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Determining Optimal Professional Development Formats: A Q-Methodology Study of Science Teachers' Preferences

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Abstract: The necessity for meeting the professional renewal needs for science teachers in the US has generated abundant research on effective professional development (PD). Yet efforts in the state of Nebraska continue to demonstrate low enrollments in science teacher PD programs. Therefore, an innovation in research was needed to discover the beliefs and expectations about science teacher PD. A combination of Q methodology and focus group discussions with 29 science teachers in six geographical areas of the state identified three PD-seeking factors: the Scientists, the Veterans and the Entrepreneurs. The Scientists yearn to increase their own science knowledge and enable authentic science learning for students. Veterans seek new ideas and resources to improve science student learning and especially prefer stipend-supported PD options. Entrepreneurs desire opportunities to enhance teaching practices and exchange teaching ideas with scientists and other science teachers. Those who design PD for science teachers will benefit from understanding these three factors and the resulting research-informed suggestions for organizing appropriate PD models to satisfy the needs of each teacher factor.

Introduction

Educational reforms, whether driven by policy or research, rely on professional development (PD) opportunities for teachers that enhance their subject matter and pedagogical knowledge as well as offer new instructional strategies (Borko, 2004; Putnam & Borko, 1997; Sykes, 1996; Wilson & Berne, 1999). However, when teachers' background, experiences, knowledge, beliefs and needs are not considered, many PD programs for science teachers fall short (Loucks-Horsley et al., 2003; Wilson, 2013). While research has focused on effective PD for teachers (Zhang Parker, Koehler & Eberhardt, 2015), few studies have considered teachers' rationale for PD needs as articulated subjectively and holistically for themselves. We are interested in learning more about how science teachers describe their needs and desires for PD.

The University of Nebraska-Lincoln Center for Science, Mathematics and Computer Education (CSMCE) has hosted Nebraska Math and Science Institutes (NMSSI) for Nebraska mathematics and science teachers for about 7 years. Unfortunately, NMSSI enrollment data (from 2010 to 2015) showed that cancelled PD institutes due to low enrollment were nearly three times more prevalent in science (35% of 34 proposed institutes) than in mathematics (12% of 241 institutes). Given that we as professors are

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tasked with the goal of providing continuing education for Nebraska science teachers, we developed this 1-year research project to (1) understand more about how Nebraska science teachers find and choose science-specific PD and (2) organize recommendations for aligning PD options with teachers' needs.

Science Teacher Professional Development

Current research on science teacher PD framed our approach. Professional development opportunities for teachers have historically occurred as isolated events, disconnected from the workplace (Guskey, 1986; Loucks-Horsley et al., 1998). Science teachers who lack positive or effective experiences choose to participate minimally in PD experiences (Chval et al., 2008; Ramlo, 2012). Professional development programs in which teachers have an opportunity to apply new knowledge and practices as they learn can insure positive experiences and lasting effects on teachers' practice (e.g., Loucks-Horsley et al., 2003; Putnam & Borko, 1997). In situated PD, student learning is directly related to teacher knowledge of the subject matter area or content and pedagogy, and PD can be expected to improve student learning as well (Diamond et al., 2014; Loucks-Horsley et al., 2003). As Putnam and Borko explain (1997), situated PD provides learning opportunities that are constructive and within the context of authentic classroom practices.

Models

Science teachers in the United States are challenged by the ways traditional, text-based science instruction and test-focused curricula initiatives limit thinking beyond the confines of school (Cobb, 1994; Greeno, Moore & Smith, 1993). Potentially powerful PD models include supportive measures such as peer coaching, reflective practice (DeSouza & Czerniak, 2003), collaborative action research and case studies. Such long-term PD can increase teachers' content knowledge and guide instructional strategies (Lewis, Baker & Helding, 2015; Porter et al., 2003). We understand PD should consider teachers' beliefs (Clarke & Hollingsworth, 2002), be well organized, carefully structured, purposefully directed and focused on content and/or pedagogy (Guskey & Suk Yoon, 2009). However, not all science teachers need to learn the same content (in the sciences in this case), pedagogy (study of instructional methods and strategies) or both (Schneider, Krajcik & Blumenfeld, 2005). Such a "one-size-fits-all" approach is ineffective (Hobbs & Moreland, 2009). This may be especially true for teachers of science.

Policies

Teachers pursue professional development for a variety of reasons, including requirements by local school boards, state education departments and personal interest in increasing their content and pedagogical knowledge (Maldonado, 2002). Nebraska state statutes do not require a teacher to earn continuing education credits beyond their initial teaching license (Nebraska Department of Education, 2014). Federal legislation, however, requires states to ensure *high-quality* professional development for all teachers (NCLB, U.S. Congress, 2001; Every Child Achieves Act, U.S. Congress, 2015). Thus, each state defines standards for their teachers and their PD. Some states require teacher PD as an ongoing requirement for teachers' continued licensure (Avalos, 2011). Nebraska, a local control state, does not require ongoing PD for continued licensure.

Method

We selected Q methodology as a unique research strategy to systematically identify opinions (Brown, 1980; McKeown & Thomas, 2013; Stephenson, 1953) about the most appropriate PD for science teachers. Q methodology allowed us to examine science teachers' full viewpoints rather than their ratings of individual PD statements or traits, as more common scales or surveys employ in their units of analysis. The results of Q methodology denote the ways personal values cluster together rather than in terms of individual traits or statements (Brown, 1980). Although sorting has been used as a research technique, Q methodology includes factor analysis as a method of statistical analysis and in-depth interpretation of data to support the resultant statistical structures. Here, focus group discussions added an important dimension to the interpretation of the viewpoints.

Concourse Development and Sampling for the Q Set: A Two-Phase Approach

The subjective and personal assessment of the professional interests and needs of Nebraska science educators was conducted in two phases. The first phase involved science teachers who attended the Nebraska Summit on Math and Science Education and helped to generate ideas and opinions about science teacher PD to build a substantial concourse. The concourse in this study began with more than 250 statements derived from science educators who participated in the summit discussion about the possibilities for, limitations of and new ideas about PD for science teachers. Their suggestions were then added to statements drawn from the literature about PD (an additional 50 statements) and written into statements for the full concourse. The second phase consisted of an invitation to a subset of these and other teachers to participate in the sorting and focus group discussions.

For the first phase, to generate a concourse of innovative ideas at the conference, we implemented Parnes' (1992) model of creative problem solving. This is a four-stage process that encourages divergent and convergent thinking, helping participant teachers generate ideas, imaginative solutions, and ways to break through any "thinking blocks" that have hindered the growth and development of science teacher PD options in Nebraska. Specifically, six sessions of educators (n=110) were asked to think in terms of possibilities, access and networking across five areas: sustaining a community of science teachers, authentic science learning experiences, informal science learning, reading and writing in science and science for diverse learners. Participant notepads recorded written ideas and session note takers recorded the spoken ideas of the teachers. Finally, these teacher-defined problems and ideas generated during the conference guided our sampling of the concourse to result in the Q set (see Appendix 1).

This process produced a concourse of more than 300 ideas, which was sampled by the homogeneity and heterogeneity principles (Brown, 1980). That is, we organized similar ideas into categories (homogeneity), and then we kept the varying and different ideas within each category (heterogeneity), eliminating redundancy and awkward wording. The categories were content, pedagogy, collaboration, PD, administrative support and community connections, with approximately four to eight statements in each category, resulting in a Q set of 47 statements (Appendix 1).

In the second phase, data were collected across six geographical areas of Nebraska by first engaging participants in sorting the 47 statements and then involving participants in focus group discussions, which provided field data to assist in the interpretation of factor arrays. According to common practices in qualitative research (Creswell, 2014), focus group researchers select a small group of people (usually 5 to 10) and prompt them to talk about their perceptions, opinions, ideas and attitudes related to a particular topic. In this study, once participants had completed the Q sort, we posed questions in an interactive group setting regarding the sorted statements and encouraged participants to initiate conversation or to respond to other group member comments. These sessions (Q sort plus discussion) lasted about 1.5 hours each. Discussions were recorded and transcribed so participant comments could be aligned with the resultant interpretation of factor arrays of statements.

Participants

All attendees from the Nebraska Summit on Math and Science Education who had participated in phase one (n=110) were invited to participate in phase two (Q sorting and focused discussions on PD). Twenty-four conference attendees, along with five additional rural science teachers identified by regional staff (n=29), participated in the phase two. Six session sites were determined according to the physical locations and available meeting spaces of the volunteers (such that no one would need to travel more than 50 miles to the session site). Session groups ranged from two to 10 teachers. Attendees received a stipend for participating in the Q sort and follow-up focus group discussion. Though these group sizes varied, all participants had opportunity to both speak and reflect, to share their own ideas and respond to the ideas of others.

The participants took about 30 minutes to individually read and sort the 47 statements. Participants were to select the two most like their own opinions and two most unlike their opinions. Then the participants arranged the 47 statements from most unlike to most like along a horizontal continuum on a quasi-normal grid of 11 columns (with the most unlike on the left to the most like on the right; values used were -5, -4, -3, -2, -1, 0, 1, 2, 3, 4 and 5). We photographed and recorded the sorts to ensure fidelity to participants' choices.

Findings

The Q sorts were analyzed using PQ Method (Schmolck, 2014). The quantitative analysis of the sorts included correlation, factor analysis and rotation and calculation of factor scores. In Q analysis, each sort is correlated to all other sorts, resulting (in this study) in a 29 X 29 correlation matrix. This matrix was factor analyzed, and the factors were then rotated. We first tried several rotations of a centroid analysis and found large similarity among the sorters. We then used a principal components analysis, followed by a Varimax rotation, and raised the significance level of the relationship of a sort to the factor to .45 or greater on only one factor to capture the differences among viewpoints. Table 2 demonstrates the demographic information about the sorters and shows the defining sorts used for the factor score calculations. When the z-scores of the three arrays were correlated, there was still considerable agreement across the factors (Factors 1 and 2, r=.59; 1 and 3, r=.63; 2 and 3, r=.59). There were eight defining sorts for the first factor, five for the second and seven for the third, with eight confounded sorts (sorts achieving significance on more than one factor see Appendix 2). Yet the difference among the factors appeared to highlight what we heard in the focus interviews and what was reviewed in the transcripts, which prompted retaining this solution for further interpretation.

Three researchers led this effort: a principal investigator, a graduate research assistant and an expert Q methodology consultant. We are three experienced classroom teachers (two science teachers – one elementary and one secondary – and one a former elementary principal/headmaster); our collective educational experiences no doubt entered into our interactive review of the data. We approached interpreting the factor arrays of this study from a classical, interpretive perspective (Denzin, 1970), yet first keeping with the holistic viewpoint of Q interpretation (Watts & Stenner, 2012) and intended to provide understanding about the differences in the thinking of Nebraska science teachers about PD. Certainly, the factor groupings were determined quantitatively, but the interpretation of the factors included the traditional z-score arrays holistically considered, comparisons of statements across factor arrays, distinguishing statements, consensus statements and data from the transcriptions of the focus group discussions in addition to our field notes. Our multiple forms of data strengthened the findings of this study. Furthermore, all three researchers participated in a day-long interpretation of data and later refined the narrative of each type (factor array) with supportive data to define the Scientist, the Veteran and the Entrepreneur.

Finally, to manage for the transferability of these findings, we provide here concrete suggestions for each factor array or type of teacher rather than abstract universals. Rich, thick descriptions such as these (Lincoln & Guba, 1985) help to establish typicality, wherein detailed knowledge of the particulars helps consider similarity in new contexts (Stake, 1978), thereby enabling transferability to situations subsequently encountered.

Factor Array One: The Scientists

Factor Array One was defined by the sorts of eight teachers whom we called the Scientists (Appendix 2). These science teachers (five elementary and three secondary) are mostly rural, male teachers who hold master's degrees in science, science education and educational studies. They also are science leaders at the building, district and state level, yet they are the least experienced group in terms of their teaching experience.

Not like me — Like me

−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
(40)*	(33)	43	16	36	39	41	3	(15)*	29	(6)
(2)*	10	(22)	26	19	12	4	35	(11)*	23	(14)*
	7	18	8	24	46	(34)*	38	30	31	
		47	37	9	(42)*	21	13	20		
			(17)	(5)	32	(27)*	44			
				(25)*	45	1				
					28					

Figure 1. Factor array for the Scientists. Distinguishing statements are in parentheses.
All distinguishing statement z-scores are at the $p < 0.05$ level of significance.
*Statements at the $p < 0.01$ level of significance

The statement array positions for this factor (Figure 1) show the highest positive and negative values in the theoretical sort and the distinguishing statements. Statement 14 not only gave rise to the name for this factor, the Scientists, it also reflects their interest in working with real scientists. A desire to bringing the work of real scientists into their classrooms by implementing problem-based learning is supported by statement 15. The statements most unlike the Scientists' own thoughts support their desire to learn new scientific knowledge and research and show they are willing to adapt their instruction to incorporate their newly acquired skills and knowledge (statements 2, 22 and 33).

Consistent with the suggestion by Kitzinger (1999), Q data for all statements for each array are provided in Figures 1 to 3. In general, the Scientists are primarily focused on science content. They seek opportunity to increase their own science knowledge and to enable authentic science learning for students (Figure 1, statement 14). The Scientists primarily value inquiry learning (hands-on teaching and learning options), experiments (over teacher demonstrations) and problem-based learning (Figure 1, statement 15). As a group, the Scientists are not content to follow a scope-and-sequence or simply do science inquiry. Rather, they are focused on learning about current science research and practice to help connect their students to real-world, cutting edge science applications and career aspirations. Data to support these conceptual themes are presented here for the ideas of real-world science and problem solving, as well as for a valuing of science content over pedagogy.

The Scientists agreed that they would all like to work with real scientists (Figure 1, statement 14). They liked to implement problem-based learning (Figure 1, statement 15). As a group, the Scientists were more interested in science content and applications that would interest students. They were less enthusiastic about pedagogy or classroom management PD, as one of their lowest scoring statements was number 40, "I really need help with managing difficult students" (Figure 1).

As focus group conversations turned to the advantages of working with real scientists, one participant, Jack (all names are pseudonyms [all participants were assigned pseudonyms]), remembered the summer the National Science Foundation (NSF) supported his Research and Engineering for Teachers (RET) program as his best PD experience. He explained, "I got to work alongside real scientists doing real research – and then being able to share out that information, you know, taking this [to the classroom]" (Focus Group, May 13, 2015). Another participant, Ted, remembered a similar program sponsored by 3M, where "…they would have science teachers come into their labs and actually be part of their on-going research – literally working side by side with their scientists, chemists [and] physicists – and tying into what the students could be doing" (Focus Group, May 7, 2015). A third participant, Kyle, appreciated a model he experienced while teaching in another state, where university professors frequented the school and "…basically, if you needed something from that university, they would come; they would be there in an instant" (Focus Group, April 24, 2015). Jack said, "We don't always have the opportunity to apply it in our classrooms because we're not going to have all the technology [or lab space] a real scientist has…but, you know, we can inspire kids and we can share some of those stories with them in classroom instruction" (statement 34) (Focus Group, May 13, 2015).

The Scientists value real-world problem solving (statements 15 and 27)**.** One participant, Debbie, explained that an introduction to hands-on, inquiry-based science teaching at the elementary level actually helped her to identify as a science teacher. Following a "focus on the kids' passions," she said, "I've become more passionate [about science] the more I've learned about it and the more I've had opportunity to teach it" (Focus Group, May 6, 2015). Debbie seeks help in managing inquiry-focused lessons when time limitations interfere with the time children need to figure things out on their own. To further explain her frustration, she noted, "Many of the investigations take longer than 30 minutes, so teachers are [telling students] how [to do the lesson] which goes against the whole [idea of] inquiry base" (Focus Group, May 6, 2015).

Kyle, a middle school teacher, lacks the equipment necessary for hands-on science lessons (statement 27). New safety regulations have limited use of "anything with flames." As he sees it, "[We] need that stuff, [but] if we have a candle [we] need to make sure that the kids are not touching the candle. My view is, if you get hurt doing science, at least you are doing science" (Focus Group, April 24, 2015). Debbie values Nebraska's Keep Improving Content Knowledge and Skills (KICKS) workshops (recent, state-funded efforts), which have helped her become a reflective teacher who "does background work to make sure I know what I am teaching before I teach [my kids] so that I'm not giving them any misconceptions" (statement 2) (Focus Group, May 6, 2015).

Valuing content over pedagogy (statements 14, 15 and 27), the Scientists seek content-focused PD. For one participant, Nate, PD has primarily involved graduate coursework. Nate pursued a master's degree because he "wanted more chemistry background." He explained, "My majors were mathematics and physics and [now] I'm teaching physical science, chemistry and sometimes biology" (Focus Group, May 7, 2015). Ted appreciates the design of the Nebraska KICKS workshop where he "literally worked through the entire state standards for 12th grade physics – what Nebraska students are expected to know in physical science and physics" (Focus Group, May 7, 2015). Ted liked working with scientists and other high school science teachers to "do it, see it and comprehend it. It's a concrete way of applying what we've just learned – a concept that our students are expected to learn" (Focus Group, May 7, 2015). Another participant, Diana, appreciated that the KICKS workshops modeled inquiry so well. As she explained, "[You experience the lesson] and then you talk about it from a teacher's perspective. That's what makes it different. I mean, you actually struggle through [the lesson], and you see the student's side" (Focus Group, May 7, 2015).

The Scientists are challenged to find practical classroom ideas (statements 14 and 15). Ted attended Nebraska Association for Teachers of Science (NATS) once but does not plan to go back: "It's in a rotten location as far as I'm concerned. It's too far away from me…and I just didn't get a lot of value out of it, personally" (Focus Group, May 7, 2015). Kyle expects he is like all teachers who want to challenge themselves to grow but warns, "You don't have to teach me classroom management" (statement 40) (Focus Group, April 24, 2015). Another participant, Ben, is familiar with PD programs offered through an early childhood training center (though not all sessions are science related). Ben doesn't choose to attend many of these programs and thinks, "Maybe I am just too picky, but they don't seem to like anything I would be interested in – I mean there are lots of sessions that I don't want to go to" (Focus Group, April 24, 2015).

Factor Array Two: The Veterans

Five teachers comprised the Veterans factor (Appendix 2). Notably, these science teachers, two elementary and three secondary, are largely urban, female teachers who hold master's degrees and science leadership positions at the building or district level. Factor 2 is one of the more experienced groups across the three science teacher factors.

Not like me — Like me

−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
7	47	(45)*	8	39	19	4	31	35	29	27
(11)*	10	5	18	(38)*	(25)*	20	23	(28)*	6	34
	(22)	2	33	17	44	32	1	(42)*	(12)	
		37	(46)*	16	(40)*	2	21	41		
			9	15	24	14	(43)*			
				36	(30)	(26)*				
					13					

Figure 2. Factor array for the Veterans. Distinguishing statements are in parentheses. All distinguishing statement z-scores are at the $p < 0.05$ level of significance.
*Statements at the $p < 0.01$ level of significance

The Veterans are primarily interested in science pedagogy and equipment. The statements identifying the Veterans (Figure 2) show the highest positive and negative values in the sort. The distinguishing statements are marked. Statements 12, 42 and 43, combined with focus group discussions (April 24, 2015, and May 6, 2016), provided the name for this group: These teachers have passed beyond the novice stage and are interested in honing their craft for all of their students' success (Figure 2, statements 30, 40 and 43). They look for opportunity to increase their science teaching effectiveness and thereby insure successful learning for all students (statements 12 and 42). As a group, the Veterans enjoy a proven track record and an established relationship with their administrators (Focus Group, April 24, 2015, and May 6, 2015). This status earns them some freedom when it comes to instructional decisions (statement 42). The Veterans are focused on learning about new science curricula and teaching materials to help meet students' needs (statement 43).

The Veterans are defined by their preference for PD that pays them a stipend and offers concrete, practical ideas for their daily classroom operations (statements 12 and 28). They also are adamant about what their needs are for PD and want to find the PD they need, not be told what they need (statement 42). The Veterans are not enthusiastic about online learning but would like to be involved in a statewide network of science educators (statements 22 and 45).

Statement array positions and z scores defined the preferences and values that guide the ways in which the Veterans seek out suitable professional development: student learning, classroom resources, and personal needs. Participants' discussion group remarks help to illustrate the Veterans' thoughts about PD (statements 12 and 43).

The Veterans prioritize student learning in choosing PD (statements 12 and 42). Linda, an elementary science teacher, didn't really become interested in science until she started teaching. Though she has never felt confident in science, as she watches her students and observes their passion, "I think, way more than I [feel]. I'm in a 3rd grade [classroom and] I feel like sometimes I'm learning along with [my students] as I teach my science" (Focus Group, May 6, 2015). One of the hallmarks of a Veteran is their interest in successful science teaching with diverse students (statement 42). As Rhonda, an elementary science specialist explained,

> I am willing to take that shot so that kids get more exposure to science. Because I have some difficult students that I deal with and … they come to me without very much support, because this is the one place in the building where they can be successful and feel that they are successful. (Focus Group, April 24, 2015)

Though the district does not provide any special assistance, these children don't seem to need additional support because "science is so interactive they can find a way to be successful" (Focus Group, April 24, 2015).

Classroom resources are another draw to PD for the Veterans (Focus Group, April 24, 2015). Deanna, a secondary science teacher, has found a valuable learning opportunity for herself and her students. As a dual-enrollment instructor for a local university, she has earned access to the University of Nebraska-Omaha's Glacier Creek Prairie Preserve. This resource enables her to help lessons come alive. She is "…actually [able to] go out and do on-site data collection, [using vocabulary words like] biotic and abiotic factors [while] collecting specimens and trying to get a little bit of a ballpark [figure on the] density of undergrowth and what insects might be out there" (Focus Group, May 6, 2015).

As a group, the Veterans seek specific learning and have trouble finding what they need at district or state sessions (statements 12 and 43). For example, one participant, Linda, was just beginning to use science notebooks in her classroom, so she chose to attend a NATS conference session to learn more. Linda said, "This lady was presenting on science notebooks and I [immediately thought], 'You're making a scrapbook!' I mean, everything was just a picture here and a picture there" (Focus Group, May 6, 2015). Linda was frustrated and confused since her understanding about how to use science notebooks included more than simple picture collections and wondered, "Is this what I'm supposed [to be doing]?" (Focus Group, May 6, 2015). She was especially confused since this was a NATS presentation. Deanna referred to difficulty in finding PD that matches her needs and suggested, "I [look to] my science colleagues right there in the building with me. We often bounce ideas off of each other and act as [each others'] sounding boards" (Focus Group, May 6, 2015).

PD must cater to these teachers' needs. Deanna wants lots of options so she can meet her individual professional needs. She expressed frustration with finding an appropriate level of PD "…because I am sure what you need in the fifth grade is very different from what I need in the high school level" (Focus Group, May 6, 2015). As she further explained,

> I've attended NATS over the years, and if I walk away with one good secondary session, I'm pretty happy. Most of the time, I'm…thinking, "OK, how can I somehow modify that and incorporate that into my classroom?" I've actually had more success attending the Nebraska Association of the Gifted (NAG) annual conference [adapting strategies for accelerated learners] to the secondary level. (Focus Group, May 6, 2015)

Another participant, Paige, prefers summer PD that is 3 to 4 days long, "something that continues on into the school year, something to hold you accountable." In her thinking, "that is where you learn and grow, if you actually have to take it to your classroom [and] use it. Some of those things that I have developed…I still pull out and use, because I had to develop them [myself]" (Focus Group, April 24, 2015).

Science pedagogy is another component these Veterans look for in their PD choices (statements 12, 42 and 43). One participant, Rhonda, finds there is very little science-specific PD. When she heard about a possible science program comparable to Math in the Middle (a graduate certificate program at the University of Nebraska-Lincoln), she thought, "Oh my gosh, finally this is something I would love to do… [I'm] always looking for those things just to better myself, better my kids, so that science doesn't get pushed aside for reading and for math" (Focus Group, April 24, 2015).

Deanna discovered a very practical application for Vernier probeware. She learned to use Vernier probes with her AP students. As she explained, "It's just instant graphing and we can go right into [it]." She finds it helps her students do more science in a shorter period. For example,

> There are times where we go through the lab…my students need to know how to do an enzymatic rate that would take more than 45 minutes to do the whole project. I make them do it so they understand the procedure and why we're doing each step. But with the Vernier probes, I actually give them the data to use when they're forming their conclusions [so they can] analyze an enzyme on day 2 and have it be at the same rate as the enzyme on day 1. (Focus Group, May 6, 2015)

Factor Array Three: The Entrepreneurs

Seven teachers comprised the Entrepreneurs factor: two elementary and five secondary, largely rural, female teachers who do not hold master's degrees or science leadership positions at the building, district or state level. This was one of the more experienced groups across the three science teacher factors (Appendix 2).

Not like me — Like me

−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
(47)*	5	33	(10)*	15	13	32	1	(4)	6	(23)
7	43	18	26	8	(35)	30	38	29	34	27
	(42)*	(11)*	(40)*	28	45	24	(36)*	3	(25)*	
		2	(20)*	17	19	31	12	14		
			37	16	(22)*	39	46			
				(44)	(41)	21				
					9					

Figure 3. Factor array for the Entrepreneurs. Distinguishing statements are in parentheses. All distinguishing statements z-scores are at the $p < 0.05$ level of significance.
*Statements at the $p < 0.01$ level of significance

The statements that identified the Entrepreneur factor show their preference for new ideas and collaboration in PD opportunities (Figure 3, statements 4 and 36), which led to the name given this factor. With their experience, professionally and educationally, these teachers understand the value and purpose of PD (statements 4, 25 and 35). They know what kind of PD fits their own learning and learning needs (statements 23 and 36) but also accept guidance in choosing PD (statement 42).

The Entrepreneurs are primarily interested in adopting fresh, new science teaching strategies (statements 4, 20, 35 and 36). As a group, the Entrepreneurs are not content to continue teaching the same old lessons in the same old ways (statement 36). They seek opportunity to explore innovative teaching practices and to interact with other science teachers and scientists in the process (statement 25 and 36). The Entrepreneurs primarily value student outcomes, as they expect fresh, new ideas will increase their effectiveness with all students (statement 35).

The Entrepreneurs prefer hands-on activities in their PD to provide follow-up afterwards either through mentorship or onsite support (statements 23 and 25). They disagree with the Veterans in that they wouldn't mind being told what they need in terms of PD, and they do believe they have time for PD as well (statements 42 and 47).

The Entrepreneurs look for new ideas (statements 4, 25 and 36). One participant, Dana, said, "We learn more from watching other [classroom] teachers than we do ever from somebody who's out writing a book and hasn't been in a classroom for 12 years because classrooms change over time" (Focus Group, May 12, 2015). Dana is looking for new ideas in science PD. She clarified, "I sometimes feel like, the longer I'm in teaching, the more I just do the same thing the same way over and over again. Sometimes, I may know the material, but it's nice to see a new way that it's presented" (Focus Group, May 12, 2015). Another participant, Laura, appreciated an opportunity to participate in a PD program called Coached Science Inquiry (CSI), where she worked with a mentor teacher who would review Laura's teaching videos and guide her personal reflection over a 2-year period. She explained, "It's been one of the most valuable programs I've participated in because you can sit back at the end and go, 'Oh! That worked well with that class'" (Focus Group, May 12, 2015). Mandy, an experienced fifth-grade teacher, is new to science teaching and looking for PD to help increase her science teaching effectiveness. As she explained, she knows some science but not the science she is expected to teach:

> I think I'm different than all the rest of you because [science teaching] got dumped in my lap. I actually love sharks. I love to teach sharks to Nebraska kids [but] as far as weather and levers and pulleys, I knew nothing – and when we divided up the science curriculum, I ended up with this (Focus Group, May 7, 2015).

Mandy is looking for new ideas and strategies for teaching science building-wide (grades K to 5). Her goal is to "have the kids leave our elementary schools liking science" (Focus Group, May 7, 2015).

The Entrepreneurs are eager to collaborate with others during and after their PD events (statement 25 & 36). One participant, Kasey, prefers prolonged workshops and opportunities to learn with other teachers like herself. She is teaching AP Chemistry for the first time and had a good experience in a recent summer workshop: "It was a 4-day summertime workshop with a general chemistry professor [who] really understood the curriculum [and] it was all high school teachers, some who had taught AP Chemistry and some who had not" (Focus Group, May 6, 2015). Another participant, Laura, spoke of the importance of ongoing support:

> It is pivotal because [when] you go back and digest it [you] might have a couple questions and…you can ask people [for help]. So, if there's something like a forum online [to get] people together for that continuation, it [works] well and I think that's essential. (Focus Group, May 12, 2015)

Consensus and Perceived Limitations

Several statements showed consensus across the group of participants (n= 29) (Table 1). Teachers shared agreement with statements related to the (1) importance and value of PD (Table 1, statement 6, array positions 5, 4 and 4 for factors 1, 2 and 3, respectively; statement 29, array positions 4, 4 and 3 for factors 1, 2 and 3, respectively) and (2) internet and social media as PD delivery systems (Table 1, statement 37, array position -2, -3 and -2 for factors 1, 2 and 3, respectively). However, the Scientists, Veterans and Entrepreneurs considered these options from different perspectives. Here we present the agreed-upon statements (with similar or identical array positions) and some contextual details about the different wants and needs of teachers across the three factors to explain how different teachers might seek the same PD options but for different reasons (Table 2). This section details some additional concerns and limitations teachers introduced during the open-ended focus group discussions.

As stated, all the participants value PD and think it is important (Table 1, statements 2, 4, 6, 42 and 47). The focus group discussions yielded stories and comments from the teachers to further explain how they might share the same, but different, ideas about the value of science teacher PD.

For example, Scientist Ted, a high school science teacher, expressed enthusiasm about his new foray with the Cosmic Ray Observatory Project (CROP) sponsored by the Department of Energy and University of Nebraska-Lincoln (UNL) Physics Department. As Ted explained, both he and his students will learn from UNL physicists about how to install and read school-based monitors to study the frequency and strength of cosmic rays, which cause large scale disruption within the atmosphere. And, most important, Ted exclaimed, "[My students] get to understand why it matters" (Focus Group, May 7, 2015). This project will allow Ted and his students to learn about new scientific research and work as citizen scientists to help collect data.

Veteran Paige, a middle school science teacher, explained she had recently visited with the Vernier (sensors and probeware) sales representative at a conference sponsored by NATS. She learned, "I have some of the old [Vernier] equipment, and he says it can be used with the [new software]. But how? I mean it would take some practice using that stuff so you [could] know how to teach it to the kids" (Focus Group, April 24, 2015). This PD opportunity aligns with Paige's quest to access new teaching materials to improve student learning.

Entrepreneur Mandy, the experienced fifth-grade teacher new to science teaching, was frustrated by her students' recent scores on the Nebraska Educational Science Assessment (NESA). She explained her need to learn successful strategies for her students:

> I would like some help as a science teacher trying to be better and better at what I do. Several of you have mentioned things [like] we need to teach the primary vocabulary. What I need is professional development [about] what I can give my kids to (a) help them love science and not feel like they're idiots, and (b) prepare them for your crankshafts [when they get to high school] because I'm floundering here. (Focus Group, May 7, 2015)

Participants understood the need for social media as PD delivery systems but preferred different aspects of social media to meet their needs (Table 1, statement 37). The focus group discussions yielded stories and comments from participant teachers that can help to explain how these teachers share the same, but different, ideas about their value of the Internet and social media when it comes to professional development options.

For example, Scientist Jack wants PD to be relevant, to "bridge the gap between our books and the real world" (Focus Group, May 13, 2015). Jack expects science teachers would like to incorporate real-world problems in their classroom, but "sometimes we don't even know about what's going on in manufacturing [or] what's going on in the chemistry world [for example]" (Focus Group, May 13, 2015). He worries that teachers don't really know how to teach students about cutting-edge science (if they haven't had some personal experience with it themselves). He points to nanotechnology:

> I don't know about nanotechnology [but] I would love for my kids to learn more about it. I can tell my kids about it. I can show them a video. I can connect them to stuff on the Internet, but I cannot be the expert. And I think that's kind of where professional development [can help]. How can we teach it to our kids in a way that's hands-on, that's real [and] not just some worksheets and a video? (Focus Group, May 13, 2015)

Nate seeks opportunity to engage students in real research to help students understand, but they need active involvement:

> Science isn't [just] reading stuff out of a book, memorizing facts [or learning] the laws. It's applying knowledge, solving problems, asking questions, and figuring out methods of solving problems. If we could get that incorporated, that would be pretty cool professional development (Focus Group, May 7, 2015).

Veteran Josh depends on PD that gives him the opportunity to observe and glean support from a model teacher. He was particularly impressed by a recent physics teacher:

> He showed us specific things he does, and I see that and I'm thinking, "Okay that's something I could take directly [to the classroom] as is. And then from that I can

> use [his] ideas to make better lesson plans just from seeing a good one in action." (Focus Group, May 7, 2015)

Entrepreneur Paige explained, since she doesn't have a physics background, she does not know how to use some of the physical science equipment in her closet. She exclaimed, "I know that you can probably do some really cool things, but I don't know what those are. I don't know how to work all of that [equipment] or even what it is exactly" (Focus Group, April 24, 2015). This hands-on learning need would be difficult to fill via Internet or social media.

Entrepreneurs Sally and Paige have attended KICKS for 3 years. They value the learning and the sharing with fellow teachers. Sally says, "It has been incredible because we've learned a lot of content, we have taken activities back to our classrooms, and we have networked and that is great" (Focus Group, April 24, 2015). Deanna claimed it helps to attend workshops with other teachers like yourself and, "the closer the match the better" (Focus Group, April 24, 2015). She clarified, "You walk away with more than one idea and resources – and you network as well" (Focus Group, April 24, 2015). Kasey looks to the College Board AP community where you can go to a blog and "get immediate response from more experienced teachers, and I think that's really helpful for teachers who are asked or told they're going to teach the AP level [but] don't really have the experience to teach it" (Focus Group, May 7, 2015). Sometimes, Entrepreneurs find the collaborative support they need right across the hall. Mandy teaches across the hall from a life-skills class for students with special needs, where there are nine one-on-one paraprofessionals. When Mandy and her students were building a weather station, she invited the life-skills students and their paraprofessionals to come outside to help her class. She elaborated:

> So, we had lots of help building our weather station, which was great for me and my kids, but the life-skills kids still go out to their weather stations and keep their weather charts. [This collaboration] worked for the benefit of them and most definitely for my kids. (Focus Group, May 7, 2015)

Discussion

We set out to understand how Nebraska science teachers find and choose PD that fits their personal and professional needs in order to advise the Nebraska CSMCE and others on how to improve science teacher PD in Nebraska. We identified three factors that define the interests and beliefs of science educators who participated in the Q sort and discussions: the Scientists, the Veterans and the Entrepreneurs. These factors organize the lens by which these teachers choose PD activities:

1) The Scientist values the content and working with real scientists. Preferred PD for the Scientists would include science fieldwork as well as opportunities to build science content knowledge and engage in real-world science problem solving.

2) The Veteran values science pedagogy and teaching materials. Preferred PD for the Veteran would include interactions with science teaching resources and materials, a focus on student learning success and provision of a stipend.

3) The Entrepreneur values innovative science teaching strategies. Preferred PD for the Entrepreneurs would include opportunities to interact with others, such as scientists and science teachers, to help them stay on the cutting edge of their practice.

A view of the consensus areas between and across the groups identified ways in which these teachers' motivations (according to their own specific type) might provide insight into the ways one could design science teacher PD that addresses teacher needs across the factors. These consensus areas are particularly helpful in that they detail the ways different teachers might find value in the same PD experience but for different reasons. Focus group discussions enabled study participants to raise concerns not directly prompted by the Q sort. These concerns draw attention to some important issues related to Nebraska teachers' participation in science PD. Some of these are logistical in nature (i.e., scheduling and communications), while others point to science-unique concerns related to students with special needs and AYP calculations (i.e., pedagogy and support). These teacher participants help us to better understand their personal and professional needs and enable PD providers to match programming to teachers' needs.

Our results align with some prior research. As other researchers have determined, and these Nebraska teachers recognize, long-term PD programs (such as KICKS and CSI) help to increase teachers' content knowledge and improve instructional strategies. We determined, as did Hobbs and Moreland (2009), that a "one-size-fits-all" science teacher PD approach is ineffective. In our analysis, however, teacher participants did not sort into simple demographic groups (by age, teaching experience, regional location) but rather by professional teaching and learning values, which cut across demographic descriptors. These research results are unique and add new understanding to the multiple realities science teachers face when seeking PD that fits their personal needs.

Recommendations

Below we have organized our research results to recommend ways science PD providers in Nebraska might approach future programming to meet the preferences and needs of Nebraska science teachers: combined options that appeal to multiple teacher values and preferences, expanded options to include virtual technologies, improved promotion strategies to insure teachers learn about PD opportunities and coordinated efforts. As we intended, the descriptive data here may aid the transferability of these findings and help others consider similarity in new contexts (Stake, 1978). Thus, these science teacher factors may well resonate with a broader audience of science PD providers and thus help guide development of science PD beyond the state of Nebraska.

Providers of PD may use the typology consensus framework in designing their programs. Successful PD models might wisely incorporate options that appeal to multiple teacher values and preferences. The three teacher factors identified in this study can help guide PD design and management that align with the varying needs of PK-12 science teachers. While the three factors can help providers organize workshops and programs for unique groups of teachers, the consensus areas could guide purposefully selected features to help attract a broad group of teachers. As the consensus items across the Scientist, Veteran and Entrepreneur prototypes suggest, some might choose to provide a PD session that includes updates on current research, introduces new teaching materials/equipment and models new teaching practices to appeal to teachers across groups. Teachers will sign up for different reasons: the Scientists will be interested in the cutting-edge science, the Veterans will be seeking the new materials and resources, and the Entrepreneurs will be enthusiastic about the opportunity to gather innovative science teaching ideas. Others might choose to organize ways to mentor scientists and science teacher educators on the inclusion of these features in Nebraska science PD.

PD providers may want to explore virtual options. Expanded science PD options will necessarily require the use of virtual technologies that help offset teachers' time out of the classroom or away from families. While not all valued PD experiences can be supported via virtual systems, CSI and KICKS programs have successfully accessed virtual systems to support personalized coaching support. The University of Nebraska-Lincoln Center for Science, Mathematics and Computer Education might encourage exploration of virtual options to manage for teachers' issues and concerns related to scheduling and availability. Professional Development providers might consider a blended approach, wherein some of the PD is delivered virtually (the content perhaps), with face-to-face follow-up options designed to appeal to each of the three factors of teachers: the Scientists might visit university researchers' labs, the Veterans might interact with new classroom teaching materials and the Entrepreneurs might work with a master teacher to explore related pedagogical practices.

Professional development providers should improve the communication of their opportunities. We were surprised to discover the magnitude of teacher concerns related to science PD communications; it seems some teachers are connected (to listservs or email lists), while others are not. In general, teachers did not seem to know how to *get* connected – rather, it seemed teachers considered such connection a mysterious matter of chance. Given that good communication is an imperative to science teachers' PD enrollment, we recommend improved plans to advertise and promote PD options. Since the current Nebraska system largely depends on administrators' and curriculum coordinators' forwarded emails, state leaders might combine efforts in developing and maintaining an email list that goes directly to science teachers. Another idea would be to develop a shared website or portal to help all PD providers advertise programs in one place (and teachers could learn where to find information). Sorting systems should enable teachers to match their needs to PD opportunities.

The Center for Science, Mathematics and Computer Education should lead the coordination of statewide science PD opportunities. In its current mode, multiple groups are working independently to organize and support limited Nebraska science PD options. These include the Nebraska Department of Education (NDE), Nebraska Association of Science Teachers (NATS) and Educational Service Units (ESUs), as well as some school districts. The Center for Science, Mathematics and Computer Education might lead collaborative efforts to increase the number of PD options and maximize the quality of PD experiences across the state. In this, CSMCE might encourage leaders to revisit historic operations (such as meeting venues and locations). Perhaps NATS could sponsor sessions at Nebraska Educational Technology Association (NETA) or Nebraska Association for the Gifted (NAG) conferences. Perhaps NATS, ESUs and the NDE could work together to organize regional science PD

Long-term solutions may require a policy change. Though current research points to a positive relationship between content knowledge and teacher effectiveness (Darling-Hammond, 2000; Davis, Petish & Smithey, 2006; Herman, Clough & Olson, 2013), current Nebraska policies and regulations delimit opportunity (via minimum requirements for licensure and continuous certification) for Nebraska science teachers to gain and grow their science content knowledge and pedagogical practices. It may be that current Nebraska policies in teacher certification requirements serve to undermine science teachers' continuous PD. As Cochran-Smith & Villegas (2014) argue, policymakers need to engage in a review of research regarding the content and pedagogy teachers need to define and implement highly effective teaching practices. Policymakers who ignore these research data "set insufficient minimum requirements for teacher licensure and make teacher education a 'race to the bottom'" (Olson et al, 2015, p. 24).

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Appendices

Appendix I: Q Set

*1. I look forward to reconstructing and refining my current understanding of science teaching practices.
2. I avoid PD when the focus is on changing my ideas, attitudes, and perceptions.
*3. I value time to exchange ideas with other teachers.
4. It's a good way to grow personally and professionally.
5. I gain more from my reflections in the classroom than from organized PD.
*6. I am genuinely interested in learning.
7. What I am doing in my classroom is already better than anything I might learn.
*8. I need to learn how to integrate other disciplines into science content.
*9. Interdisciplinary PD allows time with other teachers in my building.
10. I avoid incorporating science field work in my curriculum.
11. I feel a little nerdy about learning.
12. I seek concrete and practical ideas relative to day to day operation in my classroom.
13. I would like to incorporate more technology into my classroom.
14. I would like to work with real scientists.
15. I would like to implement problem-based learning.
*16. I'd rather observe another teacher to get more ideas and reflect on my own teaching style.
*17. One-to-two-hour sessions rarely give me enough information.
*18. I prefer to attend PD online, so I can set the meeting time according to my personal calendar needs.
*19. I look for a series of PD topics to deepen my understanding.
20. When it comes to science PD, I prefer content focus as opposed to teaching focus.
*21. I want lots of choices in PD options.
22. I find it hard to learn online.
23. I like hands-on activities.
24. I prefer PD held near my home or school.
25. PD should provide continuity, follow-up, and onsite support.
26. I especially like PD that offers course credit.
27. I like PD that provides materials for my classroom.
28. I am more likely to participate when I am paid a stipend.
*29. It's my professional responsibility to explore and learn new ideas to keep my teaching fresh.

30. It's important to discuss problems facing todays' children and youth in a group setting with other teachers.
31. I enjoy solving problems that students experience.
*32. Give me many and different instructional strategies to challenge students.
33. It would take long-term support for me to effectively differentiate instruction to match student needs.
34. Ideas gained, and skills learned help enhance my effectiveness with <u>all</u> students.
35. Student learning is the most important outcome of teacher PD.
36. Coaches or mentors help me continue innovative practices.
*37. Why don't we do more with social media and collaboration?
38. I value structured opportunities to improve my teaching practices.
*39. Wouldn't it be great to learn alternative ways to assess student knowledge?
40. I really need help with managing difficult students,
41. It is essential to match instruction with diverse student needs.
42. Don't tell me what I need! Let me find a spot (along the continuum of PD needs) that fits me.
43. Professional development must be differentiated to my needs.
44. I have the leadership skills to actively participate in a network of teachers and scientists across the state.
45. Professionalism for me is to be involved in a statewide network of science educators.
46. Create an innovative structure for teachers to collaborate in same content areas across regions.
47. I don't have time for PD.

*Consensus across the three arrays. Statements 1, 3, 16, 18, 19, 21 and 39 were also non-significant

Appendix II: Factor Matrix Identifying Defining Sorts and Demographic Description by Sorter

Factor (Individuals)	Factors Loadings			Number total, n	Science Teaching Experience, (Average ± SD)	Master Degree	Urban	Female	Elementary, K-6
	1	2	3						
Scientist	-	-	-	8	7.75 ± 3.96	7	2	2	4
Ben	**0.5364X**	0.3536	0.0242	-	11	X			X
Kyle	**0.8707X**	0.1814	0.2075	-	4	X	X		
Debbie	**0.6368X**	0.3362	0.3502	-	9	X		X	X
Daniel	**0.6514X**	0.4057	0.3538	-	4	X			X
Mattie	**0.5576X**	0.3488	0.3390	-	2	X		X	X
Nate	**0.6547X**	-0.2493	0.3242	-	8	X			
Ted	**0.7012X**	0.0439	0.2536	-	12				
Jack	**0.5010X**	0.3753	0.3049	-	12	X	X		

Factor (Individuals)	**Factors Loadings**			**Number total, n**	**Science Teaching Experience, (Average ± SD)**	**Master Degree**	**Urban**	**Female**	**Elementary, K-6**
	1	**2**	**3**						
Veteran	-	-	-	5	12.00 ± 2.83	3	4	4	2
Paige	0.0673	**0.6435X**	0.3505	-	9			X	
Rhonda	0.4511	**0.549X**	0.2462	-	11	X	X	X	X
Deanna	0.3519	**0.6817X**	0.2324	-	15	X	X	X	
Linda	0.1486	**0.6117X**	0.1916	-	15	X	X	X	X
Josh	0.1212	**0.6976X**	0.1702	-	10				
Entrepreneur	-	-	-	7	11.22 ± 10.56	2	2	7	2
Sally	0.3770	0.2620	**0.4919X**	-	15		X	X	
Laura	0.2770	0.3484	**0.6794X**	-	24			X	
Dana	0.4466	0.0556	**0.5655X**	-	24			X	
Kasey	0.0901	0.0757	**0.8067X**	-	11			X	
Sophia	0.2180	0.1774	**0.6462X**	-	5	X		X	X
Candy	0.2167	0.3511	**0.6486X**	-	31		X	X	
Mandy	0.317	0.2406	**0.6491X**	-	3	X		X	X
Confounded	-	-	-	8	18.75 ± 9.32	7	0	7	3
Nicole	0.6646	0.0771	0.5818	-	33	X		X	X
Jacob	0.4261	0.3871	0.4218	-	33	X			
Joyce	0.0119	0.4751	0.6791	-	19			X	X
Todd	0.5798	0.5244	0.2049	-	11	X			
Jasmine	0.6432	0.5209	0.0271	-	19	X		X	
Margaret	0.4881	0.2930	0.4619	-	16	X		X	X
Tammy	0.3675	0.5200	0.5143	-	32	X		X	
Jane	0.3702	0.4900	0.4867	-	12	X		X	
Noelle	0.4978	0.4086	0.4776	-	8	X		X	