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Improving Postsecondary STEM Education: Strategies for Successful Collaboration and Brokering Across Disciplinary Paradigms

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This paper describes factors that influence the success of collaborations involving STEM and Education faculty at research universities who work towards postsecondary STEM education improvement. We provide insight into how interdisciplinary faculty may successfully collaborate given their different disciplinary backgrounds and familiarity with education research and theory. We explore the importance of "literacy brokers," individuals we identify as helping STEM faculty understand and respond to education research and theory. In addition, we discuss the relative advantages of appointments of these key individuals within STEM versus Education departments. We identify five key strategies that can help build and sustain collaboration and establish the critical role of literacy brokers at institutions that strive to improve STEM education beyond isolated and disconnected initiatives.

Stem faculty members at research universities are expanding a movement to improve science and mathematics teaching and learning at their institutions in dynamic and diverse ways (Bouwma-Gearhart, 2012; Bush et al., 2008; Foster et al., 2010; Hamos et al., 2009; Handelsmann et al., 2004). Faculty efforts to improve postsecondary STEM education often involve collaborations between faculty from STEM departments, typically based in colleges of Arts and Sciences (hereafter STEM faculty), and those from departments and colleges of Education (hereafter Education faculty), where teaching specialists are often located. The effects of collaborations of this sort have been the topic of recent studies (Bouwma-Gearhart, 2011; 2012; Bouwma-Gearhart & Adumat, 2011; Frank & Shapiro, 2007; Westat, 2009), notably via the National Science Foundation's Math and Science Partnership grants (Foster et al., 2010; Hamos et al., 2009).

Yet the research literature concerning these collaborations, in fact concerning faculty work in general, most notably focuses on barriers and typically provides few practical recommendations that work within the current realities of modern universities (Bouwma-Gearhart, 2011; Bouwma-Gearhart & Adumat, 2011; O'Meara, Terosky, & Neumann, 2009). The many barriers to successful interdisciplinary collaborations between postsecondary educators include the overwhelming power of discipline and department in faculty members' professional identity (Levine, 1993) and professional advancement (Holley, 2009), as well as philosophical and cultural differences between disciplines that impede collaborations (Braxton & Hargens, 1996; Frank & Shapiro, 2007; Hora, Millar, & Ramaley, 2010). In general, research universities lack an educational ethos (Handelsmann et al., 2004, p. 522), thus permitting "departmental and university cultures [that] often do not adequately value, support, and reward effective pedagogy" (Anderson et al., 2011, p.152).

The most salient factors influencing the success of faculty education improvement collaborations, and notably those concerning timely STEM/Education faculty collaborations have not previously been determined. Thus we decided to explore factors influencing the success of collaborative endeavors

that meaningfully involve STEM faculty at the Association of Public and Land-grant Universities' (APLU) institutions that produce 50% of STEM baccalaureates (Keller, 2011) and yet are known for disproportionately rewarding faculty for research over teaching and teaching improvement activities (Bess, 1997; Healey, 2005; LaPointe, 2005).

This article provides insight informed by research into postsecondary STEM education reform endeavors at five universities that are committed to APLU's 131 institution-strong Science and Mathematics Teacher Imperative (SMTI). The five institutions were part of a selected group of 25 participants in a National Science Foundation grant funded through the (NSF) Math and Science Partnership (MSP) and Research Evaluation and Technical Assistance (RETA) Program that aimed to promote institutional change to strengthen secondary STEM teacher preparation. The sub-group chose to examine how they were successfully implementing undergraduate education reform, recognizing this educational component as a critical intervening variable in institutional efforts to strengthen science and teacher preparation programs. Bouwma-Gearhart undertook site visits to the five institutions: Boise State University, Florida International University, Portland State University, the University of Colorado at Boulder, and the University of California, Santa Barbara. She interviewed 66 STEM and Education faculty participating in multiple endeavors towards improving STEM education for undergraduates. Bouwma-Gearhart sought to identify practices and policies underlying successful reform that specifically involve STEM and Education faculty in order to address the question: How do STEM and Education faculty successfully collaborate to improve undergraduate education given their different disciplinary backgrounds and familiarity with education research and theory? Five key strategies were identified that need to be in place to facilitate productive collaboration among STEM and Education faculty and other individuals and groups that support the improvement of postsecondary STEM education.

Five Strategies For Successful Postsecondary Education Collaborations

1. Successful collaborations recognize that those involved in postsecondary improvement activities are at different points in their appreciation of interdisciplinary work and the value of others' expertise.

STEM and Education interviewees described an evolution of thought regarding disciplinary research and expertise from those working in disciplines and departments other than their own. The evolution process begins with a mutual suspicion of each other's discipline, particularly on the part of STEM faculty concerning Education faculty and research. Gaining trust over time and increased familiarity with research is required by interdisciplinary reform participants to evolve to a second stage of, as one interviewee described it, "simple awareness and respect for other types of knowledge." Given enough time and collaborative work, a third stage acknowledges others' research to be valuable when intended to address real problems of pressing concern.

The fourth and final stage is acknowledging other disciplines' bodies of knowledge as expertise and their researchers as experts. The interviews document that this evolution is most eye-opening for STEM faculty with respect to the field of education and its researchers. However, the valuing of STEM participants' expertise by education experts is also necessary to achieve successful STEM education improvement (as further discussed below).

2. Successful collaborations occur when participants recognize that faculty and instructors are likely to be on numerous paths and at different points in their careers with respect to pedagogical issues and experience with education reform.

Many STEM faculty admit feeling some insecurity with respect to their practices concerning teaching and learning. This is not surprising because historically little attention has been paid to developing pre-service faculty as educators in the STEM disciplines, especially on how to best teach for students' deep and long-lasting learning. In fact, related research suggests that convincing STEM faculty that teaching skills require gradual and concerted development —and that much of their professional development has lacked this—is an important step for STEM faculty towards improving their teaching practices (Bouwma-Gearhart, 2012).

Many of the STEM faculty who were interviewed were engaged in real-time, data-driven projects informed by education theory and research. Although most had been engaged with education research and theory for some time through their involvement in current and past education improvement projects past education improvement projects, they typically desired more exposure. They called for more time to engage in discussions and activities focused on teaching and learning and further guidance by those more knowledgeable of education research and theory.

The importance of opportunities to understand education research and theory to improve STEM faculty members' postsecondary teaching practices has been highlighted by education faculty and STEM discipline-based researchers alike (Alberts, 2009; Anderson et al., 2011; Bouwma-Gearhart, 2012; Handelsman et al., 2004; Mathieu et al., 2009). During some interviews, STEM faculty and instructors experienced with education research and theory indicated their desire for opportunities that allow them movement to "the next step." This step translated into moving from an exploration of education research into "actually quantifying what a teaching effect is." Yet movement along pedagogical improvement trajectories requires significant time and assistance for many STEM faculty (Bouwma-Gearhart, 2012; Mathieu et al., 2009), and even those most familiar with education research and theory lament the difficulty they initially have in deciphering this relatively new literacy. This point brings us to our third recommendation.

3. Successful collaborations recognize the critical role of literacy brokers of education research and theory in the collaboration.

STEM faculty and instructors stated that a primary way to support their engagement with education research and theory is the ability to connect them with someone more knowledgeable with pedagogical research in their discipline. Additionally, our research uncovered a strong positive relationship between STEM faculty and instructors' motivation to engage in education reform work with social connections described in education literature as literacy brokers (Perry, 2009).

Specifically, the reform collaborations that interviewees deemed most successful had key individuals who acted as 'brokers' between the two umbrella disciplinary paradigms of STEM and

The Theory of Literacy Brokering

The nature of brokering is conceptualized in a variety of ways. Some scholars (e.g., Orellana et al., 2003; Mazak, 2006) examine brokering in the context of difference, where brokering becomes a matter of translation. The implication from these constructions is that those who receive brokering assistance lack knowledge, and that brokers solely possess and supply the necessary expertise (e.g., Chu, 1998; Gentemann & Whitehead, 1983). More recent scholarship, including this paper, challenges this unilinear expertise model of brokering. Orellana et al. (2003) and Mazak (2006) suggest that both (or all) participants bring some sort of expertise to the brokering event and that the process involves the negotiation of different bodies of knowledge. Because brokering can involve negotiated meanings and distributed knowledge, brokers also have opportunities to learn when they broker (Tse, 1996).

The theory of literacy brokering, specifically, suggests that the most successful brokering events involve more than just "translation" on the part of the broker (Perry, 2009). Literacy is viewed from a sociocultural perspective which approaches literacy as a social practice in which texts mediate social activities. As a result, literacy is defined by both (a) what we do with reading, writing, and texts (i.e., research and theory) in real world contexts (i.e., higher education) and (b) why we do it (i.e., in order to improve STEM pedagogy) (Perry, 2010). Literacy brokering explains the nature of support individuals receive with everyday literacy problems. Literacy brokers bridge the knowledge and experience gaps of those struggling with unfamiliar literacies, often in informal ways during everyday situations or activities that do not have this bridging as an explicit focus. Unlike formal teaching contexts like classrooms where learning is the primary goal, learning during brokering is usually a secondary outcome that occurs during the course of another activity (Perry, 2009).

Education. Brokers were commended by STEM interviewees for:

- Translating education research and theory into forms understandable and useable by STEM faculty and instructors;
- Having a strong ability to speak the language of STEM, with respect to disciplinary ways of knowing and processes;
- Conveying enthusiasm and means for improving STEM education through rigorous education research;
- Treating all participants as intellectual peers and not inferior with respect to their pedagogical knowledge and practices;
- Meeting STEM faculty and instructors "where they are" on their trajectory with respect to knowing and understanding pedagogical research and how this may translate to practice.

Successful brokers can be housed in either STEM or Education departments. Each location brings different strengths to a collaborative endeavor. Regardless of main disciplinary and departmental affiliation, these individuals were often credited for inspiring the initial "leap of faith" of STEM faculty and instructors towards considering postsecondary pedagogical issues and related data in light of education research and theory. Individuals from "both sides of campus" fulfilled key roles of brokering and helped others to access and actually understand this new literacy.

Those with disciplinary appointments in STEM departments, notably holding STEM doctorates, were recognized by STEM faculty as "having already proved themselves in the STEM world and now in the world of education" as strong educators. These people align with others' calls (Anderson et al., 2011; Handelsman et al., 2004) for distinguished STEM researchers to highlight the false incompatibility of basic STEM research and education reform activity. Yet these STEM faculty literacy brokers were not just the Nobel Laureates and National Academy members involved in collaborations. In fact some were not even in a typical tenure-track line dictating STEM research as part of their professional responsibilities; some were STEM faculty publishing on STEM education, while others held postdoctoral positions. Regardless of exact position, their ability to make education research and theory accessible and understandable allowed them to potentially serve as very powerful change agents, exerting what some STEM faculty deemed "peer pressure" in pushing themselves, their STEM colleagues, and departments towards consideration of postsecondary STEM education problems.

Somewhat surprising, however, was the identification of another group of education research and theory brokers who were just as powerful in facilitating STEM faculty and instructors' understanding. Those identified as successful brokers of education research and theory were often faculty and instructors with their entire academic appointments in Education departments. These individuals held doctorates in Education but most often also bachelor or master's degrees in a STEM discipline. Budding pedagogy experts like Learning Assistants and postdoctoral teaching fellows were also credited, although less so, as brokers of education research and theory, most notably by the STEM faculty and instructors with whom they were charged to help improve postsecondary STEM curriculum and instruction.

4. Successful brokers frame education research and theory in relation to typical STEM research and teaching practices and acknowledged expertise.

Education research and theory experts act as brokers by making this somewhat foreign body of knowledge accessible to STEM faculty and instructors seeking support. Successful brokers not only supply missing knowledge and practices, but the most successful brokers are familiar enough with STEM disciplines to frame education research and theory in relation to typical STEM research and teaching practices. Most importantly, they recognize STEM research and teaching practices as important expertise that can inform pedagogical reform. The most successful brokers, especially those based in Education were credited by our interviewees for understanding that STEM faculty and instructors have meaningful and novel expertise to bring to the collaboration. They 'meet them where they are' and allow them to incorporate as much or as little new knowledge of education research and theory into their own reform activities as they wanted. The most effective postsecondary STEM reform endeavors at the research universities studied involved brokers with the advanced skills needed to foster this interchange. In addition, the most effective postsecondary STEM reform endeavors involved multiple highly skilled brokers from departments of STEM and Education working in collaboration and acting as leaders to unite individuals across campuses and across multiple STEM education improvement initiatives.

We recommend that organizations of postsecondary education promote the development of highly skilled brokers and secure their much-needed participation in efforts to improve STEM education. Local education research and theory brokers who already have these skills should be identified and supported in their translational roles via buyouts of their time and/or additional external motivations to secure their participation. Institutions who do not have skilled brokers should consider hiring or contracting with individuals elsewhere to serve as consultants. While we are not the first to advocate for social and professional development opportunities for faculty and instructors (e.g., Anderson et al., 2011; Handelsman et al., 2004), we go further and recommend that they should specifically allow for interdisciplinary connections involving both veteran brokers and academics who are newer to education reform. Readers interested in what brokers should have in their training background may wish to see Bouwma-Gearhart (2011) for a more lengthy discussion, Bush et al. (2008) for a discussion of fostering and retaining STEM trained and department-based faculty with education specialties, and Mathieu et al. (2009) for a description of a center-based model for education research and theory experts.

5. Formal interdisciplinary collaborative faculty groups help catalyze institutional change.

During the interviews, many mentioned that the importance of interdisciplinary faculty groups to foster collaboration and action. These groups, comprised of representatives across STEM departments and from the field of Education, were reported to have the collective power to foster, and potentially regularize widespread undergraduate education reform based on research-confirmed best teaching and learning practices. Interviewees spoke of catalyzing institutional change by "creating a population who actually know what good teaching looks like." Discussions with dozens of faculty revealed that institutional leaders can play an important role in education reform through provision of resources and creation of supportive environments. Yet from the perspective of faculty, change is only minimally attributed to top-down mandates of provosts, deans, or department chairs. Most salient to them was faculty and instructor action, driven by interdisciplinary groups that helped to ensure collaborative understanding across disciplinary paradigms.

Conclusion

There are many voices calling for postsecondary education improvement, especially for STEM, and the importance of involving both departmental members and higher-level administrators is well established (see Anderson et al., 2011; Handelsman et al., 2004). We contribute to this discourse with our articulation of strategies that strengthen collaboration and implementation across disciplines, and our discovery that in order to best drive widespread change and improve postsecondary education, it is critical to identify and empower individuals who can act as brokers between seemingly disparate disciplines in terms of research, theory, and practices and norms, and who can do so in ways that support and capitalize on the diverse experiences and expertise other individuals bring to the table.

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