AN ABSTRACT OF THE THESIS OF

Tyler L. St. Clair for the degree of Doctor of Philosophy in Science Education presented on June 13, 2016.

Title: Designing An Effective Approach to Science Teacher Educator Professional Development: Lessons from the Science Education Faculty Academy

Abstract approved:

Randy L. Bell

This dissertation consists of a set of three manuscripts exploring features of effective professional development (PD) for science teacher educators. Literature about context-specific PD for science teacher educators is sparse. The first manuscript, a literature review, outlines theoretical lenses through which PD can be understood, the features of effective PD, reviews existing literature on science teacher educators, and makes recommendations about next steps for research.

The second manuscript is a mixed methods study that analyzed an array of approaches to professional development for their effectiveness and viability in the context of the Science Education Faculty Academy (SEFA). SEFA was an annual weeklong PD experience for science teacher educators in Virginia. A total of 44 SEFA participants over five years were exposed to a variety of content and session formats. Data consisted of Likert and open-ended survey responses, phone interviews, and on-site observations of SEFA sessions. Quantitative data were analyzed with descriptive and

inferential statistics, while qualitative data were analyzed using analytic induction. Participants showed significant gains in their self-perceptions related to understanding and ability to implement reform-based pedagogies; most gains were maintained after one year. Interviews and follow-up surveys revealed a variety of products and collaborations resulting from participation in SEFA.

The third manuscript of the set is a qualitative study exploring the vexation and venture model for science teacher educator PD. For the vexation and venture portion of SEFA, participants prepared a text about their issues related to the topic of high-stakes standardized testing and proposed solutions. This text served as a basis for professional discussions during SEFA. Participant-generated texts, phone interviews and field observations were analyzed using constant comparative analysis. Results indicated consensus around the issues participants faced, but a wide variety of proposed solutions. Following SEFA discussions, participants expressed greater agency in effecting change within the state and national policy arenas with regard to the issue of standardized testing. A concluding chapter to the dissertation synthesizes a comprehensive approach and makes recommendations for future science teacher educator PD derived from the contents of all three manuscripts.

Designing An Effective Approach to Science Teacher Educator Professional Development: Lessons from the Science Education Faculty Academy

by

Tyler L. St. Clair

A DISSERTATION

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Doctor of Philosophy

Presented June 13th, 2016

Commencement June 2017

Doctor of Philosophy dissertation of Tyler L. St. Clair presented on June 13, 2016.

APPROVED:

Major Professor, representing Science Education

Dean of the College of Education

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Tyler L. St. Clair, Author

ACKNOWLEDGEMENTS

Thank you to my parents for their love and continued support in my education and growth. I'm grateful to my dissertation chair and advisor Dr. Randy Bell. My decision to pursue a Ph.D. at Oregon State University was based on the opportunity to work with Randy, and his guidance over the past four years has made me a better teacher and researcher. Dr. Jennifer Maeng and Dr. Lindsay Wheeler, who are coauthors on manuscripts in this dissertation, have provided considerable direction and support for my project. I would also like to thank the rest of my thesis committee, Dr. Larry Flick, Dr. Emily Van Zee, Dr. SueAnn Bottoms, and Dr. Barry Croom for their time and valuable advice in reviewing this work. To my friends Kenny Lackey, Jennifer Fleuret, Brian Hartman, Annie Stafford, Bill Stephens, and Dr. Michelle Wilkinson, thank you for your continuous encouragement.

This research would not have been possible without the funding support from the U.S. Department of Education Investing in Innovation (I3) grant program. Finally, the numerous professors and graduate students at Oregon State University, The University of Virginia, George Mason University, Virginia Common Wealth University, William and Mary College, and Virginia Tech were critical in making the VISTA project a success.

CONTRIBUTION OF AUTHORS

For Chapter 3, Dr. Maeng and Dr. Wheeler assisted with data collection and analysis.

For Chapter 4, Dr. Maeng assisted with data analysis, design and writing, while Dr. Wheeler and Dr. Bell provided support in design and writing.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF TABLES

DEDICATION

In memory of Dr. Donna Sterling, who impacted countless students and teachers.

CHAPTER ONE

INTRODUCTION

Statement of the Problem

University professors play an important role in students' personal and academic success (Endo & Harpel, 1982; Komarraju, Musulkin & Bhattacharya, 2010). In addition to their teaching responsibilities and interaction with students, professors must devote time to other aspects of their jobs such as developing courses, producing research, staying current in their disciplines, and serving on committees (Jacobs & Winslow, 2004). Faculty members report that it is difficult to find enough time to address all aspects of their job and report other challenges as well, such as difficulty accessing resources at their institutions, lack of adequate training, and promotion and advancement issues within the tenure system (Bohen and Stiles, 1998).

Science teacher educators help prepare preservice teachers to teach science at the K-12 level, and often work with in-service teachers as well. They are usually housed in colleges of education or in the various STEM colleges within their institutions. In addition to the challenges shared among all faculty members, science teacher educators face two additional challenges. First, they are often tasked with teaching preservice science teacher methods courses and field placement supervision, but many do not get appropriate experience during their graduate programs and find themselves underprepared for this part of the job (Jablon, 2002). Second, most science teacher educators find themselves as one of the only or the sole science education faculty member in their institution (Johnston & Settlage, 2008). This isolation creates barriers to collaboration and barriers to remaining current with research in their field.

Professional development (PD) is needed to assist faculty according to their needs. A variety of approaches have been implemented including mentorship programs, peer coaching, workshops, and/or the distribution of literature to help faculty develop their research agendas or teaching ability (Caffarella & Zinn, 1999; Huston & Weaver, 2008). Most PD initiatives are relatively limited in scope and focus on only one aspect of a faculty member's position, the most common of which is teaching (Young, 1987). Comprehensive models for evaluating faculty PD programs are limited; however, K-12 literature indicates that effective PD should be focused on content, include active learning on the part of participants, be coherent, and include sustained support (Birman, Desimone, Porter & Garet, 2000; Guskey & Yoon, 2009). There is also evidence that PD should be context-specific and provide opportunities for participants to collaborate and reflect on their experiences (Desimone, 2009; Loucks-Horsley & Matsumoto, 1999).

PD experiences specifically tailored to science teacher educators are uncommon, with the sole example in the literature being the vexation and venture model, developed for the *Science Education at the Crossroads* conference (Johnston & Settlage, 2008; Settlage & Johnston, 2014). The Science Education Faculty Academy (SEFA) began in 2011 as a component of the Virginia Initiative for Science Teacher Achievement (VISTA) program. SEFA was a statewide PD initiative designed to address specific issues of science teacher educators. It ran for a total of five years from 2011 to 2015 as an annual weeklong PD experience for science teacher educators from institutions of higher education across the Commonwealth of Virginia. The design of SEFA was based on effective strategies adapted from previously successful smaller scale PD programs (Sterling & Frazier 2010; Sterling, Matkins, Frazier & Logerwell, 2007).

An important goal of the VISTA project in which SEFA was situated was to provide coherent statewide PD for elementary and secondary teachers, district-level science coordinators, and science teacher educators. Key features of VISTA include a focus on inquiry instruction, problem-based learning (PBL), and explicit nature of science (NOS) instruction. These pedagogical approaches allow students to engage in authentic scientific practices and develop scientific literacy, these being important goals for science education and key features of effective reforms-based science teaching (National Research Council, 2000; 2012). VISTA used specific operationalized definitions for these pedagogical approaches. PBL was defined as students solving a problem with multiple solutions over time, like a scientist in a real-world context. The problem and context must be meaningful to students. VISTA defined inquiry as the process of students asking questions, collecting and analyzing data, and using evidence to solve problems. Key features of NOS included that scientific knowledge is empirically derived, that it can change with new evidence or a reinterpretation of existing evidence, and that it operates within a sociocultural context. Also, VISTA emphasized that NOS must be taught explicitly (Mannarino, Logerwell, Reid & Edmonson, 2012). SEFA also included opportunities for participants to share syllabi, to learn about grant writing, The Next Generation Science Standards, engineering design, working with diverse students, and discourse. Finally, one SEFA session incorporated the vexations and ventures PD format, developed by Johnston and Settlage (2008). In the vexations and ventures session participants shared a professional issue and collaborated with colleagues to develop workable solutions.

Purpose

This dissertation includes a literature review and two research studies that seek to better understand what works and what does not work for PD targeting science teacher educators. The literature review explores how PD may be conceptualized using an array of theoretical lenses. It also describes the most important features of effective PD implementation, outlines how faculty PD may be evaluated, and makes recommendations for future research in developing context-specific PD for science teacher educators. The first empirical study explores the effectiveness of the various aspects of SEFA and characterizes participants' perceptions about their experiences with the various aspects of the program. This study addresses the following research questions:

1. How were participants' understandings of and confidence in implementing inquiry, PBL, and NOS instruction shaped by their participation in SEFA?
2. To what extent and in what ways did participants' experience with SEFA enhance their collaboration within the science education community?
3. What strengths and areas for improvement were identified by participants regarding their experience at SEFA?

The second empirical study focuses more deeply on characterizing science teacher educator attitudes around a single issue discussed during the vexation and venture session of SEFA. The vexation and venture portion of SEFA encouraged participant to share current issues and collaborate with one another to arrive at workable solutions. The issue chosen for this study was participants' perceptions of high-stakes standardized testing in the U.S., the 2014 vexation and venture issue. This study also seeks to understand how working as part of a professional learning community affected participants' perceptions about this issue. This second study yields further insights about how effective PD can be designed and implemented for science teacher educators. The research questions are:

1. What patterns exist among the vexations and ventures of science education faculty related to standardized testing? Specifically, who or what was perceived as the cause of the vexation and who or what is affected? Who or what is perceived as being responsible for the solution to the issues raised?

2. What differences exist, if any, in the vexations and ventures of faculty from education departments vs. faculty from STEM departments?

3. In what ways did participation in SEFA influence participants' thinking about their vexations and ventures related to standardized testing?

Finally, a concluding chapter proposes a comprehensive model for science teacher educator PD. This model synthesizes conclusions from the empirical studies presented in this dissertation as well as current literature about effective PD practices.

Significance of the Study

Effective PD for science teacher educators must be carefully tailored to their professional needs and context (Timperley, Wilson, Barrar & Fung, 2007). Unfortunately, little has been reported about science teacher educators in the literature, and little in the way of empirical research has been conducted relating to their PD. The literature review and two empirical studies presented in this dissertation will add significantly to the current literature on the topic.

Science teacher educators play an important role in the development of future teachers and often also provide professional support for in-service teachers. They experience barriers to collaboration with colleagues due to relative isolation in their department, and express difficulties related to design and delivery of science methods courses (Jablon, 2002); more must be learned about how to respond to these needs through a process of empirical research. This set of studies will better characterize this demographic and will draw conclusions about what works and what doesn't through a combination quantitative and qualitative methods. The context of SEFA provides a unique opportunity to explore a wide variety of approaches and activities. Findings from this dissertation will be used to make specific recommendations toward a comprehensive and responsive model for science teacher educator PD.

References

Birman, B. F., Desimone, L., Porter, A. C., & Garet, M. S. (2000). Designing PD that works. *Educational Leadership*, *57*, 28-33.

Bohen, S. J., & Stiles, J. (1998). Experimenting with models of faculty collaboration: Factors that promote their success. *New Directions for Institutional Research*, *25*, 39-55.

Caffarella, R. S., & Zinn, L. F. (1999). PD for faculty: A conceptual framework of barriers and supports. *Innovative Higher Education*, *23*, 241-254.

Desimone, L. M. (2009). Improving impact studies of teachers' PD: Toward better conceptualizations and measures. *Educational Researcher*, *38*, 181-199.

Endo, J. J., & Harpel, R. L. (1982). The effect of student-faculty interaction on students' educational outcomes. *Research in Higher Education*, *16*, 115-138.

Guskey, T. R., & Yoon, K. S. (2009). What works in PD. *Phi Delta Kappan*, *90*, 495-500.

Huston, T., & Weaver, C. L. (2008). Peer coaching: PD for experienced faculty. *Innovative Higher Education*, *33*, 5-20.

Jacobs, J. A., & Winslow, S. E. (2004). Overworked faculty: Job stresses and family demands. *The Annals of the American Academy of Political and Social Science*, 596, 104-129.

Jablon, P. C. (2002). The status of science education doctoral programs in the United States: The need for core knowledge and skills. *Electronic Journal of Science Education*, *7*.

Johnston, A., & Settlage, J. (2008). Framing the PD of members of the science teacher education community. *Journal of Science Teacher Education*, *19*, 513-521.

Komarraju, M., Musulkin, S., & Bhattacharya, G. (2010). Role of student–faculty interactions in developing college students' academic self-concept, motivation, and achievement. *Journal of College Student Development*, *51*, 332-342.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on PD for teachers of mathematics and science: The state of the scene. *School Science and Mathematics*, *99*, 258-271.

Mannarino, A., Logerwell, M. G., Reid, V. B., & Edmondson, E. W. (2012). Refining inquiry-based science instruction through PD using the VISTA Model. A paper for the Annual meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

National Research Council. (2000). Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Washington DC: National Academic Press.

National Research Council. (2012). A framework for K-12 science education. Washington, DC: National Academies Press.

Settlage, J., & Johnston, A. (2014). The crossroads model. *Educational Leadership*, *71*, 67-70.

Sterling, D. R., & Frazier, W. M. (2010). Maximizing uncertified teachers' potential. *Principal Leadership*, *10*, 48-52.

Sterling, D. R., Matkins, J. J., Frazier, W. M., & Logerwell, M. G. (2007). Science camp as a transformative experience for students, parents, and teachers in the urban setting. *School Science and Mathematics*, *107*(4), 134-147.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). Teacher professional learning and development: Best evidence synthesis iteration (BES). Wellington New Zealand: New Zealand Ministry of Education.

Young, R. E. (1987). Faculty development and the concept of "profession." *Academe*, *73*, 12-14.

CHAPTER TWO

LITERATURE REVIEW

Conceptualizing and Evaluating Professional Development for Science Teacher Educators

Tyler L. St. Clair

Abstract

Professional development (PD) provides a means to help faculty members continuously improve their skills related to teaching, collaboration, research, and/or personal growth. There are many ways to conceive of PD, depending on the intended goals and choice of learning theory. This review examines PD through the lenses of cognitive, sociocultural and motivation theoretical frameworks. Research has shown that effective PD should be coherent, engage participants in active learning around content, and offer participants chances to collaborate. It should also be of sufficient duration for intended changes to occur with sufficient ongoing support. Finally, it should be tailored as specifically as possible to the specific context in which participants work. A number of factors are known to influence the success of PD initiatives including interpersonal relationships, institutional support, personal issues, and individual characteristics.

Context-specific PD experiences for science teacher educators are rare. They are often the sole faculty member with their background in their institution and thus face barriers to forming collaborative partnerships. Additionally they report being underprepared to teach methods courses and supervise field placements. Although context-specific PD is necessary to adequately respond to their needs, these specific needs must be taken into account for PD to be

maximally responsive. Insufficient research has been conducted to adequately assess what PD features would best suit science teacher educators.

Introduction

Faculty professional development (PD) first became a priority for universities in the 1960's and 70's in response to dissatisfaction with the quality of teaching and curricula (Stanley, 2005), thus early faculty PD initiatives focused primarily on improving teaching. Aside from teaching, university professors have a variety of roles to balance in their work life. These include developing courses, participating in service activities, staying current in their academic areas, and producing research (Jacobs & Winslow, 2004). Taking these complex factors into account, O'Meara, Terosky, and Neumann (2008) succinctly define faculty growth as "change that occurs in a person through the course of her or his academic career or personal life and that allows her or him to bring new and diverse knowledge, skills, values, and professional orientations to her or his work" (p. 24). PD may be self-directed or part of a program offered by an organization or institution of higher education. Also, it may take on a variety of meanings depending on which aspects of faculty professional life it targets. PD initiatives may not be focused primarily on individuals' needs and goals, but instead may focus more directly on better serving the student body of a university, or even institutional efficiency and development (Riegle, 1987).

Theoretical Foundations of Professional Development

How one chooses to design and/or study PD depends on the fundamental stance one takes in defining the term *development*. With the myriad of theoretical frameworks present in educational literature, this task could be exhaustive. Further, many researchers are not explicit in describing their frameworks, although there are often sufficient clues to assign a framework by examining the researchers' usage of language, stated goals of PD, aspects of how these initiatives are designed, and researchers' choice of methodology. This section examines major educational frameworks and how they inform research on faculty PD. These include cognitive frameworks (constructivism and social constructivism), sociocultural frameworks (situated learning and communities of practice), and finally motivational frameworks (attribution theory and goal theory). This analysis is not meant to be exhaustive but instead is meant to provide a window into the many ways by which PD can be conceptualized.

Cognitive Frameworks

Faculty PD constructed with a cognitive lens may have a goal to characterize and/or modify individuals' thinking related to aspects of PD through qualitative approaches, or to use a quantitative approach to achieve pre/post- changes. The individual could be the faculty participant, but it is also possible that the goal would be focused on demonstrating the PD's effect on their student pre/post- cognitive gains at some later time. Regardless, the unit of analysis would be the individual and the focus would be on individual cognition. Specific research tools might include Likert surveys, open-ended surveys, interviews, narratives, and any other approach designed to access individual sense-making. One of many examples of this approach to PD in the literature is a study conducted by O'Hara and Pritchard (2008) characterizing the effectiveness of PD for teacher educators that had a goal to increase faculty knowledge about student linguistic diversity. As is often the case, no theoretical framework was presented, but methods in this study presented enough clues that they were using a cognitive framework. Data included pre/post- surveys designed to measure participant self-report knowledge about various constructs presented during the PD. Both the PD goals and research methods aligned well with a cognitive view of learning. In general, PD designed within a cognitive framework would view faculty development as an opportunity to gain new knowledge about teaching, deepen content knowledge in in a particular area, learn about new ways to secure funding, and to learn new strategies for collaborating with peers.

Social constructivism is a particular cognitive framework through which one can conceptualize faculty PD. Social constructivism views learning as occurring first within the social realm, but acknowledges that learning is still ultimately an individual phenomenon (Duit & Treagust, 1998; Hodson & Hodson, 1998). When studying individual learning in a group context it is useful to consider the dominant metaphors, meanings and implicit understandings of the group, and that individual sense making mediated by a larger social context infused with meaning (Mitchell & Sackney, 2011). While the goals of social constructivist-inspired PD may be quite similar to the constructivist goals already mentioned, there is greater consideration given to how a group functions and socializes during the learning process, and how the group context affects and influences the individual, or to allow more learning time to occur through facilitated group interaction and collaboration.

Sociocultural Frameworks

The use of sociocultural frameworks shifts the emphasis from mental schema to the context in which learning takes place, and indeed sees learning as a phenomenon not separate from that context. Brown, Collins and Duguid (1989) elegantly describe this view of learning as making *knowing* indistinguishable from *doing*. One might describe learning through the sociocultural lens as a process akin to enculturation rather than a process of knowledge accumulation or acquisition. Learning is always situated in a context and can be thought of as an increasing ability to legitimately participate or perform within that context. A particularly useful sociocultural model for describing how learning happens within groups is the “community of practice." These groups can be characterized as mutually engaged with a shared repertoire and a joint enterprise (Wenger, 1998).

Goals of faculty PD viewed through a sociocultural lens may involve facilitating the transition of faculty from a novice to expert in their teaching or research. Peer coaching, or exposing faculty to the classes of more experienced professors might be good ways to achieve these aims. The research of such initiatives would likely involve ethnographic observation or interviews and researchers would be interested in questions related to how faculty develop in their identities in their professional lives, how knowledge is distributed, or how roles are distributed among the faculty, staff and administration in a university. It may also be an ideal lens for any PD with goals related to institutional change, or research focused on characterizing the culture or changing the culture of higher education institutions. An example in recent literature of a study using a community of practice framework was interested in exploring features of PD that were specific to some of the various disciplines in higher education (Blanton & Stylianou, 2009). Their study included such questions as how "old-timers" in PD develop over time and how newcomers are recruited as well as how language used in PD mediates thinking about practice. These questions have a clear sociocultural focus. The methods of this study used transcribed video observations and a grounded theory approach to generate theory to answer these questions and are in line with a sociocultural approach as well.

Motivation Frameworks

A third important lens for viewing faculty PD is through theories of motivation. There are many motivation theories that work together to paint a picture of how individuals perceive or explain behavior, and offer explanations for why, and under what conditions individuals have a desire to engage in learning. Self-determination theory (SDT) for example views individual motivation as the interplay of internal factors (like natural curiosity or interest) and external factors (like evaluations or rewards) that work to shape behavior. SDT also emphasizes that autonomy, relatedness and competence are important for enhancing motivation toward a task (Ryan & Deci, 2000). PD aligned with SDT would have goals to increase personal motivation through development activities designed to increase autonomy and competence with regard to teaching, research or securing funding. It may also aim to help faculty view the various aspects of their job in more meaningful ways to increase external motivational incentives to change attitudes and behaviors, or even help faculty find ways to manage stress.

Attribution theory is another theory of motivation, but one that focuses on ways in which individuals are likely to explain the causes of actions and behaviors. For example, these attributions may emphasize an individual's characteristics in explaining behaviors vs. circumstances surrounding the individual. Attributions may also emphasize aspects that are easy to modify in a given situation vs. difficult or impossible to modify in a given situation (Harvey & Martinko, 2009). Once an individual has made these attributions, they experience an emotional response that influences their motivation and subsequent behavior. PD designed using attribution theory may attempt to help empower faculty see that they have the ability to improve their own teaching or career trajectory, instead of focusing on their own inadequacies as something that cannot be changed. This change of attribution could be achieved by allowing faculty to practice newly learned skills and succeed in controlled situations during PD experiences before implementing new ideas in their own practice.

A final important theory related to motivation is goal theory. This theory emphasizes the reasons why individuals are motivated to engage in learning. The goals of an individual may vary. They may be based on motivation to want to understand or to be able to do something, or the reverse- to avoid misunderstanding or not being able to do something. Further, individuals may be motivated to demonstrate their competence or abilities to others, or the reverse- to avoid showing their incompetence or lack of ability to others (Pintrich, 2000). A goal theory approach to faculty PD would be concerned with nurturing faculty who are already oriented toward self-mastery, or trying to foster that orientation. This approach may also modify circumstances to raise the stakes in some way for those already oriented toward demonstrating competence or avoiding failure.

Generally speaking, faculty PD studied through motivation frameworks seeks to characterize faculty interests, to understand personal goals and the reasons for those goals, and to examine the power of context on faculty motivation to succeed in the various aspects of their careers. The three theories described here have many compatible aspects, focusing on how motivation can play a central role in job performance. There are numerous validated research questionnaires to support research, such as the Self Regulation Questionnaire (Brown, Miller & Lawendowski, 1999), or the Attributional Style Questionnaire (Peterson, et al., 1982), among others. These instruments are designed to measure the psychological constructs relating to the theories discussed.

Effective Professional Development Practices

A significant amount of literature both at the K-12 level and in higher education has uncovered common key features necessary for effective PD. Effectiveness here refers to both a positive perception of a PD experience by participants as well as its ability to produce sustained learning and to affect practice. In the case of university faculty, this may mean a sustained positive impact on classroom teaching practices, but it could also mean the ability to secure grants, design courses, collaborate, or to be more productive in publishing research. Most of the available research on PD relates to teaching; however, less of a picture is available for what effective PD means with regard to other areas of faculty professional life. The following section presents a summary of empirical findings for effective PD practices.

An important feature of effective PD is that it should be sustained long enough for learning to occur and should be ongoing so that learning is reinforced and deepened over time (Desimone, 2009; Johnson, Kahle & Fargo, 2007). In a review of the literature, Guskey and Yoon (2009) found that 30 or more total contact hours seemed to be a necessary ingredient for success, but that more time is not necessarily more effective if a program is poorly structured.

PD should also engage participants in active learning experiences (Birman, Desimone, Porter & Garet, 2000; Desimone, et al., 2002). That is to say instead of PD implementers doing most the thinking and speaking, participants should be problem solving, planning, using higher order thinking, and making sense of new material through discussion and reflection. Another important ingredient for PD is collaborative participation (Birman, et al., 2000). Colleagues with similar job responsibilities who work in similar environments will likely share similar challenges and difficulties. Thus collaboration among colleagues in the setting of well-structured PD can position participants as valuable resources to one another. Professional learning communities can help foster this type of collaboration; participants shift from being passive learners to adopting the dual roles of both teacher and learner (Glazer & Hannafin, 2006). Professional learning communities have been reported to have a positive effect on confidence, enthusiasm, and desire for future collaboration (Cordingley, Bell, Rundell & Evans, 2003). Stoll, et al. (2006) synthesized five key features of professional learning communities from a wide range of authors in a review of the literature. These features include shared values and vision, collective responsibility, reflective professional inquiry, collaboration, and the promotion of group as well as individual learning.

Next, effective PD should be focused on content. Educators do not simply require a working knowledge of their discipline; they also need pedagogical knowledge and a nuanced understanding of how both types of knowledge can work in tandem to best communicate knowledge about a particular area to others (Loucks-Horsley & Matsumoto, 1999; Shulman, 1986). This suggests that PD should not divorce teaching the teaching of methods and content. A content focus during PD has been linked to increased knowledge as well as changes to teaching practices (Cohen, Hill & Kennedy, 2002; Desimone, et al., 2002; Garet et al., 2001), while PD lacking a content focus has been shown to be ineffective (Kennedy, 1998).

PD programs should be coherent (Birman, et al., 2000; Penuel, Fishman, Yamaguchi & Gallagher, 2007). Coherence refers to all aspects of PD being aligned with desired goals, whether these are goals of a particular PD program or the larger institution in which the program is situated. Coherence can also mean consistency of a program over time. Not only is coherence of a PD program valued by participants (Penuel, Fishman, Yamaguchi & Gallagher, 2007), a coherent PD experience can both increase learning and lead to lasting changes in practice (Birman, et al., 2000).

Faculty members are far from uniform, and thus a key feature of effective PD is that it must be tailored and context-specific (Timperley, Wilson, Barrar & Fung, 2007). Participants' strengths, prior knowledge, learning needs, and diversity of experience must all be taken into account (Pellegrino, Bransford & Donovan, 1999). This complicates matters because it implies that what works for some faculty members in one context may not necessarily transfer to other faculty members or other contexts. In higher education, well-tailored context-specific PD would take into account the research interests of participants, their classroom contexts and responsibilities, their institutional resources, etc. Context-specific PD may also imply embedded components such as co-teaching experiences, mentoring, or lesson reflections with a coach (Desimone, 2009). Finally, the format and focus of any PD initiative must consider factors such as the nature of the academic discipline in which faculty work, the nature of the institution, early vs. late career needs, and it must anticipate both the current and future needs of students and faculty in a particular institution (Stanley, 2005).

Faculty Needs and Professional Development

Characterizing Faculty Professional Development

Faculty PD programs could be envisioned that address a variety of faculty needs, and so a comprehensive way of envisioning faculty PD is necessary. A literature review of PD by SRI International synthesized a list of important features by which PD programs may be characterized (Donnelly, Dove & Tiffany-Morales, 2002). Three of these features are structural in nature and include the overall format, the duration, and the extent to which the PD has collective participation. Another set of three features describe core components of delivery including the degree of active learning, the extent to which it is focused on content, and the overall degree of coherence of all parts of the program. Finally, the authors mention accessibility, degree of inclusiveness of the potential participants, and incentives for participants. Different approaches to PD format may include conferences, workshops, seminars, classroom observations, mentoring programs, peer coaching, the use of multimedia to analyze presentation and teaching styles, and/or the distribution of literature to aid faculty in their teaching and research (Caffarella & Zinn, 1999; Huston & Weaver, 2008; Stanley, 2005).

Barriers And Supports

Faculty members face an array of constraints that make change difficult and the potential effects of PD programs limited. Relatively large barriers to change reported in numerous studies include insufficient time, training, and incentives (e.g. American Association for the Advancement of Science [AAAS], 2011; Brownell & Tanner, 2012). Women and racial minorities face additional barriers. These groups tend to be underrepresented in higher education and tend to be clustered at lower academic ranks through discriminatory practices related to promotion and tenure (Menges & Exum, 1983; Perna, 2005; Turner, 2002). A poor working environment and lack of support can also impact productivity (O'Meara, Terosky & Neumann, 2008).

Caffarella and Zinn (1999) described four major factors that may either enhance or impede PD: Interpersonal relationships, institutional structures, personal issues, and intellectual and personal characteristics. Interpersonal relationships of colleagues, administrators, friends and family may either facilitate or interfere with further development. Examples include colleagues' willingness to collaborate, collegial respect, and spousal support. Second is the importance of institutional structures. These structures include providing enough opportunities and enough time for PD or external factors on the individual related to the climate (collegiality and/or competitiveness) of the department and institution. Third are personal issues such as major life transitions, physical health, and compatibility of work life with religious and cultural values. Finally, intellectual and personal characteristics of the individual play a role. These include self-confidence, enjoyment of challenges and change, intrinsic demand for excellence in personal performance (as in teaching or research), and enthusiasm for continued professional growth.

Professional Development for Science Teacher Educators

The term science teacher educator refers to those individuals in higher education who work with preservice teachers through science pedagogy (methods) courses. They may also work to support in-service teachers through PD initiatives. These individuals tend to be housed in either education or STEM departments within their institutions. Little in the way of empirical research is available on PD specific to science teacher educators; however, some literature sources provide insight into their professional needs, and others provide narrative-based accounts of science teacher educator PD initiatives that have been tried in the past.

Science teacher educators are expected to be able to teach science methods courses and supervise student teachers, but only a minority actually get the opportunity to have these experiences while in graduate school, as most science education doctoral programs focus almost exclusively on preparing students for research (Eisenhart & DeHaan, 2005; Jablon, 2002). They report feeling underprepared for these central parts of their jobs. Further, it is common for science teacher educators to find them selves as one of the only individuals, or even the sole individual with their background in their institution (Johnston & Settlage, 2008). Opportunities for collaboration are therefore limited, and would seem to necessitate collaborative relationships across university lines in a region or state. In addition to the relative isolation of science teacher educators, Bohen and Stiles (1998) report three challenges to faculty collaboration. These include the promotion and tenure system primarily rewarding individual achievement, a lack of administrative support for collaborative efforts (and in particular cross-disciplinary efforts), and lack of training for forming and maintaining partnerships in academia. Adding to these challenges, science education faculty report that science faculty often doubt the existence of a meaningful research base in education and that they perceive the field of education as an area for which everyone is an expert (Harwood, 2004). For cross-disciplinary partnerships to function well, there must be mutual understanding and respect.

Various organizations exist to facilitate presentation and dissemination of science education research at the state and national level including The National Association for Research in Science Teaching (NARST), The Association for Science Teacher Education (ASTE), and The National Science Teachers Association (NSTA). As a PD experience, these organizations primarily serve as a platform for science teacher educators to learn about current research. Other than the traditional research conference format, there is only one alternative model for science teacher educator PD described in the literature- namely the Science Education at the Crossroads conference (Johnston & Settlage, 2008; Settlage & Johnston, 2014). This annual meeting is focused on creating meaningful conversations around issues of importance to anyone engaging in science education research, but focuses primarily on building collaborative relationships among mid-career educators (Johnston & Settlage, 2008; Settlage & Johnston, 2014). This conference uses a model for discussion called “vexations and ventures.” Prior to attendance, participants are required to submit a text that addresses a challenge they face (their vexation) and their thinking toward overcoming that challenge (their venture). Discussions during the Science Education at the Crossroads conference are structured and tied to these participant-generated texts. As this is the only PD model reported in the literature specific to science teacher educators, more research is needed to determine what effective context-specific PD for this demographic would entail.

Evaluation of Professional Development

Guskey (2000) outlines five domains by which PD programs may be evaluated for their effectiveness. Though this model best suits PD designed to change teaching practices, it speaks to the wide range of effects that could potentially be evaluated. These domains include:

1. Participants' reactions to and level of satisfaction with the program
2. Participants' learning and demonstration of new knowledge or skills
3. Participants' implementation of new knowledge and skills
4. The eventual effect on student learning outcomes
5. The effect of the PD on larger organizations in which the individual is situated.

Most of these criteria are quite general and can be applied to a wide range of professional development experiences in higher education. The first domain is the easiest to measure and may include the assessment of participant's self-perceptions of their learning, or satisfaction with various PD components. This model is useful at differentiating between successful learning of new knowledge or skills and whether or not this learning led to actual changes in practice. One study videotaped science professors' classrooms following their attendance at a workshop focused on active learning strategies. These professors clearly demonstrated they learned new knowledge following the PD, but on returning to their classrooms showed little change in their teaching practices (Ebert-May, et al., 2011). These results suggest a potential disconnect between self-perceptions about practice and actual practice; thus it is helpful to distinguish these two domains in PD evaluation. Fourth on the list, the eventual effect on student learning outcomes, is specific only to PD initiatives primarily focused on modifying teaching practices. This criterion would need to be modified to include other outcomes depending on the PD's goal such as increased long-term job satisfaction, success in procuring grants, success in publishing, etc.

This evaluation model is useful because it is potentially compatible with a wide range of educational theories (e.g. constructivist, motivation, or sociocultural frameworks). While mostly concerned with individual perceptions and practice, it includes a dimension that relates to interplay of the individual and their situated institutional context. A hierarchy of evaluation is also implied in this model. Positive perceptions about PD are generally necessary to achieve gains in the other dimensions (Guskey, 2000), and positive changes in perceptions and knowledge do not imply changes to practice (Ebert-May, et al., 2011).

Discussion

It is possible to conceive of PD in a variety of ways, but implementers must have well-defined goals and a clear understanding of what is meant by development. For example, development may be framed as an individual learning new knowledge and skills in the case of cognitive theories, a change in interest or attitude according to motivation theories, or a change from novice to expert practice according to sociocultural theories. PD experiences must be designed and implemented according to best practices presented in the literature, namely they should be of sufficient time for learning to occur (Desimone, 2009; Johnson, Kahle & Fargo, 2007) and engage participants in active learning with a content focus (Desimone, et al., 2002; Garet et al., 2001). Effective PD should have coherent goals (Birman, et al., 2000; Penuel, et al., 2007), should provide opportunities for collaborative discussion (Birman, et al., 2000), and should be context-specific to the professional lives of participants (Timperley, et al., 2007).

While generic PD experiences are common, creating context-specific PD involves careful consideration of the needs and professional circumstances of participants. Without tailoring PD in this manner, initiatives can only be so effective. Few studies exist describing science teacher educators and their professional needs (Jablon, 2002), and only one model of tailored PD for this demographic has been presented in the literature (Johnston & Settlage, 2008; Settlage & Johnston, 2014). While Johnston and Settlage's (2008) vexation and venture model includes opportunities for collaboration through active discussion, its implementation was not systematically studied for its effectiveness.

The vexation and venture model may not be equally suited as a vehicle for the range of content that could be delivered in a science teacher educator PD (e.g. grant writing, research, new teaching practices, or syllabus sharing). Feedback from participants about their perceptions of these sessions would be valuable. Specific areas that need to be addressed are whether some topics are more suited to this format than others, what length of time for these discussions is most appropriate, and whether the choice of content should be relatively uniform for all participants or left completely up to the individual participant. Though promising, further study of the vexation and venture model is needed within the context of science teacher educator PD.

In addition to this single tried format, it is important to investigate a wide range of possible approaches in order to determine what features of PD would be best suited to the needs and context of science teacher educators. Such research must be grounded in effective principles of PD from the literature and be based on a coherent theory of learning. One such example is the Science Education Faculty Academy (SEFA). SEFA was a five-year PD initiative in Virginia designed to provide an opportunity for science educator professional growth and collaboration (McDonnough, Sterling, Matkins, & Frazier, 2012). SEFA offered a wide range of content and session formats. The following chapters in this dissertation use the lens of social constructivism to study the variety of approaches used at this week-long PD experience for science teacher educators in Virginia. The first study uses a mixed methods approach to explore the effectiveness of a range of approaches and content, while the second study focuses on the viability of the vexation and venture model in particular. Taken together, these two studies have the potential add significantly to the literature.

References

American Association for the Advancement of Science. (2011). Vision and Change: A Call to Action, Final Report, Washington, DC.

Birman, B. F., Desimone, L., Porter, A. C., & Garet, M. S. (2000). Designing PD that works. *Educational leadership*, *57*, 28-33.

Blanton, M. L., & Stylianou, D. A. (2009). Interpreting a community of practice perspective in discipline-specific professional development in higher education. *Innovative Higher Education*, *34*, 79-92.

Bohen, S. J., & Stiles, J. (1998). Experimenting with models of faculty collaboration: Factors that promote their success. *New Directions for Institutional Research*, *25*, 39-55.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*, 32-42.

Brown, J. M., Miller, W. R., & Lawendowski, L. A. (1999). The self-regulation questionnaire. In L. VandeCreek, & T. L. Jackson (Eds.), *Innovations in clinical practice: A sourcebook*, vol. 17 (pp. 281–292). Sarasota, FL: Professional Resource Press/Professional Resource Exchange.

Brownell, S. E., & Tanner, K. D. (2012). Barriers to faculty pedagogical change: Lack of training, time, incentives, and… tensions with professional identity? *CBE-Life Sciences Education*, *11*, 339-346.

Caffarella, R. S., & Zinn, L. F. (1999). PD for faculty: A conceptual framework of barriers and supports. *Innovative Higher Education*, *23*, 241-254.

Cohen, D., Hill, H., & Kennedy, M. (2002). The benefit to professional development. *American Educator*, *26*, 22-25.

Cordingley, P., Bell, M., Rundell, B. & Evans, D. (2003). The Impact of Collaborative CPD on Classroom Teaching and Learning. In: Research Evidence in Education library. London: EPPI-Centre, Social Science Research Unit, Institute of Education.

Desimone, L. M. (2009). Improving impact studies of teachers' PD: Toward better conceptualizations and measures. *Educational Researcher*, 38, 181-199.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S. & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*, 81-112.

Donnelly, M. B., Dove, T., & Tiffany-Morales, J. (2002). Technology-related professional development in the context of educational reform: A literature review. Arlington, VA: SRI International.

Duit, R., & Treagust, D.F. (1998). Learning in science: From behaviorism towards social constructivism and beyond. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 3–26). Boston: Kluwer.

Ebert-May, D., Derting, T. L., Hodder, J., Momsen, J. L., Long, T. M., & Jardeleza, S. E. (2011). What we say is not what we do: effective evaluation of faculty PD programs. *BioScience*, *61*, 550-558.

Eisenhart, M., & DeHaan, R. L. (2005). Doctoral preparation of scientifically based education researchers. *Educational Researcher*, *34*, 3-13.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*, 915–945.

Glazer, E. M., & Hannafin, M. J. (2006). The collaborative apprenticeship model: Situated PD within school settings. *Teaching and Teacher Education*, *22*, 179-193.

Guskey, T. R. (2000). Evaluating Professional Development. Thousand Oaks, CA: Corwin Press.

Guskey, T. R., & Yoon, K. S. (2009). What works in PD. *Phi Delta Kappan*, *90*, 495-500.

Harvey, P., & Martinko, M. J. (2009). An empirical examination of the role of attributions in psychological entitlement and its outcomes. *Journal of Organizational Behavior*, *30*, 459.

Harwood, W. S. (2004). Science education reform: factors affecting science and science education faculty collaborations. *Research In Science Education: Reform In Undergraduate Science Teaching For The 21st Century.* Greenwich, CT: Information Age Publishing.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, *79*, 33-41.

Huston, T., & Weaver, C. L. (2008). Peer coaching: PD for experienced faculty. *Innovative Higher Education*, *33*, 5-20.

Jablon, P. C. (2002). The status of science education doctoral programs in the United States: The need for core knowledge and skills. *Electronic Journal of Science Education*, *7*.

Jacobs, J. A., & Winslow, S. E. (2004). Overworked faculty: Job stresses and family demands. *The Annals of the American Academy of Political and Social Science*, *596*, 104-129.

Johnson, C. C., Kahle, J. B., & Fargo, J. D. (2007). A study of the effect of sustained, whole-school PD on student achievement in science. *Journal of Research in Science Teaching*, *44*, 775-786.

Johnston, A., & Settlage, J. (2008). Framing the professional development of members of the science teacher education community. *Journal of Science Teacher Education*, *19*, 513-521.

Kennedy, M. M. (1998). *Form and substance in in-service teacher education* (Research monograph no. 1). Arlington, VA: National Science Foundation.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on PD for teachers of mathematics and science: The state of the scene. *School Science and Mathematics*, *99*, 258-271.

McDonnough, J. T., Sterling, D. R., Matkins, J. J., & Frazier, W. M. (2012). *Virginia science education at the crossroads: Connecting science education faculty to a professional community.* A paper for the Annual meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

Menges, R. J., & Exum, W. H. (1983). Barriers to the progress of women and minority faculty. *The Journal of Higher Education*, 123-144.

Mitchell, C., & Sackney, L. (2011). *Profound improvement: Building capacity for a learning community*. Taylor & Francis.

O'Hara, S., & Pritchard, R. H. (2008). Meeting the challenge of diversity: Professional development for teacher educators. *Teacher Education Quarterly*, *35*, 43-61.

O'Meara, K., Terosky, A. L., & Neumann, A. (2008). Faculty Careers and Work Lives: A Professional Growth Perspective. *ASHE Higher Education Report*, *34*, 1-221.

Pellegrino, J. W., Bransford, J. D., & Donovan, M. S. (Eds.). (1999). *How People Learn: Bridging Research and Practice*. National Academies Press.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, *44*, 921-958.

Perna, L. W. (2005). Sex differences in faculty tenure and promotion: The contribution of family ties. *Research in Higher Education*, *46*, 277-307.

Peterson, C., Semmel, A., Von Baeyer, C., Abramson, L. Y., Metalsky, G. I., & Seligman, M. E. (1982). The attributional style questionnaire. *Cognitive Therapy and Research*, *6*, 287-299.

Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, *92*, 544.

Riegle, R. P. (1987). Conceptions of faculty development. *Educational Theory*, *37*, 53-59.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*, 68.

Settlage, J., & Johnston, A. (2014). The crossroads model. *Educational Leadership*, *71*, 67-70.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*, 4-14.

Stanley, C. A. (2005). Faculty PD for the 21st century. In *Higher education: Handbook of theory and research* (pp. 441-480). Springer Netherlands.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*, 221-258.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). Teacher professional learning and development: Best evidence synthesis iteration (BES). Wellington New Zealand: New Zealand Ministry of Education.

Turner, C. S. V. (2002). Women of color in academe: Living with multiple marginality. *The Journal of Higher Education*, *73*, 74-93.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*, 1-8.

CHAPTER THREE

STUDY ONE

Mixed-Methods Analysis of Science Teacher Educator Professional Development

Tyler L. St. Clair, Lindsay B. Wheeler & Jennifer L. Maeng

Abstract

This investigation explored a learning community approach for PD specifically catered to science teacher educators. The Science Education Faculty Academy (SEFA) was a five-day PD experience with the objectives to help faculty collaborate, learn about new research relevant to teacher development, share effective teaching strategies, and network to build infrastructure to support science education across Virginia. Data were gathered from 44 participants across five years. Quantitative survey response data and qualitative data that included field notes, surveys, artifacts, and interviews were analyzed using a concurrent transformative mixed methods approach with regard to SEFA objectives and to gain insight into participants perceptions about strengths of SEFA and areas for improvement. Likert scale questions measured participants' perceived understandings of key aspects of the PD including inquiry, nature of science (NOS), problem-based learning (PBL), and various other constructs relevant to participants' professional work. Paired sample *t* tests indicated statistically significant gains across almost all measured constructs for participants' pre- and post-SEFA scores as well as at a one-year delayed post-time interval. Qualitative data explored participant understandings about SEFA constructs and indicated SEFA was an important experience that affected participants' ability to be effective as science teacher educators. Further, participants reported the ability to collaborate with colleagues was an especially valuable part of their experience. SEFA engaged participants as

active learners, promoted collaboration, all in alignment with broader state science education initiatives.

Introduction

Professional Development in Higher Education

University professors are important to students' personal and academic success (Endo & Harpel, 1982; Komarraju, Musulkin & Bhattacharya, 2010). Even a high-quality relationship with a single faculty member can have a great impact upon students' university life and future careers (Rosenthal, et al., 2000). Professors confront a variety of barriers that influence their teaching and interacting with students. Jacobs & Winslow (2004) indicate they take on a variety of roles that are difficult to balance, including demonstrating successful teaching, developing courses, serving on committees and producing research. Other difficulties faced by university professors include inadequate access to resources, not having enough time for all aspects of their job, promotion and tenure issues, and inadequate training (Sunal et al., 2001). Barriers to faculty collaboration in higher education also exist due to the nature of the tenure system. Bohen and Stiles (1998) point out that the tenure system rewards individual achievement, that many professors have not had sufficient experience with collaboration, and that administrative structure in higher education does not adequately support collaborative work.

Professional development (PD) is needed to help navigate these challenges, and helping professors in supporting students should be an important component. Many approaches to faculty PD have been tried in the past. These have included workshops, mentorship programs, peer coaching, or distribution of literature to attempt to aid faculty in their research and teaching responsibilities (Caffarella & Zinn, 1999; Huston & Weaver, 2007). In spite of the multiple aspects to a professor's work, most faculty PD initiatives focus on only one aspect of their professional responsibilities, most often teaching (Young, 1987). Eleser and Chauvin (1998) surveyed more than a hundred faculty members across multiple departments in a university about their professional goals, and found that perceived professional needs included a desire to improve teaching performance. They also expressed a desire to maintain and broaden in-depth content knowledge of their field, increase productivity in research, and to improve skills related to research methods and techniques.

A number of key features are necessary for PD programs to be effective. First, they must be of sufficient duration for learning to occur and be ongoing (Desimone, 2009; Johnson, Kahle & Fargo, 2007). They should also be focused on content (Cohen, Hill & Kennedy, 2002; Desimone, et al., 2002; Garet et al., 2001) with chances for participants to engage in active learning around that content (Birman, Desimone, Porter & Garet, 2000; Desimone, et al., 2002). Participants should also be provided plenty of chances to collaborate (Birman, et al., 2000). PD programs should be coherent, with all aspects of the program aligned with the same goals, and for ongoing PD, this alignment should be consistent over time (Birman, et al., 2000; Penuel, Fishman, Yamaguchi & Gallagher, 2007). Finally, it is important for the content of PD to be specifically tailored to the context in which participants work and take into account participants' prior knowledge and experiences (Desimone, 2009; Timperley, Wilson, Barrar & Fung, 2007).

Science Teacher Educators

Science teacher educators have the important role in teaching and mentoring new teachers into the teaching profession. They are most often housed in either colleges of education or colleges of the various STEM disciplines within universities. They may also hold dual appointments. They are often expected to help arrange and supervise field placements for their preservice teachers and to teach science methods courses (Jablon, 2002). Methods courses offer preservice teachers an opportunity to develop their skills integrating science content with research-based pedagogical strategies (Lederman, Gess-Newsome & Latz, 1994) and to properly implement standards in their instruction. Staying current with research-based teaching practices is thus critical for science teacher educators due to their impact on preservice teacher learning and ultimately PK-12 student learning.

Science teacher educators, in particular, face some additional challenges. Almost all institutions expect new science teacher educators to teach methods classes and supervise preservice teachers in their field placements; however, not all new teacher educators have had this experience as part of their graduate programs. Thus, they find themselves underprepared for this aspect of their job (Jablon, 2002). Complicating the issue, most new science teacher educators find themselves in the isolated position as one of the only people or the sole person with this role at their institution (Johnston & Settlage, 2008). This relative isolation compared to faculty in other department makes it difficult to stay current with research and makes collaborating with peers a significant challenge. In a review of the literature, Harwood (2004) describes the benefits of collaboration between science and education faculty within the same institution, but few studies have focused on PD activities that specifically emphasize collaboration among science teacher educators. The only example of PD in the literature catering specifically to science teacher educators is a model called *vexations and ventures* developed by Johnston and Settlage (2008). The vexations and ventures model requires participants to write about and share a professional issue they face, followed by opportunities for colleagues to listen and discuss these issues in a group format and to come up with potential actionable solutions.

An approach that may be of use in fostering collaboration among science education faculty is creating and maintaining a professional learning community that include faculty members from multiple universities. Professional learning communities are a growing focus for research in recent years. These communities value members as a resource and rely on the members' knowledge and experience, often using a form of collaborative inquiry to facilitate discussions (Vescio, Ross & Adams, 2008). In a review of the literature, Stoll et al. (2006) characterizes a learning community as a group with shared vision that collaborates, possesses collective responsibility, and engages in reflective professional inquiry. Further, Stoll and colleagues (2006) describe them as valuing both individual and group learning. A learning community format for science teacher educators PD that offers extended and meaningful contact with colleagues would be a logical choice for meeting their need to stay current with pedagogical research and to foster collaborative relationships.

Science Education Faculty Academy (SEFA)

One such PD program that focuses on supporting educators within a professional learning community is the Science Education Faculty Academy (SEFA). SEFA operated from 2011-2015 as an annual weeklong PD experience for science teacher educators situated in the larger Virginia Initiative for Science Teacher Achievement (VISTA) statewide program. The VISTA program was funded as a 5-year Investing and Innovation (i3) validation grant by the U.S. Department of Education and also included PD for elementary teachers, secondary science teachers, and science coordinators (Sterling & Frazier, 2010; Sterling, Matkins, Frazier, & Logerwell, 2007).

As recommended by Birman et al. (2000), SEFA engaged participants in active learning around relevant content, which included hands-on activities and discussions about inquiry, PBL, NOS, effective discourse, and grant writing. SEFA implementers intentionally aligned this content with the statewide VISTA initiative and provided participants with consistent definitions of VISTA constructs. There is no clear and consistently used definition of the term “inquiry instruction” in the science education literature, which leads to confusion when attempting to generalize or compare studies investigating this topic (Anderson, 2002). VISTA’s operationalized definition of inquiry was specified as *asking questions, collecting and analyzing data, and using evidence to solve problems* (Bell & Maeng, 2012). Similar ambiguity exists with problem-based learning (PBL) (Savin-Baden, 2000). VISTA operationalized PBL as *students solving a problem with multiple solutions over time like a scientist in real-world context*; both the context and the problem must be meaningful to students and it should incorporate inquiry instruction (Bell & Maeng, 2012). VISTA also emphasized the nature of science (NOS). There are many ways to describe NOS. Often it is presented in the form of key tenets deemed appropriate for K-12 teachers and students of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). VISTA focused on the following key tenets of NOS: 1) scientific knowledge is empirical, reliable and tentative, based on observation and inference; 2) scientific theories and laws are different kinds of knowledge; and 3) many methods are used by scientists to develop scientific knowledge. Without proper guidance, teachers do not often teach NOS, and when they do, such instruction is often implicit (Capps & Crawford, 2013). VISTA emphasizes that NOS must be taught by explicitly drawing students’ attention to it, because students do not learn when taught implicitly (Abd-El-Khalick & Lederman, 2000).

SEFA reserved blocks of time for participants to collaborate, addressing the problem of isolation and helping to foster a professional learning community among participants. A model developed by Johnston & Settlage (2008) called *vexations and ventures* was used each year to focus discussions on a relevant topic in science education. During the vexation and venture session, participants shared an issue with the group, their thoughts about potential solutions, and then listened to input from their peers. Another opportunity to collaborate in a meaningful way was provided toward the end of the week each year to plan projects and/or presentations- often to be delivered at the Virginia Association of Science Teachers (VAST) conferences or meetings of the Virginia Science Education Leadership Association (VSELA). Finally, unstructured time in the evening was provided for participants to interact in a less formal way.

Theoretical Framework

This study examined five consecutive years of SEFA through a social constructivist lens. Developed by Vygotsky (1978), social constructivism emphasizes the collaborative nature of learning and rejects the notion that learning occurs divorced from a social context. In other words, social constructivism recognizes that individual learning is inextricably rooted in the meanings, dominant metaphors, and implicit understandings of one's social environment (Mitchell & Sackney, 2011). Another key feature of social constructivism is that while learning is first co-constructed socially, it is still fundamentally viewed as a change that takes place within individuals (Duit & Treagust, 1998; Hodson & Hodson, 1998).

SEFA was designed to function as a professional learning community comprised of science teacher educators from institutions across the state of Virginia. The rich discussion format of SEFA focused heavily on sharing and collaboration, among both implementers and participants. The choice of a social constructivist framework is an ideal choice to acknowledge the importance of group dynamics in a professional learning community, while keeping data collection and analysis squarely focused on understanding individual learning and sense making.

Purpose

The present study addresses the need to better understand context-specific PD for science teacher educators by comprehensively examining SEFA. The following research questions guided the investigation:

1. How were participants' understandings of and confidence in implementing inquiry, PBL, and NOS instruction shaped by their participation in SEFA?
2. To what extent and in what ways did participants' experience with SEFA enhance their collaboration within the science education community?
3. What strengths of and areas for improvement were identified by participants regarding their experience at SEFA?

Methods

Participants

Participants attended SEFA voluntarily. Across the five cohorts of the SEFA, a total of 44 science teacher educators participated. Of those 44 individuals, 12 attended two years of SEFA. The purpose of allowing participants to attend multiple years of SEFA was to allow for continuity across cohorts, to draw upon the knowledge of previous attendees, and to strengthen ties among science teacher educators across the state. Demographic data (gender, ethnicity and position) was self-reported by participants and can be found in Table 1. Participant IDs are used throughout this paper to protect participant identities.

Table 1
SEFA Participant Demographic Data

Year	Total	Gender		Position					Ethnicity[2]		
		Female	Male	Assistant Professor Education	Associate or Professor, Education	Assistant Professor, Science Area	Associate or Professor, Science Area	Other (Adjunct, Education and Continuing Studies)	Caucasian	African American	Asian American
1	8	4	4	2	2	1	1	2	6	2	0
		(50%)	(50%)	(25%)	(25%)	(12.5%)	(12.5%)	(25%)	(75%)	(25%)	(0%)
2	5[1]	5	0	3	1	0	1	0	2	2	1
		(100%)	(100%)	(60%)	(20%)	(0%)	(20%)	(0%)	(40%)	(40%)	(20%)
3	10[1]	6	4	4	1	2	1	2	9	1	0
		(60%)	(40%)	(40%)	(10%)	(20%)	(10%)	(20%)	(90%)	(10%)	(0%)
4	15[1]	12	3	2	4	1	4	4	12	1	3
		(80%)	(20%)	(13%)	(27%)	(7%)	(27%)	(27%)	(80%)	(7%)	(20%)
5	6[1]	4	2	1	0	0	2	3	4	2	0
		(67%)	(33%)	(17%)	(0%)	(0%)	(33%)	(50%)	(67%)	(33%)	(0%)
Total	44[1]	31	13	12	8	4	9	11	33	8	4
		(70%)	(30%)	(27%)	(18%)	(9%)	(20%)	(25%)	(75%)	(18%)	(9%)

Note: [1]Participants are only included for the first year in which they participated.
[2]Participants may self identify with more than one ethnicity and percentages may add to >10.

Context

SEFA was a five-day (27 contact hours) PD experience with the primary purpose to build statewide infrastructure to support effective science teaching and learning through the format of a professional learning community. The implementation team of SEFA ranged from five to seven facilitators (depending on the year). These facilitators were experts in science education and worked collaboratively to develop the structure and content of the program. SEFA was held at a major university in Virginia in late May each year of implementation. Participants engaged in presentations, activities, and discussions to achieve the following SEFA objectives (McDonnough, Sterling, Matkins, & Frazier, 2012):

1. Collaborate to identify challenges and develop solutions in science teacher education at the licensure level and within institutions of higher education,
2. Learn about new research related to effective science teacher development and science teaching,
3. Share effective teaching strategies for how to best meet the needs of elementary and secondary science teachers at the licensure and advanced levels through collaborative grant proposals, as well as collaborative syllabi and experiences for implementation in methods courses and teacher PD seminars, and
4. Network to establish an infrastructure of support among science teacher educators across the state (Virginia Science Education Professors - VSEP) that augments and supports existing infrastructure for science teachers and coordinators in the state.

Additionally, participants submitted an initial ~1000 word “vexation and venture” text on a chosen theme important to science teacher education each year prior to SEFA.

The theme was different each year and participant texts served as the foundation for discussions throughout the week. For the five years of SEFA respectively these themes included inquiry instruction, NOS instruction, social justice, standardized testing, and online distance learning.

Each day began with an overview of the topics to be covered and then concluded with an exit slip designed to help participants identify what they learned, how they could apply their learning in their own setting. This exit slip provided formative feedback to the implementation team on a daily basis. Integrated throughout each day were opportunities for collaboration and discussion. Table 2 provides an overview of the topics and activities covered each day and their alignment with SEFA objectives. In order to foster continued contact, participants were given a means to stay in touch with one another through a group Facebook page as well as through an online storage space for sharing files. Additionally, participants were encouraged to attend other Virginia science education organizations such as the Virginia Association of Science Teachers (VAST) and the Virginia Science Education Leadership Association (VSELA).

Table 2
Overview of SEFA Activities and Relevant Objectives (in parentheses)

	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Year 1 & 2	PBL- vehicle for inquiry (2, 3)	NOS (2,3) PBL in methods courses - syllabi sharing (1, 2, 3) PBL scenario development (3) Discourse (3)	Vexation and Venture (1) Collaborative planning (4)	Grant Writing and Funding (3)	Collaborative planning (4)
Year 3	Vexation and Venture (1)	PBL- vehicle for inquiry (2, 3) PBL scenario development (3) PBL in methods courses - syllabi sharing (1, 2, 3)	NOS (2,3) NGSS (2,3) Preparing Pre-service Teachers for High-Needs Students (1, 2, 3)	Discourse (3) Grant Writing and Funding (3) Collaborative planning (4)	Collaborative planning (4)
Year 4	Vexation and Venture (1)	PBL- vehicle for inquiry (2, 3) PBL scenario development (3) PBL in methods courses - syllabi sharing (1, 2, 3)	NOS (2,3) NGSS (2,3) Discourse (3)	Preparing Pre-service Teachers for High-Needs Students (1, 2, 3) Grant Writing and Funding (3) Collaborative planning (4) Engineering Design (2)	Collaborative planning (4)
Year 5	Vexation and Venture (1)	PBL- vehicle for inquiry (2, 3) PBL scenario development (3) PBL in methods courses - syllabi sharing (1, 2, 3) Engineering Design (2)	NOS (2,3) Grant Writing and Funding (3) NGSS (2,3)	Collaborative planning (4)	Attend VISTA Elementary Science Institute (2)

Data Collection

Data consisted of pre-/post-/delayed-post surveys, follow-up interviews of a subset of participants, researcher field notes, and artifacts from SEFA. Participants completed the pre- and post-SEFA surveys on the first and last days of the PD, respectively. Interviews were conducted via phone within one month following SEFA. Delayed post-surveys and interviews were administered a full year after participation. Full-day observations were made during the fifth day of the first year and the first and second days of the second year. For years three through five, observations were made over the entire week. A panel of three experts in science education, evaluation, and measurement provided support for face and content validity of all survey questions and interview protocols. The variety of data collected allowed for triangulation, which increased the validity of the findings.

Surveys. Surveys contained 15 Likert-scale items that ranged from one (not very proficient) to five (highly proficient) and were administered pre- and post-SEFA. These items elicited participants' self-perceptions of understanding of and proficiency incorporating inquiry, PBL, and NOS instruction into their science methods courses (aligned with research question 1). Other Likert questions assessed participants' incorporation of research-based science instruction into their courses, perceived ability to seek out funding, and perceived ability to collaborate with colleagues (aligned with research question 2). The post-survey contained 5 additional Likert-scale questions and 4 open-ended questions related to participants' perceptions of the strengths and weaknesses of SEFA and the quality of SEFA relative to other PD experiences in which they have previously participated (aligned with research question 3).

Approximately one year after participation in SEFA, participants completed a delayed post-survey. In addition to the questions on the pre- and post-surveys, the delayed post-survey asked participants to indicate the extent to which they implemented what they learned in SEFA over the year. Additional open-ended questions elicited participants' estimate of how many PK-12 students, preservice and in-service teachers they impacted. Delayed post-surveys were administered only to the participants in the first four years due to the five-year timeframe of the VISTA grant. See Appendices A through C for survey questions.

Interviews. Following analysis of the pre- and post- SEFA survey, participants were selected for follow-up phone interviews. Selection criteria were based on comparing pre- and post-survey responses. In the first three years, a subset of participants were contacted who indicated small, moderate, or large Likert changes in their proficiency of the key VISTA constructs following their experience. In the fourth and fifth year, all participants were contacted for interviews (and still characterized according to their pre- to post-change). A higher percentage of participants were contacted in the fourth and fifth years because data were being gathered from all participants in these two years for additional qualitative studies. Overall, a total of 26 post- and 9 delayed post-interviews were conducted. Across all five years, this sampling provided a good window into a wide range of participant understandings and opinions. Interview questions focused on participants' perspectives on the most and least valuable aspects of SEFA, components of the SEFA they planned to implement, and suggestions for improvement. Interviews also served as a member-check of these participants' survey responses, providing information about their understandings of the SEFA constructs as well as their perceptions about perceived strengths and weaknesses of SEFA. Finally, one of the members of the implementation team who attended all five years of SEFA was interviewed to serve as a member check for the researcher's qualitative inferences about events. See Appendices D through F for interview protocols.

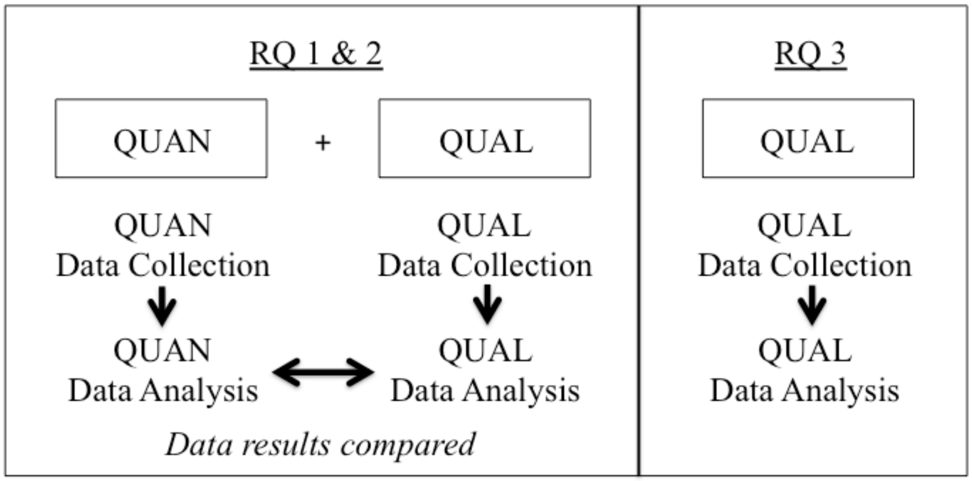
SEFA Observations. Observations were conducted of SEFA sessions the fifth day of the first year and the first and second days of the second year. The full week of SEFA was observed in the third through the fifth year. Qualitative field notes captured the format and organization of SEFA sessions and provide detailed information about the specific schedule of events on observed days. Notes contained both observations and researcher inferences.

Artifacts. Collected artifacts included the daily schedule of SEFA given to participants, artifacts produced by participants, and copies of PowerPoint presentations used by implementers.

Data Analysis

This study was analyzed using a concurrent transformative mixed methods design. This approach means that qualitative and quantitative data were collected at the same time, and that a theoretical framework was use to guide data analysis. Quantitative and qualitative data were analyzed separately, and then results of each data type were compared before making final conclusions. Comparison of data at the conclusions stage enhances overall validity and is a characteristic strength of using this type of mixed methods design (Johnson, Onwuegbuzie & Turner, 2007). The first two research questions were answered using a mix of quantitative and qualitative data, while the third research question was answered using qualitative data. See Figure 1 for an explanation of the concurrent transformative mixed methods design of this study.

Figure 1
Concurrent Transformative Mixed Methods Design



Quantitative and qualitative data were gathered across five years of SEFA. Participants' responses to the pre-, post-, and delayed post-Likert surveys were analyzed using descriptive and inferential statistics. For each participant, mean scores and standard deviations were calculated pre-, post-, and delayed post- along with an aggregated mean score for those survey items assessing inquiry, NOS, and problem-based learning. Data sets were confirmed to be normally distributed through visual inspection of Q-Q plots. For each construct, a paired sample *t* test was used to determine differences in pre- and post- as well as pre- and delayed post-Likert scores. These measures indicated whether gains were achieved and if they remained stable over time. Only a subset (79%) of participants responded to the delayed-post surveys, so independent *t* tests were run to check if there were statistically different means in pre- or post-SEFA scores for responders vs. non-responders. Using an $\alpha=0.05$, no significant differences were found between these two groups for any construct.

A Bonferoni correction was not applied to the paired sample t tests because while this correction method accounts for type I error, it magnifies type II error, and thus is not recommended universally (e.g. Rothman, 1990). There may be justification for Bonferoni corrections in some studies where avoiding type I error is most critical, for an exploratory study examining what may or may not be effective in PD the danger of type II error is just as serious as type I error. As a caveat it is important to mention that in the 24 total non-aggregated *t* tests that were performed, an average of about one of those tests could show a significant difference where none exists with an alpha level of 0.05.

Due to the longitudinal nature of the study, analytic induction, as described by Bogdan and Biklen (2007), was used to analyze open-ended survey responses and interview transcripts. Early data were examined for patterns with the goal of characterizing the experiences of participants of SEFA. From these patterns, preliminary categories were developed, and consisted of themes that were common to at least two participants. For example, the positive comments about SEFA were examined for similarities among participants leading to the creation of themes such as *positive perception of collaboration* and *the perceived ability that SEFA specifically addressed needs of science teacher educators*. Themes were revisited with each new set of data collection to check for continued viability and modified accordingly. The goal of this inductive analysis was to acquire and refine insights into participant understandings of inquiry, NOS, and PBL after their participation in SEFA, to gain descriptive information about participants' experiences with collaboration, and to understand participants' perceived strengths and weaknesses of SEFA. Qualitative field notes and artifacts provided further insight into describing the format and context of participants' experiences. Three researchers read the body of data and came to consensus on emergent themes and patterns that resulted in the final categories presented. These conversations occurred across the multiple years, and were refined over time through the process of inductive analysis.

Results

Both quantitative measures and qualitative analysis of the survey and interview responses suggested that participants perceived positive outcomes with respect to the program's key objectives. Participants recognized the value of SEFA in addressing the needs of science teacher educators and offered their detailed information about perceived strengths and weaknesses about the program. Data regarding the various Likert survey constructs are presented first (inquiry, NOS, PBL, etc.). This is followed by findings relating to broader impacts, collaboration, and finally perceived strengths and weaknesses.

Inquiry, NOS, and PBL Instruction

Overall, participants' survey responses showed they perceived themselves to be proficient or highly proficient in their knowledge of and ability to enhance preservice and in-service science teachers' inquiry, NOS, and PBL instruction following SEFA. Analysis of interview transcripts revealed that participants held a wide range of understandings about these constructs.

Inquiry instruction. While the majority of participants entered SEFA with relatively high self-perceptions about their knowledge of inquiry (M=3.7), participants expressed less confidence in their ability to enhance pre-service and in-service inquiry instruction (M=3.3 and 3.0 respectively). Following SEFA, participants reported statistically significant higher perceptions for all three of these three constructs and these gains remained significantly higher than pre-means after one year. See Table 3.

Table 3
Likert Scores Related to Inquiry Instruction

	Perceived knowledge of inquiry	Ability to enhance preservice teacher inquiry	Ability to enhance in-service teacher inquiry	Aggregated Inquiry score
	M (SD)	M (SD)	M (SD)	M (SD)
Pre (n=44, 100%)	3.7 (1.0)	3.3 (1.0)	3.0 (1.0)	3.4 (0.9)
Post (n=44, 100%)	4.2* (0.9)	4.1* (0.9)	4.0* (0.9)	4.1* (0.8)
Delayed Post (n=29, 76%)	4.3* (0.7)	4.0* (0.8)	4.0* (0.9)	4.1* (0.7)

Note. n=36 for Pre- and Post-Ability to enhance in-service teacher inquiry category (Question was not asked in first year).
* = significant difference from pre-mean ($p<.05$)

Quantitative data reflected participants' self perceptions with regard to inquiry, while qualitative interview responses yielded information about participants' actual understandings. During SEFA, inquiry was presented to participants as a process where students ask questions, collect and analyze data, and using evidence to solve problems. Participants demonstrated wide variety in their definitions of inquiry. One participant stated, "My definition of inquiry would be that there is a question that's being pursued by the students that the students are deeply engaged in that question and that they are collecting and/or using data to answer that question" (SEFA5F2, post-interview). This response indicted high alignment with the SEFA definition; however, more commonly participants gave responses that only partially overlapped with the SEFA definition. For example:

> Inquiry? Okay, well that's definitely got to be students performing scientific-based experiments in the way a scientist actually does it. So they have the materials they are manipulating, and they are essentially conducting research in a way that a scientist would do so (SEFA2F7, post-interview).

In this response, the participant restated in her own thinking all parts of the SEFA inquiry definition, but did not explicitly mention asking questions. Other showed less alignment with the definition. "It's basically just seeking information by questioning- the level of metacognition involved where students question their thinking and not accepting typical answers but to lead to a broader understanding of something" (SEFA1M4, delayed post-interview). This participant mentioned only the asking questions portion of the definition, leaving out that inquiry involves students collecting and analyzing data, and using evidence to solve problems.

Some participants also mentioned their perceptions related to learning about inquiry at SEFA:

> It allowed me to develop a common language for what inquiry means and then based on that solidification of the definition I was better able to develop inquiry-based lessons for the pre-service teachers I teach and also the in-service teachers that I work with in a summer institute and throughout the year (SEFA2F9, post-interview).

In addition to benefiting from an operationalized definition of inquiry, this participant's response speaks to the benefits of building coherent statewide infrastructure around common definitions of research-based teaching methods.

NOS instruction. Participants entered SEFA with a slightly lower NOS group mean pre-score compared to inquiry pre-scores. Perceived knowledge of NOS was higher (M=3.5) than perceived ability to enhance preservice or in-service teacher knowledge of inquiry instruction (M=3.0 and 2.9 respectively). Following SEFA all three constructs showed statistically significant gains that remained significantly different than pre-means after one year. See Table 4.

Table 4
Likert Scores Related to NOS Instruction

	Perceived knowledge of NOS M (SD)	Ability to enhance preservice teacher NOS M (SD)	Ability to enhance in-service teacher NOS M (SD)	Aggregated NOS score M (SD)
Pre (n=44, 100%)	3.5 (1.0)	3.0 (1.1)	2.9 (1.1)	3.2 (1.0)
Post (n=44, 100%)	4.2* (0.8)	4.0* (0.9)	3.9* (0.9)	4.1* (0.7)
Delayed Post (n=29, 76%)	3.9* (0.8)	3.8* (0.8)	3.8* (0.9)	3.9* (0.8)

Note. n=36 for Pre- and Post-Ability to enhance in-service teacher NOS category (Question was not asked in first year).
* = significant difference from pre-mean (p<.05)

Rich discussion occurred among participants each year trying to define NOS. SEFA emphasized three core tenets in particular. These were that science is empirical, that it can change with new evidence or reinterpretation of existing evidence and that it exists in a larger sociocultural context. It was also emphasized that NOS must be taught explicitly to students. As with inquiry, participants expressed their definition of NOS in numerous ways, the majority of which were partially aligned with the SEFA definition. One participant having all three tenets in their definition said:

> Nature of science instruction would be getting more at the idea of what do students learn about how science is done in the real world. So learning that it's a collaborative effort. It's not this thing that exists without scientists but it's a human endeavor as well. And that it's competing at some representation of what the real world is rather than some law that's been passed down from generation to generation and scientists are actually going in and creating a model of what they notice and then seeing how closely that model is to the real world. And then of course they maybe change their model as more evidence becomes available (SEFA4F12, delayed post-interview).

More commonly, participants had only one or two tenets in their definition of NOS. The following participant emphasized only the empirical aspect of science. “The nature of science instruction is using the connections of science in exploring science concepts in a manner that scientist due to discover things about our natural world (SEFA5F4, post-interview). Another participant mentioned different aspects:

> I think about the nature of science as revolving around the tenets of the nature of science such as science is based on observation – we use our five senses to help us learn more about science. With the nature of science it involves using more than one…there's not one best method, if you will, to discover and generate knowledge about science. It's tentative, it's subject to change, based on new ideas. And also one thing I like about nature of science, which is important, it does involve creativity and innovation (SEFA2F10, post-interview).

This participant mentioned the SEFA tenet that scientific knowledge is subject to change, but also mentioned other aspects beyond the three emphasized SEFA tenets including science involves creativity, that it is based on observation and inference and that there is not only one scientific method. Participants often mentioned the three tenets of the SEFA definition, but few mentioned the need to teach NOS explicitly.

PBL instruction. Participants' perceived knowledge of PBL was higher (M=3.4) than their perceived ability to enhance pre- and in-service teacher PBL instruction (M=3.1 and 2.8 respectively). Statistically significant gains were achieved following SEFA, with gains remaining significant after one year. See Table 5.

Table 5

Likert Scores Related to PBL Instruction

	Perceived knowledge of PBL	Ability to enhance preservice teacher PBL	Ability to enhance in-service teacher PBL	Aggregated PBL score
	M (SD)	M (SD)	M (SD)	M (SD)
Pre (n=44, 100%)	3.4 (0.9)	3.1 (1.1)	2.8 (1.0)	3.2 (0.9)
Post (n=44, 100%)	4.2* (0.9)	4.1* (1.0)	3.9* (0.9)	4.1* (0.8)
Delayed Post (n=29, 76%)	4.0* (0.7)	3.9* (0.8)	3.7* (0.8)	3.9* (0.7)

Note. n=36 for Pre- and Post-Ability to enhance in-service teacher PBL category (Question was not asked in first year).
* = significant difference from pre-mean ($p<.05$)

The PBL construct was presented at SEFA as students solving a problem with multiple solutions over time like a scientist in real-world context; both the context and the problem must be meaningful to students and it should incorporate inquiry instruction. Participants mentioned many of these aspects of the SEFA definition during their interviews. One participant stated, “Problem-based learning is an overarching question that is real world-based, some sort of messy problem involved, and that students are seeking to find an answer to that problem in as many ways as they can” (SEFA5F2, post-interview). This definition is partially aligned with the definition presented at SEFA, but the role of students working as scientists using inquiry is absent.

Another participant reported a definition that emphasized different aspects of PBL instruction:

> It’s made me realize what exactly it is, because I wasn’t quite, I just kind of thought of it as it being very, as almost being separate from inquiry. You used an inquiry approach where you start with a question and a problem-based approach when you start with a problem, but the two really can be intermixed a little bit more. You can do problem-based learning starting with questions, which to me is very much a hallmark of inquiry (SEFA1F2, interview, Year 1).

This participant seems to be working out the relationship between inquiry and PBL, and that PBL starts with and overarching problem. On the other hand, she did not mention anything about solving the problem with multiple solutions over time. Finally, some participants included contextualized examples in their definitions to help illustrate their meaning. For example:

> We need to build a parking garage in the middle of the city because there's not enough parking, and so we need to accommodate that,' and then taking that one simple problem and you think about all of the elements that are involved, so it's not meant to be something that's completed in one class block, but it could take days or weeks or it could be a term project, because there's so many different aspects involved in it. I really like problem-based learning, but it made me think about how it helps the students make it all relevant and how things tie in together (SEFA3F8 post-interview).

This definition is very descriptive of a specific PBL scenario but would also be partially aligned because it does not mention students acting as scientists or the necessary inquiry component.

Additional constructs. Participants responded to additional pre-, post-, and delayed post-Likert survey questions related to their perceived ability to incorporate research-based strategies into methods instruction, and ability to seek out funding opportunities (i.e. grant). Two other measures were captured at only post- and delayed post-intervals. These were the extent to which participants feel networked to other science teacher educators to engage in future collaboration, and the extent participants expect to implement what they learned in the near future. Participants' perceived ability to incorporate research-based strategies into methods instruction showed statistically significant pre- to post-gains and remained significant after on year. Perceived ability to seek out funding showed significant improvement following SEFA, but these gains were not maintained after one year. For the final two constructs- the extent to which participants felt networked with science teacher educators and the extent to which participants expected to implement what was learned, means were high following SEFA (M=4.6 for both). Results from the delayed post-survey however showed a significant reduction in both scores after one year (M=3.9 and 4.2). See Table 6.

Table 6
Likert Scores for Remaining SEFA Constructs

	Ability to incorporate research-based strategies M (SD)	Ability to seek out funding M (SD)	Extent to which you feel networked M (SD)	Expect to implement what was learned M (SD)
Pre (n=44, 100%)	3.3 (1.1)	3.1 (1.0)	NA	NA
Post (n=44, 100%)	4.0* (0.9)	4.0* (0.9)	4.6 (0.8)	4.6 (0.7)
Delayed Post (n=29, 76%)	4.2* (0.8)	3.3 (1.0)	3.9** (1.0)	4.2** (0.9)

Note. n=43 for Post-Extent to which you feel networked Box (One non-respondent)
* = significant difference from pre-mean (p<.05)
** = significant reduction from post-means (p<.05)

Collaboration and Networking

Qualitative responses yielded a descriptive picture of participant collaboration and networking. Many participants mentioned opportunities for collaboration as a primary factor in deciding to attend SEFA. One participant shared, “The main reason I joined SEFA is that I was looking to introduce myself to more of the Virginia educators in the area, the science teacher educators in the area” (SEFA2F6, delayed post-interview). In post-surveys and in interviews the majority of participants were optimistic about collaboration, and shared similar feelings about their plans to work on presentations, journal articles, and grant with colleagues they met during SEFA. For example, one participant responded, “I plan to work with other university site faculty especially during the school year to possibly write some grants or have some programs that will help preservice teachers" (SEFA5F1, post-interview). After one year, another participant recalled a particular SEFA session that she felt was helpful in building these lasting relationships:

> The vexations and ventures exercise was an excellent kick-off to the week. It allowed me to get to know each of the participants and their primary concerns, identify individuals who share concerns and interests of mine, and work with them later in the week to collaborate and form long-term professional contacts (SEFA1F4, delayed-post survey).

Delayed-post interviews painted a picture of how much and what type of collaboration had occurred over a one-year time frame. The majority of participants reported that they continued to value collaboration fostered by SEFA. Some participants reported unqualified positive experiences with continued collaboration. One participant recalling his experience at SEFA after one year said:

> While we were there we were discussing collaboration, even when we go out to eat we would sit there and talk about ways to collaborate in the future. So we talked about collaboration throughout the entire week. Many of us have already begun projects such as writing and submitting articles together and possibly visiting our respective universities to come do some training (SEFA1M4, delayed post-interview).

It was clear from for other participants however that while some degree of communication with colleagues was maintained after one year, the degree of collaboration was superficial. "I'm staying in touch with individuals who have been to SEFA. It has been basically just staying in touch" (SEFA3M3, delayed post-interview). Another participant offers some insight into the difficulties of remaining in touch with colleagues at a distance:

> At the end of the program I was hoping to stay in touch with some of the members, and I have to an extent, the people that are here at [my university]. But outside it's been challenging. I think just everybody gets busy so I haven't really participated in any of the online forums or anything, but it's been nice to see that people are still posting things. I often will at least read the headlines, if not read the whole articles, realizing that these conversations are still happening (SEFA4F12, delayed post-interview).

This response indicates a desire to remain connected to the larger SEFA community but difficulty doing so in practice. The participant mentioned that distance was a mediating role in that while she stayed in touch with other SEFA colleagues from her home institution more easily than SEFA colleagues at other institutions.

Broader Impacts

Delayed post-survey and interview responses described a wide range of products that resulted from their participation in SEFA a year after their attendance. These included presentations at VAST, journal articles, PD programs related to PBL for in-service teachers, and summer camps for students that incorporated PBL. One participant shared the following:

> I wrote an article for [my university's journal] on the VISTA experience. It is the featured article in the recently published journal. I co-authored an article on our group PBL research. I revised my course syllabi to revolve around PBL for the methods class. I presented three sessions at VAST based on my group research. My students presented a session featuring their PBL units. I implemented PBL into the Shining Stars Camp (last summer for at-risk middle schoolers)… And, much to my surprise, this past week I was named Outstanding Faculty of the Year. My work in science education was cited during the award ceremony (SEFA1F1, delayed-post survey).

Participants also mentioned incorporating aspects of what they learned into their preservice teacher science methods courses. One participant shared, "I have used the problem-based learning strategies, including the weather tamers scenario, with my preservice teachers. I have taught the nature of science and used the VISTA poster" (SEFA2F7, delayed post-survey). Participants like this one reported using a wide range of teaching methodologies they had learned while at SEFA.

Perceived Strengths and Weaknesses of SEFA

Analysis of qualitative survey and interview data suggested participants valued many aspects of the SEFA experience and that it was highly relevant to their work in the field of science education. For example, “I have felt more confident in my abilities as a science teacher educator. I always knew the science, but felt lacking on the education component. I now consider myself a science teacher educator - not a scientist in education” (SEFA1F2, delayed-post survey). Another participant shared, “It was very informative for me. I totally enjoyed the entire presentation and I look forward to doing some things in the future with the other instructors and VISTA” (SEFA4F2, post-interview). Most participants had very positive feelings about their experience overall with targeted suggestions for improvement. This section presents specific themes that emerged about what participants most valued and their suggestions for improvement.

Grant writing. Overall, participants found the session on grant writing to be helpful. One participant noted “the grant writing information was very helpful for me as a new faculty member. There were some very helpful tips on writing the grant itself and where to start looking for grants that best fit my abilities at this point in my career” (SEFA3F5, post-survey). Additionally, some participants mentioned that they had plans to work on future grants with other SEFA attendees. “I plan to work with those folks to write grants and collaboratively work towards moving science education forward in VA” (SEFA4M3, post-survey). Finally, some participants indicated their experience at SEFA helped them successfully obtain grants and other sources of funding. The following participant stated:

> I have used my participation in SEFA as support for travel grants and grant proposals. The travel grant was to supply funds for a working trip to Malaysia to

> provide capacity-building workshops for environmental educators, the grant is a proposal to develop STEM education (especially the engineering aspect) in local schools (SEFA1M2, delayed post-survey).

Participants found the combination of the grant session along with learning new SEFA constructs to be a helpful foundation for writing and securing grants that aligned with the content presented at SEFA.

Vexations and ventures. A rich view emerged of participant perceptions surrounding the vexation and venture paper and discussion session. Participants had positive opinions about the session overall. For example, "I loved the 'ventures and vexations' [session] as a reflective tool, and plan to use it with my methods students (SEFA1F4, post-survey). Most participants who mentioned the vexation and ventures had generally positive things to say, but noted specific ways this aspect of SEFA could be improved. One participant suggested moving the session to a different time.

> I think scheduling the V & V day for later in the week may be more beneficial... The participants didn't know one another, and we were expected to contribute to discussions (offering ideas) to people with whom we knew nothing about. I found it to be an awkward experience (SEFA3F8, post survey).

This participant expressed a desire to form connections and establish a rapport with other participants prior to sharing her vexation and venture with others. Other participants noted that the session was beneficial to a degree, but that having a set theme caused a degree of overlap in what was being said during the discussion. "I liked the vexation and venture, however by the end of the day it felt like we were repeating ourselves a bit" (SEFA5F4, post-survey). While collaborating around shared issues was seen as valuable, in the words of this participant, the session suffered due to a lack of variety in the discussion.

Learning new definitions. Participants expressed positive perceptions about learning new definitions at SEFA including inquiry, PBL, NOS, engineering design, the Next Generation Science Standards (NGSS), and discourse as the way in which these constructs were learned at SEFA. The following few excerpts from participant survey responses are meant to show a sample of these perceptions. After the positive learning outcomes that occurred at SEFA, this participant noted a particular highlight. "The engineering design activity was my favorite because it gave the team that I was working with an opportunity to design and develop an idea, based on need" (SEFA4F4, post-survey). Another participant highlighted her experience with the NOS session. "The most valuable strategy that I learned this week was about being explicit when teaching NOS" (SEFA4F9, post-survey). Finally, one participant mentioned the strategies that she perceived to be helpful to her future science methods courses. "The strategies that were important enough that I plan to start incorporating into my course in the fall are: Discourse, PBL, and using NGSS in conjunction with [Virginia state standards]" (SEFA3F1, post-survey).

Opportunities to collaborate. Participants strongly valued opportunities to collaborate with other science teacher educators from across the state. One participant reported, "I got to reconnect with science teacher educators and leaders and to meet and get to know many new people in this area, expanding my professional network" (SEFA5F2, post-survey). Another participant who expressed similar positive sentiments added, "I would include more time for faculty to collaborate" (SEFA5F1, post-survey). The two most representative themes among participants were that they valued collaboration and wanted more of it.

Pacing and timing. Across all years, participants mentioned that the fast-paced nature of the SEFA schedule and the long hours were taxing. These comments were also heard during qualitative observations between various SEFA sessions. One participant mentioned the need to "Slow down and give participants time to process and absorb/ think of ways to integrate these ideas into their work" (SEFA4F6, post-survey). Other participants mentioned that the days or week could be shortened:

> The sessions were too long and intense without enough breaks. It's unhealthy for me to sit still for that long… Personally, if you want this intensive of an experience, then three days is as long as I care to try to remain focused (SEFA1M3, post-survey).

Participants also expressed frustration with the environment, which due to laboratory activities did not allow food and drink. "Meet in a room that isn't a lab where coffee is allowed. Seems superficial but was a common complaint" (SEFA3F1, post-survey). Importantly, while participants expressed negative perceptions about pacing, timing, and restrictions related to food and drink, comments about the value and enjoyment of the content of the sessions were positive.

Returning participants. When asked about attending SEFA in the future, one returning participant suggested it would be better to have a different experience for returning participants versus new participants:

> Rather than having those folks do something that they did pretty much the previous year, either have it at a tier level where they're doing something totally different such as spending more time developing a grant or spending more time developing some type of research agenda and have them help facilitate some of the experiments with the new folks (SEFA1M4, delayed-post interview).

To some degree the implementation team responded to these requests while keeping session topics and goals of SEFA uniform from year to year. For example, one participant noted:

> I think that it was a good idea to include past participants on the agenda to share-out. Since the atmosphere was very relaxed and low key, I did not mind not [being] informed of my minor role in advance (SEFA2F7, post-survey, 2nd year of participation).

Along similar lines, some participants expressed curiosity about how others implemented the strategies and content covered at SEFA and that they would like for this sharing to be part of a follow-up experience. "I would like to attend a follow up to find out what progress had occurred with others I attended with earlier" (SEFA1M1, delayed post-survey). Overall participants were interested in returning to a SEFA follow-up baring any schedule conflicts and had specific suggestions about how to manage the roles of new and returning members.

Discussion

SEFA provided participants with an opportunity to learn about effective instructional approaches, provided opportunities for collaboration with other science education faculty across the state, and helped these faculty members develop various skills related to succeeding in their careers. SEFA demonstrated key features deemed necessary for successful PD, including a focus on content (e.g. inquiry, PBL, NOS, grant writing, and others) and active learning of these constructs during SEFA sessions. Further, SEFA gave participants plenty of time to collaborate both formally and informally, with some sessions having this as a primary aim (e.g. syllabi sharing and vexation and ventures). There is also clear evidence of coherence in the alignment of SEFA objectives with the larger VISTA initiative at all levels of science education across Virginia. Most importantly, SEFA was context-specific to the needs of science teacher educators providing them with ways to learn about new content that could be implemented in science methods courses and a way for faculty to cross university lines to collaborate as part of a larger statewide science teacher educator community.

Participants' understandings of key SEFA constructs (inquiry, NOS, and PBL) evident through surveys and interviews most often showed partial alignment with SEFA definitions, and sometimes showed full alignment. Participants' confidence in their understanding of key SEFA constructs showed significant pre- to post-gains that were still significant after one year. There were a few notable exceptions. Participants' confidence at securing grant funding was no longer significant after one year indicating that perhaps there was mixed success in applying to and/or receiving grants. One explanation could be that once participants started grant writing tasks after SEFA they had less confidence in their abilities than immediately following the session. Or perhaps sufficient time passed before participants began to write grants that the session was no longer helpful. Boyer and Cockriel (1997) determined that while training in grant writing is important to future success at securing grants, non-tenured faculty require more time and support than tenured faculty for all aspects of the grant writing process. The level of support provided at SEFA was possibly too limited to be of use for faculty members new to the grant writing process.

Although post-SEFA means were high for the categories of feeling networked to other science and the degree with which participants expect to implement what was learned, scores after one year were significantly reduced. The drop in mean scores for feeling networked is explainable by the barriers science teacher educators face to collaboration being relatively isolated in their institutions (Johnston & Settlage, 2008). SEFA did much to help faculty build professional relationships, such as providing time to collaborate on projects, setting up a Facebook page and maintaining an online file-sharing site, but data suggest any PD initiative for science teacher educators must to do more to maintain a community over time. Strengthening relationships could involve working more closely to align with goals of other state science organizations or to spread out contact hours to have more frequent face-to-face meetings over a given year. Wenger (1998) suggests relationships within a community may be strengthened by having shared goals and working toward a joint enterprise. For future science teacher educator PD, it may be necessary to have a strong focus for the group following in-person meeting times to better maintain group cohesiveness. Also, maintaining a robust online community seems critical for maintaining relationships were face-to-face time is limited. Overall, SEFA participants overwhelmingly valued chances to collaborate with colleagues and reported this was a major factor in their decision to attend.

The drop in mean scores after one year for the degree to which participants expect to implement what was learned at SEFA is harder to explain, as surveys and interviews elicited numerous examples from participants that they had in fact used what they learned from SEFA in a variety of ways. Perhaps after one year, a subset of participants decided to adopt different approaches, or perhaps the picture is more complex with more data needed broken down specifically by which approaches participants continued to expect to implement and which they didn't.

Finally, participants' comments about areas of strengths and weakness for the format and content of SEFA provided valuable suggestions for modifications that could be used in PD initiatives. SEFA was highly responsive to the needs of science teacher educators. Lessons learned from SEFA have the potential to transform the practice of science teacher educator PD, and SEFA should be considered as a possible model for PD in other states or regions.

The purpose of this study was to explore a range of approaches to PD and thus for inferential statistical analysis, type 1 and type 2 error were both potential problems. Results should be qualified in that all *t* tests were interpreted with an alpha level of 0.05, with no Bonferoni correction applied. Also, results from this study are specific to the 44 science teacher educators who took part in SEFA and results are not necessarily generalizable to other contexts. Within the state of Virginia, 36 colleges or universities have approved teacher educator programs (Virginia Department of Education, 2012) and an internet search of these institutions revealed a total of 42 assistant, associate, or full professors in education departments are employed as science teacher educators. Numbers of science teacher educators within STEM departments generally were not available. Since a total of 20 assistant, associate, and full professors from education departments took part in SEFA across the five years of implementation, this sample represents 48% of the statewide population. So, although SEFA attendees were a sample of convenience, these numbers represent a sizable fraction of science teacher educators in Virginia.

This study has indicated a variety of effective approaches that may be used in future science teacher educator PD programs. Responding to the professional needs of science teacher educators with tailored PD not only positively impacts individual faculty members, but also the large number of preservice and in-service teachers with whom they will work over their careers.

This research was supported by funding from the U.S. Department of Education Investing in Innovation (i3) grant program. However, the results presented here do not necessarily represent the policy of the U.S. Department of Education, and you should not assume endorsement by the Federal government.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, *22*, 665-701.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, *13*, 1-12.

Bell, R., & Maeng, J. (2012). *Statewide PD to support reforms-based science instruction: Results from the 1st year of implementation*. A paper for the Annual meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

Birman, B. F., Desimone, L., Porter, A. C., & Garet, M. S. (2000). Designing PD that works. *Educational Leadership*, *57*, 28-33.

Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theories and methods (5th Ed).* Boston, Massachusetts: Pearson Education, Inc.

Bohen, S. J., & Stiles, J. (1998). Experimenting with models of faculty collaboration: Factors that promote their success. *New Directions for Institutional Research*, *25*, 39-55.

Boyer, P., & Cockriel, I. (1997). Factors influencing grant writing: Perceptions of tenured and nontenured faculty. *SRA Journal*, *29*, 61-68.

Caffarella, R. S., & Zinn, L. F. (1999). PD for faculty: A conceptual framework of barriers and supports. *Innovative Higher Education*, *23*, 241-254.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education*, *24*, 497-526.

Cohen, D., Hill, H., & Kennedy, M. (2002). The Benefit to Professional Development. *American Educator*, *26*, 22-25.

Desimone, L. M. (2009). Improving impact studies of teachers' PD: Toward better conceptualizations and measures. *Educational Researcher*, *38*, 181-199.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S. & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*, 81-112.

Duit, R., & Treagust, D.F. (1998). Learning in science: From behaviorism towards social constructivism and beyond. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 3–26). Boston: Kluwer.

Eleser, C. B., & Chauvin, S. W. (1998). Professional development how to's: Strategies for surveying faculty preferences. *Innovative Higher Education*, *22*, 181-201.

Endo, J. J., & Harpel, R. L. (1982). The effect of student-faculty interaction on students' educational outcomes. *Research in Higher Education*, *16*, 115-138.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*, 915–945.

Harwood, W. S. (2004). Science Education Reform: Factors Affecting Science and Science Education Faculty Collaborations. *Research In Science Education: Reform In Undergraduate Science Teaching For The 21st Century.* Greenwich, CT: Information Age Publishing.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, *79*, 33-41.

Huston, T., & Weaver, C. L. (2008). Peer coaching: PD for experienced faculty. *Innovative Higher Education*, *33*, 5-20.

Jablon, P. C. (2002). The status of science education doctoral programs in the United States: The need for core knowledge and skills. *Electronic Journal of Science Education*, *7*(1).

Jacobs, J. A., & Winslow, S. E. (2004). Overworked faculty: Job stresses and family demands. *The Annals of the American Academy of Political and Social Science*, 596, 104-129.

Johnson, C. C., Kahle, J. B., & Fargo, J. D. (2007). A study of the effect of sustained, whole-school PD on student achievement in science. *Journal of Research in Science Teaching*, *44*, 775-786.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*, 112-133.

Johnston, A., & Settlage, J. (2008). Framing the PD of members of the science teacher education community. *Journal of Science Teacher Education*, *19*, 513-521.

Komarraju, M., Musulkin, S., & Bhattacharya, G. (2010). Role of student–faculty interactions in developing college students' academic self-concept, motivation, and achievement. *Journal of College Student Development*, *51*, 332-342.

Lederman, N. G., Abd‐El‐Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*, 497-521.

Lederman, N. G., Gess‐Newsome, J., & Latz, M. S. (1994). The nature and development of preservice science teachers' conceptions of subject matter and pedagogy. *Journal of Research in Science Teaching*, *31*, 129-146.

McDonnough, J. T., Sterling, D. R., Matkins, J. J., & Frazier, W. M. (2012). *Virginia science education at the crossroads: Connecting science education faculty to a professional community.* A paper for the Annual meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

Mitchell, C., & Sackney, L. (2011). *Profound improvement: Building capacity for a learning community*. Taylor & Francis.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, *44*, 921-958.

Rosenthal, G. T., Folse, E. J., Alleman, N. W., Boudreaux, D., Soper, B., & Von Bergen, C. (2000). The one to one survey: Traditional versus non-traditional student satisfaction with professors during one to one contacts. *Caring*, *37*, 1-46.

Rothman, K. J. (1990). No adjustments are needed for multiple comparisons. *Epidemiology*, *1*, 43-46.

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories*. London, England: Society for Research into Higher Education.

Sterling, D. R., & Frazier, W. M. (2010). Maximizing uncertified teachers' potential. *Principal Leadership*, *10*, 48-52.

Sterling, D. R., Matkins, J. J., Frazier, W. M., & Logerwell, M. G. (2007). Science camp as a transformative experience for students, parents, and teachers in the urban setting. *School Science and Mathematics*, *107*, 134-147.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*, 221-258.

Sunal, D. W., Hodges, J., Sunal, C. S., Whitaker, K. W., Freeman, L. M., Edwards, L., Johnston, R. & Odell, M. (2001). Teaching science in higher education: Faculty PD and barriers to change. *School Science and Mathematics*, *101*, 246-257.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). Teacher professional learning and development: Best evidence synthesis iteration (BES). Wellington New Zealand: New Zealand Ministry of Education.

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education*, *24*, 80-91.

Virginia Department of Education. (2012). Retrieved from http://www.doe.virginia.gov/teaching/educator_preparation/college_programs/colleges.shtml on May 10, 2016.

Vygotsky, L. S. (1978) *Mind in society: The development of higher mental processes*, ed. and trans. M. Cole, V. John-Steiner, S. Scribner & E. Souberman. Harvard University Press (original work published 1930–1935).

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*, 1-8.

Young, R. E. (1987). Faculty development and the concept of "profession." *Academe*, *73*, 12-14.

Appendix A

VISTA Pre-SEFA Survey Questions

1) Please rate your knowledge of/ability to perform the following activities in your role as a science teacher educator:

a) Knowledge of inquiry instruction.

b) Ability to enhance preservice teachers' inquiry instruction through science methods course instruction.

c) Knowledge of nature of science instruction.

d) Ability to enhance in-service teachers' inquiry instruction through PD.

e) Ability to enhance preservice teachers' nature of science instruction through science methods course instruction.

f) Ability to enhance in-service teachers' nature of science instruction through PD.

g) Knowledge of problem-based learning instruction.

h) Ability to enhance preservice teachers' problem-based learning instruction through science methods course instruction.

i) Ability to enhance in-service teachers' problem-based learning instruction through PD.

j) Ability to incorporate research-based strategies into science methods instruction.

k) Ability to seek out funding opportunities (i.e. grants).

l) Ability to systematically reflect on professional practice and work collaboratively toward solutions.

m) Collaborate with other science teacher educators at the local level.

n) Collaborate with other science teacher educators at the state level.

o) Collaborate with other science teacher educators at the national level.

2) On average, how many state-level science/science education conferences do you attend in a given year?

3) On average, how many national-level science/science education conferences do you attend in a given year?

4) How many state-level science/science education conferences are you planning to attend in the upcoming year?

5) How many national-level science/science education conferences are you planning to attend in the upcoming year?

6) On average, at how many state-level science/science education conferences do you present in a given year?

7) On average, at how many national-level science/science education conferences do you present in a given year?

8) At how many state-level science/science education conferences are you planning to present in the upcoming year?

9) At how many national-level science/science education conferences are you planning to present in the upcoming year?

10) What is your primary rationale for attending conferences? Check all that apply: (Learn about new research, Learn about new instructional strategies, Present research, Share effective instructional strategies, Networking)

Appendix B

Additional Post-SEFA Survey Questions

1) As a result of your participation in VISTA SEFA, to what extent do you:

a) Expect to implement what you learned at SEFA in the near future?

b) Feel networked with other science teacher educators in the state to engage in future collaboration?

2) Rate the effectiveness of the following components of VISTA SEFA:

a) Opportunities to share problems of practice and work toward solutions

b) Group discussion of stated problems and solutions

c) Your colleagues' responses to the problems and solutions you shared

3) What previous PD experiences (if any) have you participated in that address the topics covered in VISTA SEFA? If you have participated in such PD experiences, how does VISTA SEFA compare to those previous experiences?

4) What are the most important content and strategies that you have learned through this PD experience? (Please describe as many as apply).

5) How will you (or have you) use(d) the content, materials, and/or strategies that you learned in VISTA SEFA? (Please describe as many as apply).

6) What suggestions do you have for the instructors as they plan for future delivery of VISTA SEFA?

7) Please share any other information you think we should know about your participation in VISTA.

Appendix C

Additional Delayed Post-SEFA Survey Questions

1) To what extent did/do you:

a) Implement what you learned via your participation in the components of VISTA SEFA?

b) Feel networked to engage in future collaboration with other science teacher educators in the state as a result of participating in SEFA?

2) VISTA SEFA is composed of five days PD, an emergent Facebook page, Dropbox resources, and attendance at the VSELA conference. Which components of SEFA did/do you find to be most valuable? Why?

3) Describe the relationship between VISTA SEFA and your ability to perform your duties as a science teacher educator. In what ways did attending the VISTA SEFA facilitate your role as science teacher educator? If attending the VISTA SEFA did not facilitate your role as science teacher educator, describe why not.

4) In the past year, how do/have you use(d) the content, materials, and/or strategies that you learned in the VISTA SEFA? (Please describe as many as apply).

5) Describe any products (such as presentation proposals, publications, grant proposals, syllabi, PD seminars, etc.) you produced as a result of the VISTA SEFA that impact preservice teachers, in-service teachers, and/or PK-12 students.

6) Estimate the number within each population directly impacted by these collaborative products:

a) Preservice teachers

b) In-service teachers

c) Pre-K-12 students

7) Estimate the number of students within each population indirectly impacted by these collaborative products:

a) Preservice teachers

b) In-service teachers

c) Pre-K-12 students

8) If VISTA were to offer a follow-up to the VISTA SEFA, would you attend? Why or why not? What format would you suggest for a follow-up? What topics would you like to see addressed in a follow-up?

Appendix D

Post-SEFA Interview Protocol

This interview is designed to follow up on your responses from the VISTA College Science teacher educator Academy survey. It will be tape-recorded for transcription, then blinded.

1) What are your definitions of the following types of instruction:

Inquiry instruction

Nature of science instruction

Problem-based learning

2) How did your participation in VISTA affect your thinking about these instructional approaches?

3) Which components of the VISTA College Science teacher educator Academy (CSEA) did you find to be most valuable? Why?

4) How did you find the process of learning you engaged in at the VISTA Academy?

5) Which components of the VISTA Academy do you plan to implement in the coming year? In what ways? (Give concrete examples). *Let interviewee respond to the above general question, then follow-up with prompts to explore his/her plans regarding the following CSEA components:*

Inquiry instruction support

Nature of science instruction support

Problem-based learning instruction support

Systematic reflection on professional practice with peers

6) You mention ____ and ____ as suggestions for improvement (question 4 on the short-answer part of the post-Academy survey). Please elaborate on these suggestions.

7) How will your VISTA Academy participation influence your collaboration strategies going forward?

8) How, if at all, has VISTA supplemented the collaborative activities already offered through VAST and VSELA?

9) Describe any other VISTA-related products and/or projects that you've recently begun, or plan to implement in the near future.

10) Is there anything else we should know about your participation in VISTA?

Appendix E

Delayed Post-SEFA Interview Protocol

This interview is designed to follow up on your responses from the VISTA College Science teacher educator Academy delayed post-survey. It will be tape-recorded for transcription, then blinded.

1) What are your definitions of the following types of instruction:

a. Inquiry instruction
b. Nature of science instruction
c. Problem-based learning

2) How did your participation in VISTA affect your thinking about these instructional approaches?

3) Which components of the VISTA Science Education Faculty Academy did you find to be most valuable? Why?

4) Describe any components of the VISTA Science Education Faculty Academy that you did not find valuable. Why?

5) Which components of the VISTA SEFA Academy have you implemented this year? In what ways? (give concrete examples) *Let interviewee respond to the above general question, then follow-up with prompts to explore his/her plans regarding the following CSEA components:*

a. inquiry instruction support

b. nature of science instruction support

c. problem-based learning instruction support

d. systematic reflection on professional practice with peers

6) What, if any, is the relationship between VISTA and your practice as a Science teacher educator? Probe: In what ways has it been effective? If not, why do you think so?

7) How would you characterize your interactions with other science teacher educators from the Academy since the end of the VISTA SEFA?

Probe: To what extent have you continued to interact with other VISTA Science teacher educators? In what ways has VISTA facilitated this?

8) How will your VISTA SEFA Academy participation influence your collaboration strategies going forward?

9) How, if at all, has VISTA supplemented the collaborative activities already offered through VAST and VSELA?

10) Describe any other VISTA-related products and/or projects that you've recently begun, or plan to implement in the near future.

11) If VISTA were to offer a follow-up to the VISTA Science teacher educator Faculty Academy, would you attend? Why or why not? What format would you suggest for a follow-up? What topics would you like to see addressed in a follow-up?

12) Is there anything else we should know about your participation in VISTA?

Appendix F

SEFA Implementer Interview Protocol

This interview is designed to explicate your experience instructing at SEFA. It will be tape-recorded for transcription, then blinded.

1) What role did you play in VISTA SEFA? What portion of the agenda did you address?

2) From your perspective describe the effectiveness of your portion of instruction during SEFA.

3) Did you feel you accomplished the objectives of VISTA SEFA associated with your part of the program?

4) What went well? What didn't go as planned?

5) Describe faculty responses to your section of SEFA? Probe: Were they engaged? Did they complete assigned tasks? Can you give any evidence of learning or that the faculty were committed to the concepts or activities delivered?

6) What are your definitions of the following types of instruction:

a) Inquiry Instruction

b) Nature of science instruction

c) Problem-based learning

7) Describe your experiences implementing instruction related to the following during VISTA SEFA.

a) Inquiry instruction

b) Nature of science instruction

c) Problem-based learning instruction

d) Vexations and Ventures

e) Grant writing and professional collaboration

e) Discourse

f) NGSS

8) VISTA PD employs a "learn, try, implement" model. Explain how you perceived this model as integrated into SEFA? (Do you believe its implementation as planned was effective? Why or why not?)

9) What recommendations do you have to improve SEFA in the future?

Probe: For questions 3-5, 7, and 8, probe for comparison with previous years. (Ask how this year compared to previous years).

CHAPTER FOUR

STUDY TWO

Exploring Science Teacher Educator Perceptions about Standardized Testing

Tyler L. St. Clair, Jennifer L. Maeng, Randy L. Bell & Lindsay B. Wheeler

Abstract

This investigation explored 16 science teacher educators' perceptions about the issue of standardized testing prior to and following a week-long PD experience. All participants taught preservice teachers preparing to enter K-12 STEM classrooms; nine participants came from education departments and seven were from STEM departments at their respective institutions. Prior to the PD, each participant wrote a narrative describing an issue they encounter related to standardized testing and proposed a solution to that issue. During the PD, participants engaged in small-group discussions about their narratives in order to better understand one another's points of view about issues surrounding standardized testing and to explore possible solutions.

Data consisted of participants' narrative texts, follow-up phone interviews, field notes and artifacts from observations of the PD. Constant comparative analysis was employed to find emergent patterns in the data. Results indicated that participants were knowledgeable about the problems surrounding standardized testing and had a variety of ideas about possible solutions to those problems. Faculty members from STEM departments were more likely to report problems related to student motivation toward the sciences, while faculty from education departments more often discussed the loss of instructional time due to testing and proposed ventures that involved equipping teachers

with effective strategies. Following the PD, participants reported a high degree of consensus around the issues. There was also a marked change in participants' proposed solutions to include a greater perception of agency in effecting policy change both at the state and national level.

Introduction

The Science Education Faculty Academy (SEFA) was a professional development (PD) experience that allowed science teacher educators a chance to explore new research and share effective teaching strategies in science education (McDonnough, Sterling, Matkins, & Frazier, 2012). A portion of SEFA featured a session where participants presented a personal issue and then gathered feedback from colleagues to refine their thinking about possible ways to address this issue. This "vexation and venture" model is currently the only PD model for science teacher educators presented in the literature.

Vexations and Ventures

The vexations and ventures model was developed for use at the annual *Science Education at a Crossroads* conference (Johnston & Settlage, 2008; Settlage & Johnston, 2014), however further research is needed to evaluate this model as a form of PD. Prior to attending SEFA, participants were asked to outline an issue or problem and to propose a solution or way forward to address that issue or problem. Participants submitted their ideas in the form of a vexation and venture text. These texts also served as a basis for structured discussions during SEFA. In these discussions, participants made a short presentation of their vexation and venture to their peers, followed by a round of short clarification questions from the group. Next, the group discussed the issue without the original author's input, and finally the author rejoined the discussion to respond to issues the group raised. These structured discussions were designed to help science teacher educators gain new insights from their peers by creating a professional learning community in which new knowledge is created through group collaboration. The topic of the vexations and ventures changed with each year of implementation of SEFA. The focus of the vexation and venture issue in 2014, the year in which this study was conducted, was high-stakes standardized testing in the U.S.

High-Stakes Standardized Testing

Standardized testing has a long history in the United States. The rationale for the implementation of standardized assessments in the early 20th century came from educators concerned that grading practices in schools were too subjective (Giordano, 2005). In 1958, Congress passed into law the National Defense Education Act. The purpose of this Act was to provide increased funding to STEM subjects so the U.S. could compete internationally. This act also provided support for the implementation of standardized testing on a large scale (Heubert & Hauser, 1999). In 1965, the Elementary and Secondary Education Act provided federal funding to the U.S. education system in a variety of ways to make education more equitable with a secondary effect of further institutionalizing evaluation and accountability (Thomas & Brady, 2005). This act has since been continuously reauthorized by Congress, with the 2001 amended version termed No Child Left Behind. No Child Left Behind introduced a large number of new accountability and testing provisions for states (Bush, 2001). Since its release, much controversy has been raised about its negative effect on curricula, a focus on measuring only superficial learning, and its inappropriate assessment of limited English proficiency students and students with disabilities (Darling-Hammond, 2007). This expanded use of standardized testing raised the stakes of tests by linking test score results to student advancement, teacher evaluation, and school viability (McGuinn, 2011). With bipartisan support, the No Child Left Behind Act was replaced with the Every Student Succeeds Act (Obama, 2015). This act continued the widespread practice of standardized testing but returned some accountability to states in an effort to correct negative consequences of the high states federal pressures created by No Child Left Behind.

In addition to the increased domestic focus on testing, international assessments delivered by such as the Program for International Student Assessment and the Trends in Mathematics and Science Study rank U.S. student performance in science against students from other countries. The lower performance than desired on these standardized tests has received significant media attention and influenced U.S. educational policy decisions (Bybee, 2009; Riley & Torrance, 2003).

The development of the Next Generation Science Standards (NGSS) represents the most recent shift in the direction of school science assessment. The NGSS framework emphasizes coherence of curriculum, instruction, and assessment across all grade levels and stresses the need to move away from traditional multiple-choice formats to other styles of assessment such as performance and authentic assessment that assess a broader range of science skills such as the formulation of scientific explanations and engaging in scientific argumentation (NGSS Lead States, 2013). The NGSS assessment practices however have not yet been finalized.

Many teachers perceive standardized tests as a barrier to good teaching and feel frustrated and powerless in relation to high-level educational policy decisions that impact their classrooms (e.g. Barksdale-Ladd & Thomas, 2000). Teachers report the pressure to perform well on the tests comes from many directions, including their school administrators, peers, and the media (Barksdale-Ladd & Thomas, 2000). This pressure leads teachers to use instructional and assessment strategies that mirror the format of state assessments, even though they recognize these strategies do not reflect high quality science instruction (Abrams, Pedulla & Madaus, 2003; Wideen, O'Shea, Pye & Ivany, 1997). In other words, high-stakes standardized tests have a strong impact on curriculum and instruction.

High-stakes standardized testing is a charged issue for students, parents, and school administrators, all of whom are stakeholders affected by the current educational climate. Administrators are under pressure for their schools to show rising test scores and are often forced to cut back or eliminate school programs in the arts, recess, or other elective courses to achieve their goal (Kohn, 2001). For students, test scores are often used to determine one's ability to advance to the next grade, however, these tests are often biased against English Language Learners (Menken, 2008) and minority students (Walpole, et al., 2005). Finally, parents have reported that they see little value in current standardized tests and that they cause undo mental stress for children (Barksdale-Ladd & Thomas, 2000).

While previous studies have focused on the perceptions of the groups most directly impacted by standardized testing, as indicated above, science teacher educator perceptions of the various issues surrounding standardized testing have not yet been systematically studied. In this investigation, the term *science teacher educator* refers to any professor in higher education that helps to prepare preservice teachers to teach science at the K-12 level. These individuals are most often found in either colleges of education or colleges of the various STEM disciplines within their universities. They may teach a variety of courses in both the fields of science and education. It is important to better understand science teacher educator perceptions of standardized testing as they are responsible for preparing future teachers to work in school environments where standardized testing is currently the norm. Additionally, science teacher educators are both well informed and well positioned to leverage their opinions to better communicate these issues to the public and shape the future of standardized testing policy.

Theoretical Framework

Social constructivism frames learning as a phenomenon that is first socially co-constructed and then internalized as individual learning (Duit & Treagust, 1998; Hodson & Hodson, 1998; Vygotsky, 1978). In essence, this lens acknowledges and highlights that learning is a socially and culturally mediated process (Gredler, 1997), and it is an ideal choice for a PD experience that uses a professional learning community format. Professional learning communities function as a group of individuals who are engaged in collaborative reflective inquiry, and who possess a shared vision and set of values (Stoll, et al., 2006). Social constructivism also acknowledges that though learning first occurs in the social realm, learning ultimately takes place within the individual via the process of internalization (Vygotsky, 1978); Thus, research that uses a social constructivist framework is guided by research questions, data sources, and data analysis designed to explore individual cognition.

Purpose

One purpose of this investigation was to better understand the role of the vexation and venture model in professional development and its ability to facilitate collaborative discussions. Also important was to better understand science teacher educators' perceptions about the issue of standardized testing. The research questions guiding this investigation were:

1. What patterns exist among the vexations and ventures of science teacher educators related to standardized testing? Specifically, who or what was perceived as the cause of the vexation and who or what was affected? Who or what is perceived as being responsible for the solution?
2. What differences exist, if any, in the vexations and ventures of faculty from education departments vs. faculty from STEM departments?
3. In what ways did SEFA vexation and venture sessions influence participants' thinking about their vexations and ventures related to standardized testing?

Methods

Participants

Participants attending SEFA selected for this study were a convenience sample. A total of 16 participants attended SEFA in 2014, the year this study was conducted. Participants included 3 males and 13 females from 10 different colleges/universities in Virginia. Of the 16 participants, 9 were faculty in education colleges or departments while 7 came from science colleges or departments at their respective institutions. All but one of the participants were first time attendees of SEFA. Codes are used in lieu of names to protect the participants' identities. These codes indicate the participants' gender and position in their university. See Table 1.

Table 1
Participant Demographic Data (n=16)

Gender		Position		Ethnicity[1]		
Male	Female	Education Department	STEM Department	Caucasian	African American	Asian American
3	13	9	7	13	1	3

Note: [1] Participants may self-identify with more than one ethnicity and percentages may add to >100%.

Context

The fourth year of SEFA was held in late May of 2014 at a major university in the state of Virginia. The five-day (37 contact hours) program was implemented by a team of six facilitators. The purpose of SEFA was to provide opportunities for participants to learn about new research relating to effective science teacher development and science teaching, to provide a venue for the sharing of syllabi and effective teaching strategies, and to help participants collaborate and build professional networks across institutional lines. Additionally, SEFA was designed to foster collaboration among science teacher educators who often find themselves as the sole science education faculty member at their institution (Johnston & Settlage, 2008). Thus, participants explored an issue of importance to the science education community through a vexation and venture text (Johnston & Settlage, 2008). Participants were asked to submit their vexation and venture texts of approximately 1,000 words related to standardized testing prior to attending the PD.

On the first day, participants were given a booklet containing all participants' texts and then split into two groups of roughly equal size. A member of the implementation team acted as a facilitator for each group. Each group engaged in discussions surrounding their texts according to the vexation and venture model originally developed by Johnston and Settlege (2008) for use at the *Science Education at the Crossroads* conference. The framework for these discussions was as follows:

1. A participant presents his or her vexation and venture to the group (10 minutes)
2. The participant responds to brief clarification questions (5 minutes)
3. The participant remains silent while all other members of the group may speak about the issue (15 minutes)
4. The participant rejoins the group discussion and may respond, ask questions, or offer further information (5 minutes)

All participants shared their vexations and ventures during the first day of SEFA according to this format. There were short breaks between each presentation. The issue of standardized testing was revisited later in the week when participants were asked to create a poster summarizing the main points raised in their vexation and venture discussions. The coherent focus on standardized testing throughout the week provided an excellent opportunity to explore science teacher educators' thinking around this issue.

Data Collection

In addition to the vexation and venture texts, other data sources consisted of qualitative observations of all SEFA sessions, follow-up semi-structured interviews with 12 participants (75%), as well as other artifacts.

Observations. Qualitative observations of SEFA sessions included both type written observations and personal inferences of sessions over all five days of SEFA in order to capture any and all relevant discussions relating to standardized testing.

Interviews. The purpose of the semi-structured interviews was to clarify and elaborate upon participants' vexation and venture document as well as to better understand the role of their SEFA experience in influencing their thinking about the issues they raised. Interviews were conducted over the phone, recorded, and transcribed. Questions about participants' vexation and ventures were appended to an already existing protocol designed to assess other aspects of SEFA and validated by a panel of three experts in science education research. The questions relating specifically to the vexation and ventures were:

1. How would you describe the importance of the issue you raised in your vexation and venture, and how long has this been an issue?

2. How did you develop your thinking about your proposed solution of your venture before attending SEFA?

3. In what ways did your experience at SEFA shape your thinking about your vexation and venture, and was there some specific session or sessions that did that the most?

4. How did interactions with other participants during SEFA influence your thinking about your specific vexation and venture?

(Probe: Did any participants offer specific solutions to your vexation that you hadn't thought of before attending?)

Artifacts. Collected artifacts included initial vexation and venture text instructions to participants from the implementation team and handouts and PowerPoint slides from all SEFA sessions to better understand the context of their writings and discussions. Also, pictures were taken of posters that were made by the whole group during lunch on the 3rd day of SEFA. These posters were created by the group to summarize important themes that emerged during the vexation and venture session, as well as to brainstorm possible productive actions that science teacher educators could take to address these themes. All artifacts served to help triangulate data gathered from the vexation and venture texts, session observations, and interviews.

Data Analysis

Constant comparative analysis, as described by Strauss and Corbin (1994) was used to analyze the texts, interview transcripts, and observation field notes. First, these data sources were examined for patterns, and from these patterns preliminary categories were developed and refined through comparison with the original data set. Reported themes consisted of patterns common to at least two participants. For example, preliminary categories for participant venture texts included the two codes "help prepare teachers for teaching best practices" and "help prepare teachers with better assessment strategies." On a second comparison with the data, these were collapsed into the single code "teachers need to be better prepared in a variety of ways." Frequencies of the codes were calculated to elucidate how often particular patterns were present in the data set. Following this initial analysis, themes between science education faculty from STEM and education departments were compared to uncover similarities and differences between these groups. Themes present in data from qualitative notes of SEFA sessions and interviews following SEFA were compared to pre-SEFA vexation and venture texts to understand how SEFA affected participant thinking around their issues. To enhance reliability, two researchers first independently analyzed the data and a consensus was reached through discussion about any disagreements before reporting the final themes.

Results

Themes emerging from the vexation and venture texts are presented first along with a comparison of education and STEM faculty. This is followed by a description of any changes in participant thinking following SEFA along with a discussion of these findings and their significance.

Vexations

Overall, participants were quite knowledgeable, expressing detailed opinions about the variety of issues and research related to standardized testing. There were a number of prominent themes in the vexation portion of participants' texts. Most participants mentioned multiple issues in the vexation portion of their texts.

Standardized testing has some positive aspects. All participants raised concern about standardized testing in one way or another, but many participants acknowledged that there are some positive aspects to standardized testing. They reported that standardized tests are an important piece of information about student achievement. "On the surface, our current model of giving multiple-choice standardized tests allows us to quickly measure at least some aspect of student growth without incurring huge resource costs" (STEM-F5, V&V text). Another participant alluded to the fact that standardized testing may have some role in ensuring some level of accountability for teachers. "The intention of standardized testing at its onset was to ensure quality instruction for all students" (STEM-M2, V&V text).

Questions are basic and do not value science practice/process. Another theme focused on the style of questions common to a wide range of standardized tests. Participants were concerned that multiple choice questions are almost always focused on breadth over depth and focused on the easiest skills to assess such as remembering facts or understanding basic concepts. "Discrete isolated factual knowledge and memorization of vocabulary are often the focus, while conceptual understanding, critical thinking, problem solving, creativity, and argumentation fail to be addressed" (ED-M1, V&V text). This basic questioning style may not reveal the kind of deep learning that may be occurring for students.

> One of the problems I have with standardized tests is that they are looking for a specific answer to each question. Those students who think outside the box are ultimately penalized and may even be labeled as being unintelligent; however they may be quite brilliant (STEM-M1, V&V text).

Student skills such as analyzing, evaluating and arguing from evidence may simply be too difficult to test using a multiple-choice format or other cost-effective means. Other participants specifically mentioned that standardized test questions do not emphasize science process skills (or scientific practices). "The multiple choice exams don't allow for students to be creative in designing experiments, communicate scientific ideas, or demonstrate how they think like a scientist" (STEM-F5, V&V text). Participants perceived that the tests are not able to show deep student learning, and that many of the valuable skills students learn and practice in science classes are not measured through current standardized assessments.

Testing pressure negatively affects students, teachers, and administrators. Participants described standardized testing in schools as having a negative effect on student motivation and buy-in to learning science. One participant compared the current state of schools with his own experiences as a student prior to the implementation of widespread testing.

> The majority of my current students are not curious about science, which I think stems directly from the "teach to the test" mentality that many teachers must adopt to enable their students to score well on [state] tests… I was able to dig deep into a topic, wrestle with it, and glean additional information about the topic not presented to me during class. The students I see now either cannot do this or do not want to do this (STEM-M1, V&V text).

Participants made many such statements about standardized testing being the cause of a decline of enjoyment for students in their desire to learn and do science. Participants perceived attaching high-stakes, such as teacher evaluation, to the tests caused more testing to take place in schools. The following, written by one participant described a real exchange between two students overheard by the participant's sister, who is a first grade teacher:

> Student 1: *What special do we have today after lunch? Do we have music?*
> Student 2: *Hmm. Oh, I know! Assessment!* (STEM-F2, V&V text)

This exchange concisely portrays the concern from participants that too much class time is being spent preparing for and practicing state tests.

Participants perceived that it was unfair for schools to use standardized assessments to evaluate teacher quality or strongly influence teacher pay as this demotivated teachers. For example, one participant wrote, "School systems have become so dependent on the standardized test system that they now hold merit pay and tenure over the teachers' heads as a carrot, and if not enough students meet minimum qualifications, teachers are punished" (ED-F7, V&V text). Participants also wrote that teachers are pressured to teach in less effective ways, and that school curriculum and classroom teaching has changed to mirror the assessments.

> In an effort to meet state standardization requirements, teachers find themselves restricted to repetitive-type teaching, i.e., "teaching to the test," which primarily involves drilling students to recall rehearsed information rather than engaging in

> reflective instruction that involves science explorations and investigations (ED-F3, V&V text).

Using class time to have students take numerous state practice assessments did not go unnoticed by participants. One participant noted, "Instead of teachers building in classroom assessment to plan how to differentiate their instruction, countless hours are spent testing" (ED-F5, V&V text). In many states, and in particular Virginia, standardized testing extends down into the elementary grades and emphasizes mathematics and reading disproportionately to other subjects. This has led to increased time reviewing mathematics and reading, and a marginalization of time spent on learning science and social studies. "I also hear about how little time my elementary teachers have to teach science, as teachers are busy getting students ready for mathematics and reading standardized tests" (ED-F4, V&V text). Together these statements demonstrate the pressure on teachers and indicate that high-stakes assessments drive instruction in ways that leave teachers feeling helpless, fearful, and with no good options about how to structure class time.

Student performance on standardized tests also affects school administrators in important ways. One participant wrote:

> For administrators, standardized testing can be a source of pride if the students in their schools are doing well on the tests, or a source of fear of intervention from various agencies if test scores do not improve to meet the demands of adequate yearly progress (STEM-F2, V&V text).

Another participant painted a vivid picture of the various conclusions the public might rush to make about the quality of a school that produces low test scores:

> The perspective apparently is that the highly publicized scores tell us about the effectiveness of a school, how much the students know, how effective the teachers are in doing their jobs, and the quality of the leadership in the school. When the scores are published in our local newspapers, we can see whether or not a school

> is doing a good job of teaching its students. If the scores are low (unacceptable), we assume that students are not being taught well, that differentiation is not occurring, that the curriculum is not appropriate or challenging, or that appropriate resources have not been channeled to that school to ensure that students are getting the quality of education to which they are entitled (ED-F1, V&V text).

As long as test scores are equated with teacher quality and administrative effectiveness, participants perceived that instruction time in schools is likely to be devoted largely to test preparation, and this high-stakes culture of fear is likely to continue.

Tests are biased against certain students. Participants pointed out that standardized tests unfairly disadvantage certain groups of students. These included students of low SES backgrounds, students from minority ethnicities, English language leaners, students who move from one state to another, and international students moving to the U.S. In talking about some of these groups, one participant mentioned:

> Furthermore, research has shown that minority and low-income students are more affected by standardized tests. In states with higher percentages of African Americans, Hispanics, and poorer students, there is a greater focus on test preparation and required high school graduation exams are more common (STEM-F5, V&V text).

This quote implies that the participants perceived that increased pressure on schools to improve scores leads to more time devoted to test preparation. Another participant elaborated on the ways in which she perceived these tests are unfair to students of low SES backgrounds, namely that the pressure on teachers to show high scores dissuades them from taking jobs in high-needs districts.

> If we judge teachers solely on the performance of their students on an end of the year standardized test, then those teachers in affluent, high-achieving schools (or school systems) will routinely have higher evaluations and therefore judged to be "better" teachers. This contributes to an exodus of good teachers from poorer, rural, or lower achieving schools, the very places where they stand to make the most impact, to more affluent, higher achieving schools (STEM-F3, V&V text).

Tests are an incomplete picture of student achievement. Another perception among participants was that standardized tests do not show the full range of student achievement. One participant stated succinctly, “It is an unfair tool of measurement and an incomplete evaluation of student knowledge” (ED-F2, V&V text). Additionally, participants noted that many factors complicate summative assessments that measure student performance at only one point in time. For example, “Since standardized tests results are a single data point, they represent a snapshot of the student’s performance. There are so many uncontrolled variables contributing to a student’s performance at the assessment time“ (STEM-F3, V&V text).

Students are not being properly equipped for their futures. Finally, participants mentioned some different ways in which they felt the overemphasis on standardized testing does not adequately prepare students for their futures. Some participants expressed this in a general way, while others gave some specific examples. One example was that students are not being equipped with skills they need to enter colleges and universities. “In my opinion the students I see in my classes now are less prepared, less motivated, and less inquisitive than the students I had at the start of my career. I attribute this in part to [state] testing” (STEM-F1, V&V text). Other participants emphasized that students are not being prepared well for their future professions with the skills they will need. “If education is relegated to picking and choosing what is taught in order for students to pass the state test, what are we doing to foster creativity, inventiveness, inquiry, and investigation, which ultimately support the development of our future leaders, scientists, writers, artists, and musicians?” (ED-F1, V&V text). Participants were concerned that the skills most easily assessed on multiple choice tests are not aligned with the skills students will need when they go onto pursue higher education or enter the workforce.

Ventures

While many clear patterns emerged from participants' vexation texts, participants' ventures were far more varied and unique to the individual, sometimes pertaining primarily to a particular school or classroom context. In general, relative frequencies were lower for each of the venture themes compared to participant vexations for these reasons. Below, emergent themes that arose across two or more participants are reported.

Current tests should be modified or supplemented with other assessment types. One suggestion from participants was that the standardized tests should be modified from the current multiple-choice format. Though this was a common theme, the specific approaches suggested varied among participants. For example, one participant suggested trying to modify question format to test a wider range of skills:

> Instead of a multiple-choice test based purely on lower-level learning objectives, why not add a free response portion that asks the students to design an experiment to investigate a phenomenon or apply their content understanding to complete some task? An even more progressive idea would be to give students actual opportunities for these application/discovery experiments where the students would be asked to perform a practicum as part of the exam… Asking students to explain their experiment on an exam would also encourage teachers to focus on developing their students' communication skills. Students would have the flexibility of using a variety of modes to describe their experimental set up (pictures, text, graphs, etc.) but they would need to learn how to explain science in every-day language (STEM-F5, V&V text).

This participant proposed including questions designed to assess student understanding at a more complex level than basic facts and concepts, and to incorporate aspects of science practice into the test. Another participant was hopeful that the NGSS were written in a way that could help these changes be realized:

> Science education has an opportunity that it has not had since the mid 1990s to make significant changes to the ways in which we conduct assessment, and the NGSS has the language to help facilitate this move. The Performance Expectations sections have both the initial appearance and the philosophical underpinnings to support authentic and performance-based state-administered assessments (ED-M1, V&V text).

Similarly, other participants focused on supplementing traditional multiple-choice tests with other assessment types versus changing the style of questions on the assessments. Providing some examples, one participant said:

> Standardized tests can be one part of a comprehensive assessment system but should not be the sole or major assessment tool utilized to measure student achievement or teacher effectiveness… These solutions for the use of more authentic assessment should be incorporated in the summative evaluation of students. Other examples would include a collection of student work in portfolios, e-portfolios, and written explanations such as essays and projects (ED-F3, V&V text).

These suggestions indicate participants perceived assessing performance-based skills related to scientific practices and problem solving around authentic experiences to be important in effective science assessment.

Teachers need to be better prepared in a variety of ways. Participants reported that another possible venture would be to better prepare teachers to use best practices in their classrooms. One participant expressed this with regard to culturally responsive best practices:

> If education is to be viewed as a pathway out of the pedagogy of poverty and as promoting student achievement, then there is a significant need to implement pedagogical methodologies that are culturally responsive and connect to student lives (ED-F3, V&V text).

Others focused specifically on the need to equip teachers with knowledge and strategies that could allow them to better assess their students. "I also believe that we need to give teachers the independence to create their own assessments beyond traditional multiple choice tests" (ED-F8, V&V text). Many participants mentioned that teachers should be prepared to teach or assess in different ways, however no comments were made specifically about how to help teachers effectively implement these changes within the high-stakes testing environment of their schools.

The role of standardized tests should be re-evaluated. Some participants emphasized that ventures must be based on a change reflecting how the many stakeholders in the education system value and think about education in the U.S. Some mentioned specific changes in how test scores should be used. "Schools and states need to stop tying tenure and promotion to the test scores and stop tying the amount of aid a school will receive based on their participation and scores on the test" (ED-F7, V&V text). Other participants spoke of more general changes in attitudes as exemplified by the following:

> Time and time again I have heard colleagues quote studies saying that employers are not "that concerned with a student's major" but rather they are looking for students that can "think critically, communicate effectively, and solve problems creatively." If this is what we truly value in education, then there has to be to be a shift in the way we measure students' abilities in these areas (STEM-F1, V&V text).

These participants' sentiments indicate that a systematic change in thinking is necessary prior to implementing specific changes in schools or classroom instruction.

The problem of limited resources must be addressed in a solution. Some participants cited resource limitations in any widespread testing system and sought to provide some solutions. For example, one participant wrote, "If we offered fewer exams over a student's academic career, it is feasible that we could find the resources to grade these open-ended assessments" (STEM-F5, V&V text). Saving money by reducing the number of assessment times, or streamlining state standards to a uniform national set of standards was one way participants thought of saving money. Others had more elaborate suggestions:

> The role of authentic assessment as a valid tool for measuring meaningful workforce skills and understandings may lead to cost saving opportunities to engage students in public service efforts. For example, if students were able to demonstrate their knowledge through a public works effort there may exist not only a potential to cut testing costs, but also an opportunity to save tax payer money regarding labor associated with that public work effort (ED-M1, V&V text).

Regardless of specific differences in approaches to save money, participants indicated that solutions should be cost effective and economically feasible for schools.

The power to change the situation resides with the policy makers. A final theme emerging from the venture texts was that some participants felt that the onus of reforming the current system must come from the top down. "Policy makers at the national, state, and district levels must begin discussing alternatives to standardized testing" (ED-F4, V&V text). Others discussed the need for more transparency from those in power. "The stakeholders who reinvent these tests and standards need to become a more transparent entity and more available to those they are serving" (ED-F7, V&V text). What did not emerge as a theme in participant ventures was any perceived ability to influence policy decisions in any way. Participants did not express solutions related to helping create standards, modify standards, or lending their voices to influence top down change.

Comparing STEM and Education Faculty Vexations and Ventures

When comparing emergent themes from faculty in STEM departments (seven participants) to those in education departments (nine participants), more consensus than divergence in their vexations and ventures existed. With regard to vexations, two large differences between STEM and education faculty emerged:

1. STEM faculty members were more likely to mention vexations related to decreased student motivation toward science disciplines (71% of STEM faculty vs. 11% of education faculty).
2. Education faculty members were more likely to mention vexations related to negative effects on classroom instruction (56% of education faculty vs. 14% of STEM faculty).

With regard to the venture portions of their texts, the biggest difference between education and STEM faculty was that education faculty members were more likely to mention solutions related to teacher preparation than their STEM counterparts, such as preparing teachers to use best practices and effective/alternative assessments in the classroom (55% of education faculty vs. 29% of STEM faculty).

Participant Thinking Immediately Following the Vexation and Venture Sessions

Following the vexation and venture session, SEFA participants had a group discussion to summarize the major themes that emerged from their discussions and specific actions that science education faculty could take to address these issues. The issues about standardized testing that the group decided upon closely aligned with themes found in the vexation and venture texts. During this session the group produced two posters through consensus- one summarizing issues with standardized testing and the other outlining a path forward. The first document that the group created during this discussion included the following issues:

1. Scores are used to exclude/marginalize

2. Fear (teachers/students)

3. Causes lack of resources for teaching and poor instruction

4. Poorly conceived and designed assessments

5. Loss of instructional time

6. Lack of understanding of legislators

For the second document, participants decided on four important actions they could take to solve these issues. Three actions agreed upon in this collaborative discussion were not patterns present in the vexation and venture texts. The fourth, enhancing preservice teacher training in best practices, was a theme common to participant ventures. The poster describing specific actions included the following:

1. Visible involvement with policy makers at all levels

2. Involvement in the standards review process (may want to promote contraction of standards)

3. Equip elementary teachers to not fear science content.

4. Preservice teacher training in best practices

Since these actions were mentioned in the summary large group discussion after the vexation and venture activity during SEFA, it is possible that the vexation and venture small group discussions influenced participant thinking. The first two actions described on the second poster involved using leverage as a science teacher educator to influence policy, both through actively helping to shape future standards as well as through direct interaction with policy makers. The third new theme of equipping elementary teachers with skills so they are not afraid to teach science was not mentioned by any participant in the vexation and venture texts and first arose during the vexation and venture session discussions.

Participants' Thinking Following SEFA

Further evidence about changes in participant thinking came from phone surveys conducted within two weeks following the SEFA. Of the 16 participants attending the PD, 12 responded to interview requests (75%). The following themes arose from interview transcripts.

There was much consensus around the issues, and this was empowering. Participants mentioned hearing opinions similar to their own during the vexation and venture sessions, especially with regard to the vexations surrounding standardized testing was a positive experience. One participant said, "I just realized there's a lot of other really talented people out there that I can tap and ask for questions and network with and, again, I'm not out there on my own" (STEM-F4, Interview). Participants were happy to realize they were part of a community that shared similar concerns.

Thinking was mixed as to whether the vexation and venture session changed participants' perceptions. Participants were specifically asked in the interview as to whether or not their thinking changed following the vexation and venture session and also whether or not other participants offered helpful opinions or feedback. Two opposing themes emerged. Some participants said the vexation and venture session did not change their thinking (42% of interview respondents). When asked if the vexation and ventures session had changed her thinking, one participant said, "I would say not at all, to be fair… Nobody wrote a paper about how awesome standardized testing is" (ED-F4, Interview). On the other hand, many respondents indicated they heard interesting ideas during the session or that others gave them helpful feedback (50% of interview respondents). One participant talked about others' comments, "In fact, I had a few during my presentation, who made a comment that that was a very good idea" (ED-F2, Interview). Participant self-perceptions as to changes in thinking clearly varied.

Participants expressed greater agency to influence policy. Prior to attending SEFA, no pattern existed in vexation and venture texts that participants felt any connection to policy makers or an ability to affect policy change. Similar to the post-vexation and venture group discussion, in interviews participants expressed more opinions about policy and expressed both a desire and ability to influence policy makers:

> Well it allowed me to look at some other areas of where I could help with just not knowing the problem or seeing the problem, but also taking the problem outside of the college classroom to the legislative areas and looking at some of the other stakeholders' interest in, I guess, implementing standardization… Whenever we can, voice our opinions to legislators, to administrators and kind of move up the ladder and take it outside of the college to help get our concerns out there (ED-F3, Interview).

This participant recognized that she had the ability to share her knowledge and opinions to those in positions of power. Another participant voiced the desire to involve people at all levels in the science education community in policy decisions:

> Science teacher educators could be more heavily involved in policy in order to have practitioners' voices heard… rather than other voices that may not be as informed about education in general and, yeah, I think it's important… A lot of the comments were really thought provoking and helped me refine some of my thinking about what might work and what might not work in terms of us trying to help pre-service teachers become more engaged in policy in their careers (ED-M1, Interview).

It appears that the SEFA experience helped participants realize they were part of a larger community with shared opinions and concerns about standardized testing, and that it could be possible to work together in realistic ways to make a difference at all levels of the policy decision making process.

Discussion

Analysis of vexation and venture texts and observations of SEFA discussions revealed science teacher educator thinking about a variety of issues related to standardized testing. The high degree of consensus on these issues and deep knowledge among the members of the group is understandable considering that this charged topic relates directly to their careers and their work with preservice and in-service K-12 teachers. SEFA participants described a culture of fear for many of the stakeholders affected by standardized testing and that the tests are too limited in their scope and often biased toward certain students. One of the main goals of the standardized testing movement in the U.S. is to identify and better serve under-performing schools and high-needs students (Bush, 2001), while in fact, participants point out that these tests have the opposite effects for an assortment of reasons.

An examination of patterns in participants' venture texts revealed greater divergence than participants' vexations. This may be due to the simple fact that solutions have not yet to be tried. Also likely, while vexations are easy to state in a relatively concise way, many ventures were multifaceted and rooted in specific classroom or school contexts. Some differences among science teacher educators from STEM vs. education departments existed. Participants from STEM departments focused their vexations more often on student motivation to learn science, while faculty from education departments were concerned about loss of instructional time and focused their ventures around how to equip teachers with effective skills. These differences may be influenced by many factors such as the types of classes faculty teach, the values of colleagues in their respective departments, their prior background in learning science or the student populations they teach.

The venture portion of the texts generally lacked discussion about policy-based solutions to standardized testing issues. When policy was mentioned, participants perceived the sole responsibility of solutions to be out of their hands, resting solely with policy makers. It thus appears that science education faculty may feel as disconnected from policy decisions as do practicing teachers (Barksdale-Ladd & Thomas, 2000). A noticeable change occurred however following SEFA. Participation in the professional learning community led to discussions about policy and appeared to help foster a sense of shared vision around these issues with a greater perception of agency to affect changes in the policy arena. Standardized testing is a charged topic in the U.S. with many stakeholders weighing in on issues surrounding the tests. The group of science teacher educators in this study were well informed about these issues and have potential impact on a large number of teachers entering the teaching profession, and further have potential impact to educate in-service teachers, school administrators and the general public about the complex issues around standardized testing. Their knowledge, position, and qualifications can be leveraged to inform and influence future policy decisions at the state and national level, yet the current study suggests this ability may often go unrealized. With the ongoing adoption of NGSS by states and the as yet undeveloped corresponding assessment, this study comes at a critical time. Future research is needed to develop specific strategies to help science teacher educators be more effectively involved in policy.

This paper was the first to empirically study the vexations and ventures model, first created for the *Science Education at the Crossroads* conference (Johnston & Settlage, 2008; Settlage & Johnston, 2014). As a component of science teacher educator PD, it was able to effect change to participant thinking, and participants valued the vexation and ventures model as a means to collaborate with colleagues. Based on participant feedback, if integrated into future PD experiences it may be more appropriate to either change the topic to something less familiar or more controversial because there was too much redundancy during discussions about problems with standardized testing, a topic for which there was strong consensus. Another possible modification would be to allow participants free choice over what topic to bring to bring to the discussion. This format would align with most of Stoll, et al.'s (2006) characteristics of a professional learning community, such as collaboration, reflective personal inquiry, individual learning, and group learning; however it may not foster the development of a shared vision and set of values due to the divergent nature of issues brought to the table. This alteration might increase perceived relevance of issues for participants, but it may also have unintended effects on the cohesion and functioning of the learning community. Such major alterations would need further study. As a caveat, this investigation is a qualitative case study of 16 science teacher educators in the state of Virginia, and results should not be generalized to a larger population.

This research was supported by funding from the U.S. Department of Education Investing in Innovation (I3) grant program. However, the results presented here do not necessarily represent the policy of the U.S. Department of Education, and you should not assume endorsement by the Federal government.

References

Abrams, L. M., Pedulla, J. J., & Madaus, G. F. (2003). Views from the classroom: Teachers' opinions of statewide testing programs. *Theory into Practice*, *42*, 18-29.

Barksdale-Ladd, M. A., & Thomas, K. F. (2000). What's at stake in high-stakes testing teachers and parents speak out. *Journal of Teacher Education*, *51*, 384-397.

Bush, G. W. (2001).*No child left behind.* Washington, DC: Office of the President of the United States.

Bybee, R. W. (2009). Program for International Student Assessment (PISA) 2006 and Scientific Literacy: A Perspective for Science Education Leaders. *Science Teacher Educator*, *18*, 1-13.

Darling-Hammond, L. (2007). Race, inequality and educational accountability: The irony of 'No Child Left Behind'. *Race Ethnicity and Education*, *10*, 245-260.

Duit, R., & Treagust, D.F. (1998). Learning in science: From behaviorism towards social constructivism and beyond. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 3–26). Boston: Kluwer.

Giordano, G. (2005). *How testing came to dominate American schools: The history of educational assessment*. New York, Peter Lang.

Gredler, M. E. (2005). *Learning and instruction: Theory into practice*. Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Heubert, J., & Hauser, R. (Eds.). (1999). *High-stakes testing for tracking, promotion, and graduation*. Washington, D.C.: National Academy Press, 13-15.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, *79*, 33-41.

Johnston, A., & Settlage, J. (2008). Framing the PD of members of the science teacher education community. *Journal of Science Teacher Education*, *19*, 513-521.

Kohn, A. (2001). Fighting the Tests: Turning Frustration into Action. *Young Children*, *56*, 19-24.

McDonnough, J. T., Sterling, D. R., Matkins, J. J., & Frazier, W. M. (2012). *Virginia science education at the crossroads: Connecting science education faculty to a professional community.* A paper for the Annual meeting of the National Association of Research in Science Teaching, Indianapolis, IN.

McGuinn, P. (2012). Stimulating reform: Race to the top, competitive grants, and the Obama education agenda. *Educational Policy*, *26*, 136-159.

Menken, K. (2008). *English language learners left behind: Standardized testing as language policy.* Clevedon, England: Multilingual Matters.

NGSS Lead States. (2013). Next Generation Science Standards: For states, by states. Washington, DC: The National Academies Press.

Obama, B. H. (2015). *The every student succeeds act.* Washington, DC: Office of the President of the United States.

Riley, K., & Torrance, H. (2003). Big change question as national policy-makers seek to find solutions to national education issues, do international comparisons such as TIMMS and PISA create a wider understanding, or do they serve to promote the orthodoxies of international agencies? *Journal of Educational Change*, *4*, 419-425.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*, 221-258.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology. *Handbook of Qualitative Research*, 273-285.

Thomas, J. Y., & Brady, K. P. (2005). The Elementary and Secondary Education Act at 40: Equity, accountability, and the evolving federal role in public education. *Review of Research in Education*, *29*, 51-67.

Vygotsky, L. S. (1978) *Mind in society: The development of higher mental processes*, ed. and trans. M. Cole, V. John-Steiner, S. Scribner & E. Souberman. Harvard University Press (original work published 1930–1935).

Walpole, M., McDonough, P. M., Bauer, C. J., Gibson, C., Kanyi, K., & Toliver, R. (2005). This test is unfair urban African American and Latino high school students' perceptions of standardized college admission tests. *Urban Education*, *40*, 321-34.

Wideen, M. F., O'Shea, I. T., Pye, I., & Ivany, G. (1997). High-stakes testing and the teaching of science. *Canadian Journal of Education*, *22*, 428 - 444.

CHAPTER FIVE

CONCLUSIONS

The literature base about effective professional development (PD) practices combined with implications from the empirical studies of this dissertation can be synthesized to conceptualize a comprehensive approach to high quality science teacher educator PD. Science teacher educator PD must include the core elements of effective PD, namely that it should be focused on content through a process of active learning and collaboration with enough time for this learning to occur. The specific context in which science teacher educators work must also be considered; this context includes their professional duties, pressures, and needs. Indeed this dissertation is in direct response to the inadequacy of generic PD experiences. Using the findings presented in this dissertation it is possible to put forward an informed recommendation about what should be included in future PD initiatives for science teacher educators. These findings will be discussed according to a list of PD characteristics outlined by (Donnelly, Dove & Tiffany-Morales, 2002).

Designing Effective Science Teacher Educator Professional Development

It is important to consider a variety of factors in designing any faculty PD program. Donnelly, Dove, and Tiffany-Morales (2002) present a list of features by which such programs may be characterized. These include structural features such as format, duration, and extent of collective participation, as well as core characteristics related to delivery such as the degree of active learning, the degree to which the PD focuses on content, and the overall degree of coherence. Additional features include accessibility, degree of inclusiveness, and incentives for participation.

Structural Characteristics

Format. To meet the need of science teacher educators to collaborate across university lines within a region or state, the format of science teacher educator PD should be one in which professional discussions can occur and professional relationships can be created and maintained over time. A professional learning community approach to PD would serve this purpose well, positioning science teacher educators as both professional colleagues and learners. Maintaining such a community over time would be valuable in helping novice members develop knowledge and skills through interaction with more senior members. A learning community that is sustained over time may also help develop shared language and goals among participants, thereby easing the obstacles traditionally found in education and STEM faculty partnerships (Harwood, 2004).

Duration. A total time of at least 30 contact hours is recommended (Guskey & Yoon (2009). SEFA participants expressed that a single five-day block of time was too long of a commitment and overly taxing, so it may be better to have two or more meetings of shorter durations over a calendar year. More frequent meetings could also help foster an ongoing sense of community and open up lines of communication due to more frequent contact.

Collective participation. As defined by Stoll, et al. (2006), participants in a professional learning community should have collective responsibility. For science teacher educators this would mean working together to solve problems, whether these are small problems within contextualized science activities or larger issues related to science education such as social justice, standardized testing, or distance education. It would be beneficial for participants to work together to create conference presentations, publications, or grant proposals as means to maintain ongoing collective participation. Data in this dissertation suggest maintaining collective participation over time for faculty members at different institutions is a challenge. Creating a virtual community of practice could be one way of addressing this problem. In a review of the literature, Ardichvili (2008) outlined a set of motivating factors that have been found to enhance online participation as well as a set of barriers to address. Motivating factors include personal benefits (e.g. feeling one's contribution is valued or developing an expertise), communal benefits (developing new relationships), and normative factors (e.g. shared values, conformity, or reciprocity). Barriers that must be overcome include mitigating fears related to criticism, bridging any lack of technological aptitude, and providing clear guidelines for participant communication.

Core Characteristics

Active learning opportunities. An important feature of effective PD is that it engages participants in active learning experiences (Birman, Desimone, Porter & Garet, 2000; Guskey & Yoon, 2009). Active learning is a foundational component of many reform-based pedagogies for science teaching. Engaging science teacher educators in contextualized hands-on examples of inquiry instruction, PBL, or the science and engineering practices presented in The Next Generation Science Standards (NGSS) would both engage them in active learning and cover material that would be directly relevant to teaching science methods courses. Active learning principles can also be applied to other topics by having participants discuss, write, or problem solve.

Content focus. Participants at SEFA appreciated learning about reform-based teaching strategies that could be incorporated into science methods courses including inquiry, PBL, and NOS and showed significant sustained gains in perceived ability to implement these strategies with preservice and in-service teachers. While participants generally valued the vexation and venture discussions, some reported that vexation and venture topics were too narrow, or reported too much consensus within the group for productive discussions. It would benefit the vexation and venture session to make topics broader and allow participants to collectively decide on the topic in advance for greater engagement.

An important feature of effective PD is that the content should be tied to the context in which participants work (Timperley, Wilson, Barrar, & Fung, 2007). Pre-PD surveys could serve to poll participants about what topics would be most valued. Participants' prior knowledge should also be considered to properly choose and scaffold topics based on their level of expertise. Prior knowledge seems to be especially important for sessions focused on grant writing. SEFA participants' confidence in securing grant funding was significantly lower after one year. Boyer and Cockriel (1997) suggest that all faculty need support in grant writing, but that tenured and non-tenured faculty needs are quite different. Future science teacher educator PD experiences may want to pair less experienced faculty with faculty who have a solid grant writing record, or divide grant writing sessions into two groups receiving different levels of support based on prior experience.

Finally, discussions at SEFA related to policy changed participant perceptions about their ability to be involved in or to impact those involved in policy decision making. Prior to SEFA, science teacher educators did not perceive themselves as able to impact policy decision, strikingly similar to the perceptions of practicing teachers

(Barksdale-Ladd & Thomas, 2000). A focus on policy is warranted because science teacher educators are both highly knowledgeable about current issues in science education, and well positioned to leverage their voices, individually or collectively, to influence change.

Coherence. First, science teacher educator PD initiative should align with goals of larger science education frameworks, a timely example being the Next Generation Science Standards (NGSS). For states not adopting NGSS, alignment could be with the language and goals of state standards. Also possible, as in the case of SEFA, alignment could pertain to a regional or statewide grant or other initiative. The Association for Science Teacher Education (ASTE) is a national science education organization for science teacher educators with a mission to provide PD for science teachers from grades K-16. The ASTE provides guidelines for the design and implementation for PD including that it should be developmentally appropriate, aligned with national standards, and be grounded in professional literature (ASTE Position Statement, 2016). Specifically for science teacher educator PD, ASTE's mission does not extend beyond facilitating better preparation of science teachers. The results of this dissertation suggest science teacher educators would benefit from more robust PD at the ASTE, such as workshops on grant writing, on policy, or long-form incubator sessions. Also, state and local PDs could align themselves with content from the ASTE.

Building a community over time with both new and returning members that possesses shared language and repertoire would be another important type of coherence. This could be facilitated through the use of newsletters, a group Facebook page, or through collaborative work on conference presentations, journal articles and grant. In addition to fostering collaborative relationships and maintaining a shared set of resources, Wenger (1998) emphasizes the importance of a joint enterprise in strengthening relationships within a community. In order to maintain a robust community, future science teacher educator PD should have a relevant and meaningful set of goals beyond normal PD contact hours for participants to engage with over time.

Other Characteristics

Inclusiveness and accessibility. Science teacher educator PD should be specific enough in scope to be relevant to those involved, but should also not exclude anyone who would like to participate with on an overly narrow focus (e.g. a specific research agenda, or a focus on only one aspect of a faculty's professional life). Making a clear statement of PD goals prior to the PD and making it easily accessible would help participants decide whether or not to attend. Participant pools may overlap to some degree with attendees at national or state science education organizations. The format, content, and timing of PD initiatives could be tailored to enhance or complement participation in such organizations.

The geographic location of the PD should be reasonably accessible for all involved, or held at different sites over time to ensure equal access. For components of the PD held in person, sessions should occur at a time when most participants have time to attend (e.g. summer for longer sessions or weekends for short sessions).

Incentives. If properly tailored, many of the incentives related to science teacher educator PD would be intrinsic, resonating with already existing needs such as the desire for inter-university partnerships and new ideas for science pedagogy courses. Financial incentives could factor into participants' decisions to attend, and so reimbursement for travel expenses and lodging is recommended if funding is available.

Evaluation of Science Teacher Educator Professional Development

A comprehensive evaluation of a science teacher educator PD could be achieved using a modified version of Guskey's (2000) framework. A necessary first step is for participants to be satisfied with the various aspects of the PD. This satisfaction may be assessed using Likert surveys broken out by individual PD components, as well as open-ended survey responses allowing participants to explain perceived strengths and weaknesses in their own words. Next, the knowledge and/or skills gained by participants would need to be assessed according to the content covered during the PD. Taking a quantitative approach, this could be achieved by coding participant responses to questions about the content against predetermined definitions as aligned or nonaligned. Taking a qualitative approach, participant responses could be analyzed for patterns through inductive analysis.

Next, it would be important to see whether participants implemented new knowledge or skills in their professional context. Gains in knowledge and skills during a PD experience do not necessarily translate to changes in practice (Ebert-May, et al., 2011). Evaluation should therefore also include follow-up data to capture changes in practice. If the PD focused on teaching, in-person or video observations could focus on strategies learned in the PD. If however the PD focused on grant writing or research, participants could be interviewed after some length of time to find what products resulted and participants' description of how their PD experience impacted those products.

Guskey's (2000) model mentions the next domain in his hierarchy of evaluation as measuring the PD's effect on student learning outcomes. While this is appropriate for teaching-focused PD, it is not applicable to other topics. It would be more appropriate for a PD program covering a range of topics to simply look at transfer of learned knowledge and skills to others (e.g. students, colleagues, or administrators) as appropriate. Finally, the effect of the PD on larger organizations in which the participants work should be measured. These effects may include curricular changes within a department or university, changes to science teacher educator state or national organizations, or changes within the state or national science education policy arena.

Future Directions

In addition to a continued examination of varied content of and formats to PD are best suited for science teacher educators, it would be helpful to gain a richer picture of what aspects of PD enhance or hinder the ability for collaborative relationships to be formed and maintained over time. Further details about the nature of these relationships would be useful, such as the extent and frequency of collegial interactions, or what variables may affect these partnerships like type of institution, home department, or professorial rank.

SEFA was situated in the science education community in the state of Virginia. Science teacher educator contexts and needs may be different in other states or regions based on such factors as geographic constraints, variation in state science education organizations, or the K-12 science standards in place in that area. These differences would need to be understood before using elements of SEFA in different locations.

References

Ardichvili, A. (2008). Learning and knowledge sharing in virtual communities of practice: motivators, barriers and enablers. *Advances in Developing Human Resources*, *10*, 541-554.

ASTE Position Statement Science Teacher Preparation and Career-long Development. (2016). Retrieved from https://theaste.org/about/aste-position-statement-science-teacher-preparation-and-career-long-development/

Barksdale-Ladd, M. A., & Thomas, K. F. (2000). What's at stake in high-stakes testing teachers and parents speak out. *Journal of Teacher Education*, *51*, 384-397.

Birman, B. F., Desimone, L., Porter, A. C., & Garet, M. S. (2000). Designing PD that works. *Educational Leadership*, *57*, 28-33.

Boyer, P., & Cockriel, I. (1997). Factors influencing grant writing: Perceptions of tenured and nontenured faculty. *SRA Journal*, *29*, 61-68.

Donnelly, M. B., Dove, T., & Tiffany-Morales, J. (2002). Technology-related professional development in the context of educational reform: A literature review. Arlington, VA: SRI International.

Ebert-May, D., Derting, T. L., Hodder, J., Momsen, J. L., Long, T. M., & Jardeleza, S. E. (2011). What we say is not what we do: effective evaluation of faculty PD programs. *BioScience*, *61*, 550-558.

Guskey, T. R. (2000). Evaluating Professional Development. Thousand Oaks, CA: Corwin Press.

Guskey, T. R., & Yoon, K. S. (2009). What works in PD. *Phi Delta Kappan*, *90*, 495-500.

Harwood, W. S. (2004). Science education reform: factors affecting science and science education faculty collaborations. *Research In Science Education: Reform In Undergraduate Science Teaching For The 21st Century.* Greenwich, CT: Information Age Publishing.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*, 221-258.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). Teacher professional learning and development: Best evidence synthesis iteration (BES). Wellington New Zealand: New Zealand Ministry of Education.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*, 1-8.