Evaluation and Program Planning 43 (2014) 73–82

Contents lists available at ScienceDirect

Evaluation and Program Planning

journal homepage: www.elsevier.com/locate/evalprogplan

Designing and evaluating a STEM teacher learning opportunity in the research university☆

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ARTICLE INFO

Article history:
Received 12 November 2012
Received in revised form 22 November 2013
Accepted 27 November 2013

Keywords:
Program evaluation
Teacher professional development
University research for teachers
Engineering
STEM

ABSTRACT

This study examines the design and evaluation strategies for a year-long teacher learning and development experience, including their effectiveness, efficiency and recommendations for strategic redesign. Design characteristics include programmatic features and outcomes: cognitive, affective and motivational processes; interpersonal and social development; and performance activities. Program participants were secondary math and science teachers, partnered with engineering faculty mentors, in a research university-based education and support program. Data from multiple sources demonstrated strengths and weaknesses in design of the program's learning environment, including: face-to-face and via digital tools; on-site and distance community interactions; and strategic evaluation tools and systems. Implications are considered for the strategic design and evaluation of similar grant-funded research experiences intended to support teacher learning, development and transfer.

1. Designing and evaluating a STEM teacher learning opportunity in the research university

Millions of dollars in public and private funding flow into teacher professional development annually. Most of that funding goes into short-term programs, which generate relatively little systematic examination and dissemination of design and evaluation strategies. Scholars and practitioners leading these programs create them from scratch over and over again, resulting in wasted time and money. This paper shares what one interdisciplinary team (consisting of engineering and education professionals), learned from data collected during a university-based teacher professional development program. It was designed based on lessons learned from a similar, previous, grant-funded program. We demonstrate data-driven refinement of our methods and practice, and share these lessons so others may also build on them to conserve scarce public funding resources.

2. Background/literature review

The U.S. government has allocated substantial resources (approximately 7% of GDP) to provide education and insight to math and science teachers to stimulate educational innovation (National Academy of Sciences, 2007), including their relevance to applied professional fields such as engineering (National Science Foundation, 2008). These programs require rigorous evaluation with systematic data collection (National Science Foundation, 2011), and innovative designs of teacher learning environments that address a host of challenges (Barnes, Hodge, Parker, & Koroly, 2006). Yet relatively little systematic study focuses on the design and evaluation of such programs, leaving a gap in synergistic knowledge sharing.

Those creating and assessing teacher professional development programs have begun to more systematically investigate what and how teachers learn and develop (e.g., Guskey, 2002; Zellermayer & Tabak, 2007). While there is no single magic formula for enhancing teacher learning and practice to optimize student benefits and enduring culture change (van Driel, Beijaard, & Verloop, 2001), designers and evaluators can build on and leverage research-based lessons to enhance program effects (Julnes & Rog, 2009).

A next critical step is to examine more specifically what design features contribute to effective teacher learning, anchored in research-based design principles. This emphasis on systematic design data has begun recently to emerge in the professional

☆ This project was funded by the National Science Foundation (# 105187800, RET grant # 1009984) to University of Oklahoma College of Engineering.

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0149-7189/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.evalprogplan.2013.11.002

development literature (e.g., Wenglinsky & Silverstein, 2007). A third need, in response to recent emphasis on accountability for grant-funded programs, is to examine and disseminate effective evaluation strategies linked to professional principles (Hardré, Slater, & Nanny, 2010), which remains a gap in the existing education literature.

Overarching issues for designers and evaluators in this effort include:

1. Balance between ideal and feasible activities
2. Relationships and communication with teacher participants
3. Troubleshooting participation and engagement
4. Roles and support structures necessary for program success
5. Measurement strategies—tooling, systems, frequency, accessibility

This literature can build on what we know from educational psychology, that learning resulting in both enhanced expertise and transfer of strategies depends not only on information delivery or processes, but also on the contexts, conditions and company in which learning occurs (Amirault & Branson, 2006; Borko, 2004).

2.1. Previous design research in university-based teacher learning

A limited body of research has addressed effective strategies and practices in design or evaluation for these programs. The few existing studies have examined some features of their assessment and evaluation (e.g., Hardré, Slater, & Nanny, 2010), or designs of teacher learning experiences (e.g., Dresner, 2002; Hanegan, Friden, & Nelson, 2009). Some have examined collaborative and social dimensions of teacher development (e.g., Lenz & Lange, 2005; Musanti & Pence, 2010), motivations (e.g., Powell-Moman & Brown-Schild, 2012), the role of technology (e.g., Kabilan, Adlina, & Embi, 2011), or the formation of learning communities (e.g., Fulton & Britton, 2011; Hadar & Brody, 2010). Yet the hundreds of articles published in teacher education annually still miss the nuances that would effectively inform next-generation program design and evaluation.

2.2. Instructional design and evaluation frameworks

Systematic instructional design research strives to identify components of development that contribute to target learner outcomes (Dai, 2008; Richey & Klein, 2007). Systematic program evaluation strategically aligns assessment and criteria with goals and activities, to address outcomes formatively ("Is it working?") and summatively ("Did it work?") (Donaldson, 2009; Russ-Eft, Bober, de la Teja, Foxon, & Koszalka, 2008). Both provide evidence to strengthen and improve program designs that, in turn, promote development outcomes including individual and group expertise (Mieg, 2006; Stecher & Kirby, 2004). The integration of program design and evaluation in systematic investigation offers potential yield of information and value that exceeds either or both alone.

2.3. Enhancing engineering education

The engineering profession is diverse, ranging from industrial to environmental; applied across professions from medical prosthetics and surgical tooling to large agricultural equipment and drinking water filtration; from sports and Olympic competition to next-generation nanotechnology. Across its subfields core competencies include scientific reasoning, problem identification, inquiry and hypothesis testing (Shepard, Macatangay, Colby, & Sullivan, 2009). The school-to-university pipeline for engineering education is bolstered when teachers understand how elementary and secondary skills fit into postsecondary academic and professional education, and link them to authentic engineering applications (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Lagemann, 2002).

2.4. Design for teacher learning and change

Teachers must learn collaboration and innovation, to model these skills for students, yet many teachers retain old methods, uncertain how to implement newer ones (Brand & Moore, 2001). Effective professional development can produce lasting change in teaching practice (Musanti & Pence, 2010), which can lead to improved student learning and support school reforms (Arora, 2005). To this purpose, professional development designs that include meaningful collaboration and reflective self-perceptions support immediate success in teachers' communities of learning and practice, as well as long-term success for transfer and change (Hardré et al., 2013; Laufgraben & Shapiro, 2004). However, we need clearer guidelines to support continued innovation in design to close remaining knowledge gaps (Putnam & Borko, 2006). To better understand their role in program design and evaluation, this study focused on elements from previous research that fit both the program goals *and* needs of these teacher-learners (both assessed and expressed).

2.4.1. Motivational design

Motivational features connected to learning, and intentionally designed into professional development activities, can substantively improve program effectiveness (Hardré, 2009). Personally meaningful goals and success expectations drive teachers' investment of effort to learn and transfer new skills, supported by a climate for achieving those goals (Hardré & Chen, 2005, 2006). Teachers sometimes resist change in their long-used instructional methods and practices (Brand & Moore, 2001), or face challenges or barriers to implementation and transfer (Hardré, Nanny, Refai, Ling, & Slater, 2010). However, strategic program design can promote adoption and implementation (Dresner & Worley, 2006), such as by helping teachers see the value, utility and feasibility of new skills (Garet, Porter, Desimone, Birman, & Yoon, 2001). Based on previous research and evaluation results showing motivational challenges faced by some teachers in transfer of professional development, we recognized the need for intentional design for motivation to support efficacy and resilience.

2.4.2. Design and analysis of social networks

Social networks are connections between individuals and groups, webs of relationships through which people share information, support and ideas. We study social networks to understand how ideas and innovations are disseminated, and how social structures and relationships influence learning and change. Teachers use formal and informal social networks to access peers with similar goals and complementary expertise (Baker-Doyle & Yoon, 2011). Social network analysis is emerging as an important tool in data collection for multi-site, multi-event professional development, to address the challenge of tracking and documenting community interactions, like those in this study.

2.4.3. Situated learning design

The location and design of learning environments have profound effects on learning and development (Brown, Collins, & Duguid, 1989; Choi & Hannafin, 1995). Research universities' engineering laboratories and secondary school classrooms are very different in goals, roles, physical contexts and cultures-of-place. Learning environments that enable shared professional discourse and authentic shared experience promote identity development and transformation (Battey & Franke, 2008; Musanti & Pence, 2010). For these reasons, it was important that we assessed and monitored teachers' experiences and perceptions across their different situated