restine (1996) also notes that there is often a wariness of the "academic elitism" sometimes portrayed by members of the higher education community. Differences in working vocabulary, noted by Dolan et al. (2004), serve as an additional barrier to science outreach efforts.

Indeed, simplifying the "language of science" is a frequently-cited challenge to scientists engaged in outreach work (Crone et al., 2011; Montano, 2012; Star and Griesemer, 1989; Zhang et al., 2011). This is related to and complimented by frequent criticisms of the lack of pedagogical expertise on the part of scientists (Christodoulou et al., 2009; Collins, 2011; Nilsen, 2013; Zhang et al., 2011). When conducting outreach, scientists are often expected to engage students in inquiry-based learning, even though their training and home teaching style is most likely to be lecture-based (Doerfert, 2011; Dolan, 2008; National Academy of Sciences, 2009). It has become apparent that academics could benefit from increased knowledge of teaching and learning in order to be truly effective communicators to the public as well as exemplary instructors of budding scientists and the undergraduate and graduate level (Bouwma-Gearhart et al., 2014; Crone et al., 2011; Dolan et al., 2004).

A final barrier that presents itself to faculty getting involved with outreach is time. Amidst demands for high-quality research productivity and myriad other institutional responsibilities such as teaching, advising and committee work, outreach may be seen as an "add on" to which faculty are unable to dedicate sufficient attention for success (Foster et al., 2010). Outreach activities seem to be most successful when the participating faculty are (a) passionate about the cause and (b) well-supported by their institution or other funding (Dolan et al., 2004; Zhang et al., 2011). Changes in promotion and tenure policies to reward outreach activities are gaining popularity as a solution to this problem (Dolan, 2008; National Academy of Sciences, 2009)

Therefore, for science outreach activities to be successful, it is necessary for scientists to have sufficient training and support in order to negotiate the boundaries between the university and K-12 environments. Evaluators of outreach and partnership programs have identified two primary ways to achieve this support. Some institutions offer professional development workshops for scientists on the topics of communication, pedagogy, and outreach techniques either separately or in conjunction with outreach programs (Besley et al., 2015; Dolan et al., 2004; Foster et al., 2010). In addition, Dolan et al. (2004), Burrows et al. (2009) and Bouwma-Gearhart et al. (2014) emphasize the importance of resource professionals who are able to translate across both the theoretical and physical communities of education and science. These individuals are familiar with scientific culture and the process of science, but are also well-versed in education theory and practice. They also possess the interpersonal savvy to mediate between the two communities and create a productive, collaborative learning environment (Bouwma-Gearhart et al., 2014). Whether serving in a formal or informal capacity, the majority of partnerships rely on one or more of these "boundary workers."

Zhang et al. (2011) describe the traits that make STEM faculty successful outreach partners. In addition to possessing *"a high quality disciplinary background and credibility,"* successful outreach faculty are also good instructors and are interested in how to teach more effectively. They are student-centered and believe in the goals of outreach changing the lives of students. In addition, they are open-minded to trying new approaches, and are willing to work in teams. Finally, successful STEM outreach faculty are able to *"meet people where they are" in terms of content-level foundations, and are "in touch with their inner adolescent."* In short, successful outreach partnerships require science faculty to be supported by effective boundary workers or to be boundary workers, themselves. The question then presents itself – given the growing demand for such programs, how do we produce more successful boundary workers to facilitate successful outreach projects?

Involving Graduate Students in Outreach

The push for increased public engagement by Institutions of Higher Education (IHE) has significant implications for the way beginning scientists at our colleges and universities are being trained (Siegel, 2010; Wellnitz et al., 2002). In response to this renewed interest in bringing the university to the public, some IHE's have begun to enact changes in their promotion and tenure policies to reward quality teaching, outreach and engagement in addition to research (Dolan, 2008; Foster et al., 2010; National Academy of Sciences, 2009). However, one of the major critiques of graduate education, today, is that students' training emphasizes specialized research and technical skills while neglecting preparation in other faculty roles, such as teaching, advising, civic engagement and public scholarship (Austin, 2002; Bagdonis and Dodd, 2010; Crone et al., 2011; Pew Charitable Trusts, 2001; Tanner and Allen, 2006).

Pew Charitable Trusts (2001) surveyed nearly 10,000 graduate students and found that the majority felt unprepared for the realities of future careers both within and outside of academia. As the result of a four-year qualitative study of graduate students' socialization into the professoriate, Austin (2002) developed recommendations for more holistic graduate training. Some of these recommendations include proving opportunities to (1) develop deep knowledge and a personal philosophy of teaching and learning (2) learn about institutional service and public outreach (3) learn how to engage in interdisciplinary work or collaborate with partners outside of academia and (4) learn how to communicate with the broader public. Transforming Agricultural Education echoes Austin's (2002) recommendations, and others note that the issue of graduate student training is just as pressing in the agricultural sciences as in any other field, if not more so (Bagdonis and Dodd, 2010; Doerfert, 2011; National Academy of Sciences, 2009).

Faculty participants and evaluators of science outreach initiatives recommend strongly that training in outreach begin at the graduate level (Munson et al., 2013). As such, this is a major goal of the GK-12 program and similar "scientist-in-the classroom" initiatives that involve graduate students, to include the Graduate Extension Scholars program (Buck et al., 2006; Scherer and Jamison, 2014). When funded opportunities are not available, graduate students are increasingly taking advantage of volunteer opportunities to fill in the gaps in their formal training and prepare themselves to be effective educators and advocates as well as researchers (Foster et al., 2010; Montano, 2012). Engagement at the graduate level is therefore seen as a key piece to the puzzle for changing the culture of academia to better support outreach efforts and elevate the quality of undergraduate teaching (Burrows et al., 2009; Crone et al., 2011; Wellnitz et al., 2002).

Graduate students, however, face the same challenge as faculty in communicating science. Christodoulou et al. (2009), Crone et al. (2011), Collins (2011) and Nilsen (2013) found that graduate students struggled to simplify scientific language and effectively employ inquiry-based techniques in the K-12 setting. Given their training agenda, the majority of graduate-level science outreach programs are therefore highly-structured to provide support for learning and development of practice. In some programs, this consists of a pre-outreach training workshop (Collins, 2011; Montano, 2012). Other programs gather students for weekly or monthly planning meetings (Christodoulou et al., 2009; Wellnitz et al., 2002). Still others structure outreach activities and associated training as part of a formal, credit-bearing course or seminar via which faculty and guest speakers address the various aspects of education theory; from achievement standards and pedagogical philosophies to lesson planning, assessment and group management (Burrows et al., 2009; Christodoulou et al., 2009; Crone et al., 2011).

The basic premise behind structuring outreach programs in this way is to create a community of practice among graduate student participants and their faculty mentors around outreach education (Buck et al., 2006; Crone et al., 2011). Action is combined with opportunities for reflection based on Dewey's perspective that "educative experiences… are imbued with anticipation, development, and unity" (Christodoulou et al., 2009). Workshops, seminars, or coursework provides a scaffold for the experience of conducting outreach, allowing participants to complete the experiential learning cycle (Crone et al., 2011; Kolb, 1984). Authentic experience designing, delivering, and evaluating outreach activities is a critical component, as is training and support. "Glossing over" one or the other has negative ramifications for the success of graduate student learning and the effectiveness of the outreach they conduct (Collins, 2011; Crone et al., 2011).

Because a critical agenda of outreach training programs for graduate students is to socialize them into a community of science faculty, view graduate students as legitimate peripheral participants in this community. Their participation in outreach programming can be viewed as a part of a "dialectic of practice," by which they are obtaining a layered identity as educators and scientists which may in turn influence practice of the scientific community (Buck et al., 2006). Henceforth, graduate students participating in outreach programs are not only seen as "outreach educators in training," but as "scientists in training" and as potential change agents in the advancement of public engagement by the scientific community. Many programs aim to help graduate students incorporate outreach into their professional identities (Burrows et al., 2009; Crone et al., 2011; Montano, 2012; Wellnitz et al., 2002).

From the apprenticeship perspective, meaningful engagement with experts as well as fellow newcomers is critical to the formation of professional identity and advancement to full membership in a community of practice, not to mention the acquisition of the practical skills necessary for expertise (Lave and Wenger, 1991; Pratt, 1998). Thus, social relationships are a critical component of the outreach training process. Workshops, meetings, courses, or seminar sessions give graduate student participants an opportunity to self-reflect, self-evaluate and deepen understanding among peers (Buck et al., 2006; Crone et al., 2011). However, just as important to the learning process appears to be the mentoring relationships that participants build with community partners, program coordinators and their faculty advisors to reward quality teaching, outreach and engagement in addition to research (Dolan, 2008; Foster et al., 2010; National Academy of Sciences, 2009). However, one of the major critiques of graduate education, today, is that students' training emphasizes specialized research and technical skills while neglecting preparation in other faculty roles, such as teaching, advising, civic engagement and public scholarship (Austin, 2002; Bagdonis and Dodd, 2010; Crone et al., 2011; Pew Charitable Trusts, 2001; Tanner and Allen, 2006).

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In essence, it is critical that graduate students have the support of established scholars within the academic community who share their values around the importance of outreach education. These mentoring relationships can help to mitigate the challenges graduate students often experience around adjusting to the K-12 culture, learning "how to teach," figuring out how to make explicit links between their research and the K-12 curriculum, balancing personal and professional conflicts and dealing with the pressure of keeping up with research responsibilities in the midst of the time commitment that outreach requires (Buck et al., 2006; Burrows et al., 2009). Advisor support and time constraints continue to be significant barriers that can be eased by funding, but not eliminated (Crone et al., 2011; Montano, 2012). Therefore, for the foreseeable future, outreach programs for graduate student scientists are likely to attract students who already see the value of outreach education and who believe in this cause (Buck et al., 2006; Crone et al., 2011).

However, even if providing training at the graduate level does not necessarily "win" new students over to outreach, it does create a supportive environment that may allow outreach-inclined scientists to increasingly persist in that work (Burrows et al., 2009; Montano, 2012). Such programs help graduate students understand the realities of teaching, planning and working with stakeholders (Burrows et al., 2009; Crone et al., 2011). They also report enhanced time management skills, a helpful attribute to future faculty balancing a demanding lifestyle (Austin, 2002; Burrows et al., 2009). The majority of graduate students who participate in outreach programs report feeling better prepared to teach and more confident in their communication and evaluation skills (Burrows et al., 2009; Crone et al., 2011; Montano, 2012). Others express that their experiences with outreach encouraged them to bring more inquiry-based and hands-on techniques into the formal science classroom (Bruce et al., 1997). However, some note that the outreach environment is highly contextual and not entirely transferrable to undergraduate teaching (Buck et al., 2006).

In terms of benefits for K-12 educators and students, outreach programs that center on graduate students enjoy similarly positive reviews to those that engage professional scientists. Teachers value the enthusiasm and resources that graduate students bring into the classroom, extending the curriculum and enhancing science learning for students (Bruce et al., 1997). Graduate students serve as a 'bridge' of sorts between school-aged students and the scientific community. Not being far out of school, themselves, they often serve as effective role-models for younger students (Burrows et al., 2009; Collins, 2011). Placing emphasis on collaborative partnership with teachers, assessing and prioritizing their needs and consistently evaluating and re-configuring outreach efforts enhances benefits to K-12 teachers and students while also teaching graduate students about the iterative nature of program planning and design (Crone et al., 2011; Dolan, 2008; Dolan et al., 2004; Wellnitz et al., 2002).

Conclusions, Implications, and Recommendations

As evidenced by the literature from science education, engaging graduate students in outreach has significant potential for addressing national education-reform agendas at both the K-12 and higher education levels. When scientists are provided with sufficient support and training, they can serve as valuable partners in the enhancement of public scientific literacy and K-12 science education. However, the need to build bridges between the scientific and educational communities before engaging in outreach activities cannot be underestimated. Engaging scientists in outreach early in their career development has the potential to expand the "outreach contingent" and equip the scientific workforce with individuals who are able to bridge those gaps.

Preparation of graduate students in outreach and engagement is relevant to the agricultural science community for numerous reasons. Given the expanding global population and prevailing struggles with climate change, environmental degradation and rural community development, agricultural scientists are uniquely positioned as problem-solvers around food security, clean water, alternative energy and natural resources management. Calls for K-12 education reform are "zeroing in" on the need to address socio-scientific issues, the majority of which have connections to the agricultural and life sciences (Achieve, 2013; McFarlane, 2013). Increasingly, inter-departmental partnerships between K-12 science and agricultural education programs, as well as between K-12 science classrooms and informal programs like 4-H are seen as pathways for achieving science education goals (Myers and Washburn, 2008; Pellien, 2014; Spindler, 2013; Warnick et al., 2004). Agricultural scientists are particularly qualified from a content standpoint to assist in such initiatives.

National agendas for agricultural education emphasize the importance of engaging agricultural professionals in outreach to enhance public understanding of critical agriculture-related issues such as climate change, food security, energy security, community economic development, nutrition and environmental stewardship. Effectively "getting the message out" has implications for public policy and the recruitment of the next generation of agricultural scientists (Doerfert, 2011). Because the K-12 school system provides the pipeline to higher education, programs targeting this population have the potential to play an important role in addressing these issues (National Academy of Sciences, 2009). Furthermore, by better integrating STEM content and understanding of the scientific process into agricultural curricula at the K-12 level, agriculture educators have the potential to simultaneously assist in addressing national agendas for science education as well (Doerfert, 2011; Myers and Washburn, 2008; Warnick et al., 2004).

Up-to-date and STEM integrated curriculum requires that agricultural educators be in-touch with current research in the agricultural sciences (Doerfert, 2011). In this respect, as in the other STEM fields, engaging scientists in outreach has significant potential. Some programs that connect K-12 students and teachers with agricultural scientists, exist, but they are not as prevalent as in other STEM fields. Indeed, it has been found that – similarly in other STEM fields – there is a significant lack of opportunity for agricultural scientists in-training to practice communicating with K-12 schools and the public, even though their future careers may require them to do so (Bagdonis and Dodd, 2010; National Academy of Sciences, 2009). Those agricultural outreach programs that do exist have shown success in enhancing science learning, as well as outreach competency on the part of participating agricultural science graduate and/or undergraduate students (Gardiner, 1991; Kirwan and Seiler, 2005; Smith et al., 2014). Expanding opportunities for budding agricultural scientists is relevant to national agendas for agricultural education reform at all levels, promoting the American Association for Agricultural Educations' priorities to enhance *"meaningful, engaged, learning in all environments"* and *"efficient and effective agricultural education."* (Doerfert, 2011).

Understanding how graduate students learn and develop professional identities as legitimate peripheral participants in a dialectic community of practice could enhance the effectiveness and prevalence of outreach programs. More research in this area can help professionals in colleges of agriculture determine factors that motivate and support graduate students to engage in outreach, ingredients necessary to produce a quality outreach product that is beneficial to the K-12 community, and produce deep learning on the part of graduate student about the art and science of teaching and public engagement. Drawing inspiration from the literature on outreach in other STEM fields can provide a model from which to base agricultural outreach efforts.

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