

**Science and Mathematics Teachers' Views of the Characteristics of Effective
Professional Development: A Q Methodological Study**

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Abstract

Education researchers regularly seek to evaluate and define what encompasses successful professional development (PD) for teachers. Numerous items and lists that are considered the *characteristics of effective PD have emerged from this research*. However, follow-up with teachers on their perceived views of these characteristics is lacking from the literature. Teachers can help determine which aspects should be considered in the design of high-quality professional learning in the future. For this study, Q methodology was utilized to examine the subjective views of the teachers. Q sorts were correlated and factor analyzed (PCA with cluster rotation) to extract four significant factors on which all 17 participants loaded significantly (McKeown & Thomas, 2013; Newman & Ramlo, 2010; Watts & Stenner, 2012). These factors were examined through the lens of andragogy (adult learning theory) to determine the connections between the characteristics of effective PD and the core adult learning principles. Teachers in this study perceived effective PD as those opportunities that establish cooperative learning amongst participants, focus on improved student learning outcomes, provide opportunities for feedback, and allow for ongoing support. Future research is needed to see if the results obtained apply to other teacher populations.

Keywords: Q methodology, teacher professional development, mathematics/science education, andragogy, adult learning

Teacher professional development (PD) is considered an essential part of continual renewal in education. PD focused on pedagogical practice has improved teacher efficacy in classroom practice (Main et al., 2015; Desimone, 2009). In turn, teachers with higher self-efficacy are more confident in their practice, leading to increased levels of student achievement (Lakshmanan et al., 2011). Evidence also suggests that teacher participation in PD opportunities can lead to overall school improvement (Soine & Lumpe, 2014).

When designing and facilitating PD activities for teachers, the goal should be to ensure that the learning opportunity meets the needs and learning styles of participants. Learning should focus on the individual perspectives of teachers (where they can experiment, reflect, and request feedback), as well as on group-level perspectives where teachers are encouraged to collaborate to advance their teaching practice (Borko, 2004).

Numerous characteristics of effective PD have been identified in the literature. Guskey (2003) identified 13 lists of characteristics of effective PD, and Darling-Hammond and colleagues (2017) reviewed over 35 “methodologically rigorous” (p. v) studies to seek characteristics that would define a PD initiative as effective. Some lists of characteristics are developed by examining studies that purport successful outcomes in linking PD, teaching practices, and student outcomes (Darling-Hammond et al., 2017). Many of these lists have been developed by examining teacher responses to feedback surveys and researchers' interpretations of those opinions (Guskey, 2003).

Literature Review and Theoretical Framework

In this section, we review the research on reasons why PD is promoted for science and math educators at the K-12 level, as well as what has been deemed the characteristics of effective science and math PD. We then define what andragogy, or adult learning theory, may offer in understanding science and math teachers' perceptions of the characteristics of effective PD.

Why Teachers Seek PD

Science and math educators regularly seek out PD to fulfill their own needs and goals (Saka, 2013). For most teachers, PD is a required aspect of their jobs. As an example, science and math teachers in New York State holding teaching certification are required to complete regular formal PD to retain their certification(s) (NYSED, 2018). While teachers may have some choice in the PD they participate in, they are often required to attend PD designed with a top-down approach that does not consider the classroom needs of subject-specific teachers, like those teaching science and math (Buczynski & Hansen, 2010; Jeanpierre et al., 2005).

Best practice would suggest that school administrators can help promote PD models that consider the organizational context, culture, and climate in which teachers and administrators work (Drago-Severson, 2000). It seems the individuals that would best know this are those on the front lines of education: the teachers themselves. As such, literature recommends that science and math PD should shift away from top-down approaches to promote self-directed learning (Huang et al., 2022).

Concerns with PD

Not all PD is equally effective in improving teacher quality (Soine & Lumpe, 2014). In considering the PD science and math teachers are asked to participate in, it quickly becomes evident that in many instances, they are not consulted on the validity of this training to their contextualized needs (Lieberman, 1995). Additionally, the learning needs of science and math teachers, who likely have rich content knowledge, may require targeted support in implementing current educational reform related to their content (Arbaugh et al., 2016). Put simply, science and math teachers who are disciplinary experts in their field still need personalized and relevant learning opportunities that incorporate new reform (Ma et. al., 2018).

Furthermore, there have been issues in evaluating science and math teacher development. Evaluations of PD often measure a single event and do not consider the wide variety of opportunities in which teachers may participate (Radloff et al., 2023). Therefore, isolating a single program's effects can be challenging. Blank (2010) suggests evaluation methods for improvement initiatives must be tied closely to findings from leading research.

Understanding what aspects of science and math PD are effective for the recipients is imperative, considering the amount of money spent each year to fund these opportunities. The amount spent on PD for all teachers each year is estimated to be between \$1-4 billion (Wilson, 2013) to \$6-8 billion (Edgerton et al., 2017). This sort of investment warrants further attention.

Characteristics of Effective PD

As mentioned previously, scholars have drafted several lists of characteristics of effective teacher PD that intersect with science and math contexts. Guskey (2003) referred to at least 13 lists of characteristics that arose from the evaluation of professional learning opportunities using teacher reflections, classroom observation, and student assessment data (Fishman et al., 2003).

From this work, it is necessary to highlight a few core ideas that apply to science and math PD. For one, the literature suggests that PD is more effective in modifying teachers' practice when there is collaboration among peers (Capobianco et. al, 2021; Darling-Hammond et al., 2017). This involves the participation of teachers from the same school, department, or

grade (Desimone, 2009). Other key features include providing content-focused and active learning, providing coherence with teachers' classroom practice, and ensuring there is extended duration for learning beyond brief workshops (Darling-Hammond et al., 2017; Nadelson et al., 2015). PD should also model effective pedagogy and provide opportunities for ongoing collaboration (Main et al., 2015; Darling-Hammond et al., 2017; Garet et al., 2001).

Andragogy (Adult Learning Theory)

To delineate a framework for this study, we considered the goals of PD and teacher learning, positioning science and math teachers as adult learners. Most in the teaching field are familiar with the term pedagogy, which is typically what an educator considers in the content delivery method to students (Ball & Forzani, 2011). Pedagogy was the sole theoretical framework for education well into the 1900's and was included in references to educating adults (Knowles, 1978). However, studies have shown that a different approach is required when working with adults (Falecki & Mann, 2020). Thus, the term andragogy, a unified theory for adult learning, came into being (Knowles, 1978).

In designing learning opportunities for adults, a fundamental difference is that adults are self-directed and expect to take responsibility for decisions (Smith, 2002; Gravani, 2012). Adults approach learning from a different stage in their lives, and often have limited time to devote to learning. PD is not typically provided during the school day, but rather before or after. Additionally, teachers may be balancing child care and possible financial or family issues, while perhaps reflecting upon previously attempted professional learning that did not go well. (Giannoukos et al., 2015).

Knowles and colleagues (2015) provide for six core adult learning principles. These include:

1. Learner's need to know (why, what, how)
2. Self-concept of the learner (autonomous, self-directing)
3. Prior experience of the learner (resource, mental model)
4. Readiness to learn (life-related, developmental task)
5. Orientation to learning (problem-centered, contextual)
6. Motivation to learn (intrinsic value, personal payoff) (Knowles et al., 2015).

Recognizing science and math teachers as adult learners, these six core principles were used in the current study to evaluate participants' examinations of characteristics of effective PD.

Study Rationale

Applying a novel lens of andragogy, the purpose of this research was to examine teachers' perceptions of the aspects or characteristics of effective PD as defined by research literature. As stated above, teachers need relevant and contemporary reform-based PD opportunities that incorporate their personalized needs. As such, this new research aims to identify which currently defined characteristics of effective PD teachers most and least identify as crucial to their growth. This information can be extremely helpful to individuals who create and facilitate teacher PD opportunities.

In a thorough literature review of math and science PD research, no studies were found that ask teachers to reflect on what researchers have identified as aspects of effective PD. However, researchers in one study (Brown & Militello, 2016) selected 34 aspects of effective PD and asked school principals to consider the statements in order to “understand the perceptions principals have about elements of effective PD and the role they play in facilitating the growth of teachers” (Brown & Militello, 2016, p. 703).

While principals certainly play a role by often determining what PD teachers can participate in (Patton et al., 2015), it would seem necessary to first understand teachers' perceptions about the elements of effective PD as determined by researchers. This study does not aim to refute the 34 aspects of effective PD that were used for Brown and Militello's purposes. Instead, we seek to use these 34 aspects to understand teachers' perceptions through a lens of andragogy (rather than their administrators'), as teachers are the end users of PD.

Considering the effective elements of PD using a theoretical framework of adult learning theory as it intersects with science and math teacher PD, this study seeks to answer the following three questions:

1. What characteristics of effective PD do science and math teachers perceive as important for building teacher capacity and effectiveness?
2. What connections exist between the characteristics of PD teachers view as effective in their learning and the core adult learning principles?
3. Compared to Brown and Militello (2016), what are the similarities and differences in the perceptions of the characteristics of effective PD when the same Q sample was used with a teacher sample (thereby comparing teacher perceptions with principal perceptions)?

Methods

Overview of Q Methodology

Q methodology is utilized to understand peoples' perceptions on a particular topic (McKeown & Thomas, 2013). The use of this method began in 1935 by William Stephenson and is an adaptation of Spearman's method of factor analysis (Watts & Stenner, 2012). Through a set of procedures, a participant takes a sample set of statements (known as the "Q set") that is meant to be a representative sample of all statements on a topic, and ranks these statements in a significant order (Brown, 1980). In this study, statements are ranked "Most Identify With" to "Least Identify With", in an array referred to as a Q sort (Brown, 1980). The Q sort provides the subjective view of the participant on the topic being studied (Watts & Stenner, 2012). Once the Q sort is obtained from a participant, then the information collected is subjected to a set of 3 statistical operations that include correlation, factor analysis (principal components analysis), and computation of factor scores (McKeown & Thomas, 2013). This study employs Q methodology to better understand teachers' perceptions of what they consider characteristics of effective PD.

Q Set Design and Content

Following Brown and Militello (2016) who explored principals' perceptions of effective characteristics of PD, teachers responded to a survey that consisted of the same set of 34 validated statements (see Table 1) given to administrators in previous work. Brown and Militello's (2016) research was the first of its kind to both synthesize previously defined characteristics of effective PD, as well as to ask about stakeholders' own perceptions of those aspects. Here, we sought to ask teachers (rather than administrators) about these pre-defined aspects, while also recognizing teachers as adult learners in their field with specific and personalized needs (e.g., through a lens of andragogy). That is not to say the 34 aspects connect with andragogy, but rather that it can be assumed that teachers appraise these statements as adult learners. The goal then was to answer our three research questions by comparing the results of our administration of the Q set to teachers with the results Brown and Militello (2016) obtained by administering the survey to principals. In the current study, teachers sorted these statements and answered supporting open-ended questions that asked for their rationale(s) for their sorting.

Table 1***Concourse Statements***

Label	Statement
s1	Effective professional development involves visiting other schools.
s2	Effective professional development is research-based and built upon theory.
s3	Effective professional development involves observing other teachers.
s4	Effective professional development invests in the change process to impact student knowledge and skills.
s5	Effective professional development sustains a consistency of focus over time.
s6	An effective element of professional development is personal focused reflection.
s7	Effective professional development requires participants to be involved in the planning, implementing, and evaluating of programs.
s8	Effective professional development includes follow-up and support for transfer of learning to the school or classroom.
s9	Effective professional development includes coaching from a peer or mentor.
s10	Effective professional development involves professional learning communities with sources outside of the school.
s11	An effective element of professional development is providing constructive feedback on instructional practice.
s12	An effective element of professional development is providing a mentor to new teachers.
s13	Effective professional development includes time to collaborate with peers.
s14	Effective professional development utilizes grade level/department professional learning communities.
s15	Effective professional development focuses on curriculum and instruction.
s16	An effective element of professional development for teachers is to conduct differentiated sessions based on career stages, with specialized training for aspiring, new, and experienced teachers.

s17	Effective professional development exposes teachers to actual practice than to descriptions of practice.
s18	Effective professional development focuses on instructional strategies.
s19	An effective element of professional development is the inquiry process.
s20	State and national conferences are an effective form of professional development.
s21	An effective element of professional development is to have all-day and multiple-session meetings over an extended period of time.
s22	Effective professional development should only focus on a few concepts at one time.
s23	Effective professional development links directly with day-to-day work in real schools and classrooms.
s24	Effective professional development includes providing time, contexts, and support for teachers to think.
s25	Effective professional development includes an analysis of student work samples.
s26	Professional Learning Community book studies are an effective form of professional development.
s27	Effective professional development for teachers is university courses.
s28	Effective professional development includes providing opportunities for shared problem-solving.
s29	Effective professional development is embedded in the specific content of the student curriculum.
s30	Effective professional development integrates examination of student learning using multiple sources of evidence.
s31	Establishing a collaborative culture among colleagues is an element of effective professional development.
s32	Establishing a collaborative culture among colleagues is an element of effective professional development.
s33	A prerequisite of effective professional development is that one must have good reason to believe that the change being introduced is itself of value

s34	Professional development should be primarily school based and integral to school operations.
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From Brown & Militello, 2016, pp. 708-710.

Participants

Purposeful sampling was used to select master mathematics and science teachers with extensive PD experience (Gentles et al., 2015). Participants were mathematics and science teachers from a state in the northeastern USA that completed four years of participation in a formal PD program. Teachers' PD included weekly or biweekly sessions (e.g., every other week) that focused on introducing and supporting the adoption of innovative, reform-based science and math pedagogies (e.g., inquiry-based, student-centered, hands-on learning; Bryan & Guzey, 2020). There were also content-focused sessions about new disciplinary ideas and research. These sessions were often offered by statewide university faculty and researchers, informal educators (e.g., local paleontological institute), and teachers' own peers (e.g., more experienced in-service teachers). Teachers were required to complete a minimum of 50 hours of PD for each of the four years they were in this program (a total of 200 hours of PD over four years). To note, this requirement was *in addition to* any district and state-mandated requirements for PD that they were responsible for completing. Using purposeful sampling, there were 58 teachers that met the above criteria, thereby establishing the study's pseudo-population. Constrained by the sample-size recommendations for Q-methodology, a random sample of 25 teachers was drawn from the 58 teachers for this study, and all were invited to participate. A total of 17 teachers agreed to participate in the study, which was sufficient to meet the recommended sample size for a Q-Methodological Study (a 2:1 ratio of Q-sort statements to participants) (Watts & Stenner, 2012). Teachers identified themselves as White (n = 16) or Black or African American (n = 1) and either male (n = 9) or female (n = 8). Teachers also identified their institutional locations as either suburban (n = 10), rural (n = 6), or urban (n = 1) relative to the schools' proximity to the surrounding city centers.

Administering the Q Sort

HTMLQ (<https://github.com/aproxima/htmlq>) was utilized to administer the Q sort. First, participants were asked to sort the 34 statements comprising the Q set into three different piles (Most Identify With, Neutral, Least Identify With) (see Figure 1). Once they completed this task, participants further refined their selections by placing their choices onto a grid (the Q sort) (see Figure 2). Participants were asked to place the 34 statements on the grid, where a forced-choice distribution was used, from +4 to -4 (Watts & Stenner, 2012). After completing

the Q sort, participants were asked to explain why they chose the three items with which they most and least identify (corresponding with the three items that fell under the +4 and column and the three items that fell under the -4 column). Finally, teachers were asked to answer a set of questions that provided their demographic information.

Figure 1

Provisional Ranking Categories

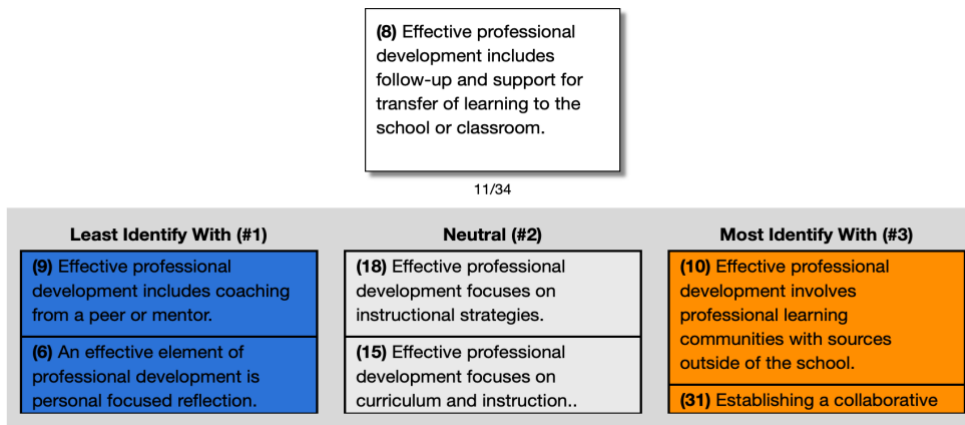
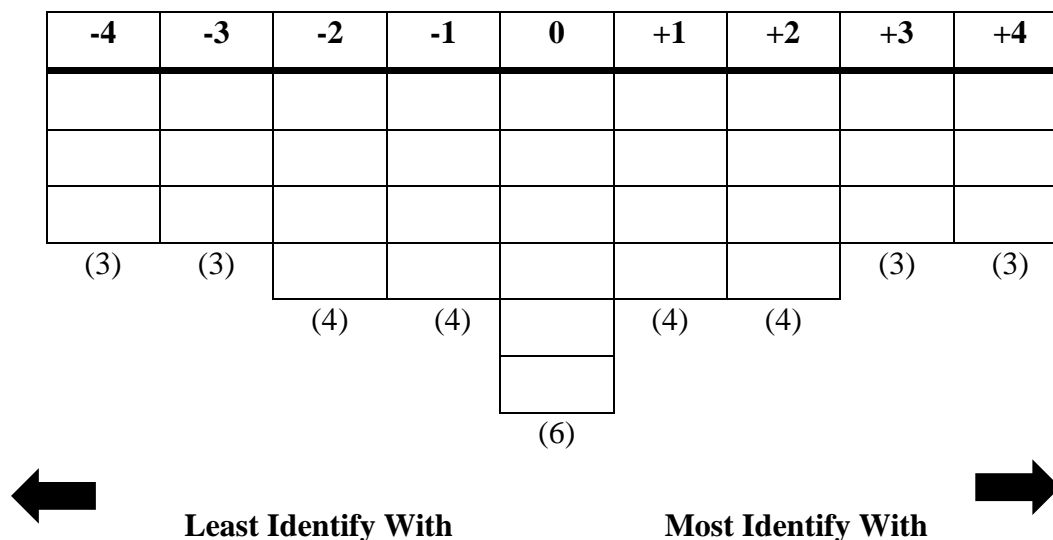


Figure 2

Q Sort Distribution Grid



Results

A total of 17 Q sorts were Pearson-correlated and factor-analyzed using the *qmethod R package* (R Core Team, 2013; Zabala, 2014). Four factors were extracted and rotated using cluster rotation (Donatello & Roulades, 2020; Watts & Stenner, 2012), representing 59% of the study variance. Of the 17 participants, all 17 loaded significantly on one of the four factors. This finding connects with the research questions in this study, as these factors are indicative of what participating teachers, as adult learners, view as effective characteristics of PD. Table 2 provides information on the teacher participants and their corresponding factor loadings. Factor loadings were all of 0.40 or above and statistically significant at the $p < 0.001$ level (Watts & Stenner, 2012). Composite reliability coefficients were all above the acceptable value of .70 (Brown, 1980). Each factor is described by the model factor array created through factor analysis. Additional questions in the instrument helped clarify teachers' ranking decisions. The statistical data and qualitative information provided by the teachers were used to develop factor interpretations.

Table 2

Participants' Factor Loadings

ID	Gender	Grade Level	Years Teaching	Subject	Factor Loading			
					1	2	3	4
P11	M	6-8	21-25	Science	0.65***			
P35	M	9-12	6-10	Math	0.73***			
P09	F	9-12	21-25	Science	0.65***			
P49	-	9-12	16-20	Science	0.84***			
P03	M	6-8	21-25	Science	0.66***			
P13	M	9-12	21-25	Math		0.79***		
P16	M	6-8	11-15	Science		0.77***		
P44	F	6-8	16-20	Math		0.71***		
P07	F	9-12	16-20	Math		0.45***		
P41	M	6-12	21-25	Science			0.57***	
P12	F	9-12	26+	Science			0.59***	
P21	M	9-12	26+	Science			0.58***	
P18	M	9-12	16-20	Science			0.83***	
P58	M	6-12	21-25	Science			0.65***	
P54	F	9-12	11-15	Science				0.84***

P02	F	9-12	16-20	Science				0.72***
P22	F	9-12	16-20	Science				0.79***

Note: *** p<.001; Eigenvalues (%): 2.98 (17.53%), 2.64 (15.50), 2.41(14.16), 2.08 (12.25); Composite reliability values are 0.95, 0.94, 0.95, and 0.92, respectively.

Factor 1: Collaboration with Peers

Factor 1 has an Eigenvalue of 2.98, and five participants loaded significantly on Factor 1, representing 29.4% of the participants and 17.53% of the study variance. Figure 3 shows the model factor array. In looking at the participants that loaded significantly on Factor 1, four were science teachers, and one was a math teacher. Table 3 provides the six highest and lowest-scoring statements for this factor.

This factor stresses the importance of teachers coming together in a collaborative culture (s31: +4). This collaboration may involve work with teachers from outside the school community (s10: +4). When provided the time to collaborate with peers (s13: +3), they can provide the support needed for teachers to think about practice in context (s24: +3). Importantly teachers want evidence that the changes in practice that PD is asking them to make will be of value to their work (e.g., will result in better student outcomes).

Participant P03 valued his experience working on “a wide variety of programs, resources, and strategies” through “the sessions that build in time for collaboration” within a professional learning team or community. Participant P09 emphasized interdisciplinary experiences when discussing s31, “Collaborating with others within one[’s] discipline AND outside of one’s discipline allows for real conversation, sharing of other interpretations or practices, and illuminates connections that exist.” Participant OP49 similarly commented on s10, arguing that:

You may get in a rut and not expand [your] horizons if you are working together only with the same people all the time, who have all the same influencers of mind/thinking. So (it is) good to have some outside sources in the mix occasionally at least.

Working with teachers outside of their own community was stressed by two participants on this factor. Participant P03 discussed a financial implication/benefit, writing, “I come from a small district with limited funding, so the sources outside the school have been key for me to gain knowledge specific to my content and my growth.” Participant P09 had to say about s10, “Professional Learning Teams or Professional Learning Communities provide trusted and rich relationships with others. Looking outside of one’s schools removes any politics or existing relationship dynamics and allows for a rich and broad exchange of ideas.”

Teachers loading on this factor seek inherent value to the PD in which they participate. This trend is often related to the limited availability of time teachers have for PD. For instance, participant P09 indicates in regards to s33 that “A teacher needs to see why [the] investment of time, energy, and taking risks to make change happen are of value. Time is a precious commodity and if value cannot be seen, it makes the PD less worthwhile to invest in.” Similarly, participant P11’s shared about teachers’ time that it is “very valuable, with too many things that pull us off our primary responsibility to our students. No one has time for PD that isn't going to be valuable.” Participant P35 sums it up by saying, “There would be little investment in the PD if you didn't think it was worthwhile.” In considering how this set of quotes relates to this factor, indications are that the collaborative connections made with others during PD can provide that value-added component teachers appreciate.

Ranking low on this factor were statements s34, s16, and s1 (all -4), and s27, s25, and s29 (all -3). For three out of four participants on this factor, s34 was ranked at -4. Teachers expressed wanting individualized PD that moved beyond focusing on school operations. Participant P11 shared that “It [PD] should be for individuals, perhaps as part of a mentoring program, and not the go-to form of PD encouraged by schools or districts.” Similarly, participant P03 stated that “PD for the sake of introducing protocols and programs is necessary for the running of a school, but it does not develop me as a professional or as a learner.”

Considering the importance of collaborative work in daily practice, two participants discussed s27 and how university courses are not a particularly beneficial form of PD. Participant P11 stated, “I've rarely taken a course that's directly applicable to making myself a better teacher. There's simply too much gap between much of academia (higher ed.) and the reality of everyday teaching.” Participant P35 said, “Some courses are beneficial, but some I don't think are necessarily worthwhile.” Participant P11 did indicate that new content knowledge can be a beneficial part of coursework, as are courses that help train one to be a better mentor, peer coach, or cooperating teacher.

Figure 3

Factor Array (Model Sort) for Factor 1

Least Identify With			Neutral			Most Identify With		
-4	-3	-2	-1	0	+1	+2	+3	+4
34	29	7	30	32	21	18	28	33
16	19	26	11	17	20	22	24	31
1	27	25	5	15	23	14	13	10
		6	3	9	12	8		
				4				
				2				

Table 3

Factor 1 Most Identify With and Least Identify with Statements

Score	Card	Statement
+4	s10	Effective professional development involves professional learning communities with sources outside of the school.
+4	s31	Establishing a collaborative culture among colleagues is an element of effective professional development.
+4	s33	A prerequisite of effective professional development is that one must have good reason to believe that the change being introduced is itself of value.
+3	s13	Effective professional development includes time to collaborate with peers.
+3	s24	Effective professional development includes providing time, contexts, and support for teachers to think.
+3	s28	Effective professional development includes providing opportunities for shared problem-solving.
-3	s27	Effective professional development for teachers is university courses.
-3	s19	An effective element of professional development is the inquiry process.
-3	s29	Effective professional development is embedded in the specific content of the student curriculum.

-4	s1	Effective professional development involves visiting other schools.
-4	s16	An effective element of professional development for teachers is to conduct differentiated sessions based on career stages, with specialized training for aspiring, new, and experienced teachers.
-4	s34	Professional development should be primarily school based and integral to school operations.

In conclusion, Factor 1 stresses the value teachers place on working collaboratively with other teachers. PD sessions that have included time for collaboration have resonated with teachers as being an effective practice. Having an opportunity to engage with teachers outside of their own district provides opportunities for additional learning from one another, and there is less concern with internal school “politics” or “dynamics”, therefore leading to the building of more trusting relationships with those involved. Also coming out strongly is the idea that PD that is not connected to teacher practice is not overly valuable to educators in terms of growth, though there is a recognition that sometimes schools and districts have a need to hold logistical types of sessions (i.e., grading systems, record keeping).

Factor 2: A Focus on Student Learning

Factor 2 had an Eigenvalue of 2.64, and four participants loaded significantly on Factor 2, representing 23.5% of the participants and 15.50% of the study variance. Figure 4 shows the model factor array. In looking at the participants that loaded significantly on Factor 2, three were math teachers and one was a science teacher. Table 4 provides a look at the six highest and lowest scoring statements for this factor.

This factor speaks to the idea that PD needs to be purpose driven, with a focus on change that ultimately impacts students’ knowledge and skills (s4: +4). Teachers are looking for a link to the day-to-day work that they do in their schools and classrooms (s23: +3) and considers their specific context (s33: +4; s24: +4). Both participants P07 and P16 emphasized the importance of determining students’ learning styles in order to devise strategies that meet the students’ needs, thereby leading to better academic and behavioral outcomes. Participants P13 summed this up well by commenting on s30, “The essence of what we do as teachers should be to promote student learning.”

In considering PD focused on the teachers’ day-to-day roles in the classroom s23, P07 shared, “I think this is the main purpose of PD. I want strategies and information which I can implement and use, and information to make me think about my instruction.” Facilitators

having grounded knowledge in classroom practice (i.e., experience implementing the topic of the PD with students) is important. Building on this idea, P44 stated about s13, “Teachers are the ones who are going to implement change within the classroom, so they need to be able to talk with other people who know and understand the conditions and culture within a classroom full of students.” Additionally, P13 said about s33 “when we're simply going through the motions because SOMEONE ELSE thinks we should learn something, we are less apt to learn, apply, or retain the information/skill/knowledge. Motivation is an enormous predictor of how effective [a] particular PD will be.”

Figure 4

Factor Array (Model Sort) for Factor 2

Least Identify With			Neutral			Most Identify With		
-4	-3	-2	-1	0	+1	+2	+3	+4
27	34	26	19	29	30	20	31	33
21	32	14	10	1	22	17	23	24
16	25	12	9	18	7	8	13	4
		11	28	15	2	6		
				5				
				3				

Table 4

Factor 2 Most Identify With and Least Identify with Statements

Score	Card	Statement
+4	s4	Effective professional development invests in the change process to impact student knowledge and skills.
+4	s24	Effective professional development includes providing time, contexts, and support for teachers to think.
+4	s33	A prerequisite of effective professional development is that one must have good reason to believe that the change being introduced is itself of value.
+3	s13	Effective professional development includes time to collaborate with peers.
+3	s23	Effective professional development links directly with day-to-day work in real schools and classrooms.

+3	s31	Establishing a collaborative culture among colleagues is an element of effective professional development.
-3	s25	Effective professional development includes an analysis of student work samples.
-3	s32	Effective professional development is primarily school-based as opposed to district-based.
-3	s34	Professional development should be primarily school based and integral to school operations.
-4	s16	An effective element of professional development for teachers is to conduct differentiated sessions based on career stages, with specialized training for aspiring, new, and experienced teachers.
-4	s21	An effective element of professional development is to have all-day and multiple-session meetings over an extended period of time.
-4	s27	Effective professional development for teachers is university courses.

The participants on this factor ranked lowly the statements s27, s21, s16, s34, s32, and s25. Teachers are not necessarily interested in PD that is integral to school operations or is district-based and prefer when it is specific to their contexts (s34: -3; s32: -3). Participant P44 stated about s34, “I think there is value to making PD specific to the needs within content areas.” Comparably, participant P07 expressed the importance of sending teachers to PD conferences focused on their content area and related to their pedagogical practice so that they can then bring new information back to their colleagues.

Three out of four participants on factor 4 ranked (s27) at a -4, and the fourth ranked it at -3. Support for university courses as PD is low, as this type of learning does not provide the authentic classroom context teachers have said is important. Participant P07, a seasoned teacher, stated, “As an older teacher, who feels that their teacher education lacked in areas, I think it’s *[sic]* hard for universities to keep up in their courses.” Likewise, participant P13 shared about his training that, “I cannot think of too much in my Master's program that was as helpful as actually doing the work.”

In conclusion, Factor 2 centers increased student learning and knowledge as the motivating factor for teachers when considering PD opportunities. Teachers desire support directly linked to their classroom context and work with their students. Facilitators of PD with

recent classroom experience will likely be those individuals whom teachers will be more open to learning from as they can help connect new learning to the classroom context.

Factor 3: Ongoing Support

Factor 3 has an Eigenvalue of 2.41, and five participants also loaded significantly on Factor 3, representing 29.4% of the participants and 14.16% of the study variance. Figure 5 shows the model factor array. In looking at the participants that loaded significantly on Factor 3, four were science teachers, and one was a math teacher. Table 5 looks at the six highest and lowest-scoring statements for this factor.

This factor considers the ongoing support and PD required for effective change. Follow-up and support for the transfer of PD to the classroom was scored highly (s8: +3). This transfer of PD is supported when teachers get opportunities to engage in actual practice rather than just hear about it (s17: +3). There is a time component associated with ongoing support, and this time should include collaboration with peers (s13: +4). Coming through strongly on this factor once again is the need for intrinsic value in changes being introduced (s33: +4).

Participant P21 shared that for him, meaningful PD is not a one-time meeting or workshop that is administered and forgotten quickly, but rather should give “adequate time for teachers to think about new ideas, implement new strategies, and collaborate with one another.” Participant P41, a veteran teacher of 26 years, has seen “so many new methods, techniques and gimmicks...many of them were very good...but...I learned them that day, and NEVER saw them again; we were never given time to refresh, relearn or make them real!”

Once again for this factor, the long-term impacts of PD are mediated by teachers' perceived value of changes in practice. Participant P49 realized that “the entire staff is forced into hours of PD that they may feel is not of benefit/not helpful for themselves or their students.” It takes time to accumulate evidence to reveal the effectiveness and value of PD during on-going teaching practices, as shared by a science teacher P18 that “I want to know what works and see it work.” Participant P58 advocated the effect of PD-encouraged culture so that “each effective PD session builds and transforms what has come before.”

New teachers may require additional ongoing PD and mentoring support through the mutually beneficial mentor-mentee relationship. Participant P12 stated, “Teachers need help initially. If they don't get that in the beginning from a strong teacher, they may go awry.” Providing ongoing support can positively impact a mentor's learning as well. Participant P18 shared that “working as a mentor makes me reflect on my own practice [because] I have to analyze my choices and have evidence to support those decisions before I can mentor another.”

More importantly, he shared that the self-reflection required to offer mentoring support retrospectively “provides an immense amount of self-growth as an educator.”

Statements ranking low on Factor 3 include s29, s25, and s20 (all -4), and s30, s16, and s4 (all -3). Considering this factor gets at the notion that teachers desire ongoing learning and support for effective change, three out of the five participants ranked attendance at conferences lowly (s20). Participant P58 shared, “I think there is nothing wrong with these if they are well designed, but I don't see this as a requirement for good PD.” Participant P21 stated, “These can be effective if the person/people attending are accountable for bringing information or resources back to their home school - and even better if there is a specific reason for attending a specific conference.” For participant P18, the costs of attending conferences were of concern. He shared, “I rated this low because they are costly to attend, I have to pay for the costs all by myself, I have to take time off of school and be away from my classroom.” Unsurprisingly, attendance at a conference as a one-off type of learning would score lower on a factor defined by ongoing support through the learning process. The negatively ranked s30, s16 and s4, together, insightfully stated that teachers need ongoing support: 1) in a less changing process to impact students; 2) not using multiple sources of evidence to examine students' performance; and 3) to conduct homogeneous PD sessions no matter the career stage of the teachers.

Also ranked lowly by the teachers on this factor is the role PD should play regarding content-specific PD. In considering s29, participant P41 shared, “NO! Good PD should be effective for all grade levels and all curriculum [*sic*]. If a certain method works for math, it should be good for all other areas as well.” This response indicated that content was not important. Yet, Participant P18 shared “I found that I have a thirst for all content-related PD. It doesn't have to directly impact my curriculum. I just want to know this content.” So there is a mix in agreement around this idea.

In conclusion, Factor 3 centers around the need for ongoing support for the successful transfer of learning from a PD opportunity to the classroom. Having the ability to collaborate with other peers in this process may be helpful. New teachers will require additional mentoring for this process. Participants in PD need to feel that there is value to change. On the opposite of ongoing learning are one-off learning opportunities similar to what a conference provides. While there may be beneficial pieces of a conference, the transfer to practice is often limited due to a lack of time when teachers return to the classroom. PD that extends beyond the curriculum and is useful over multiple situations seems to be favored by the participants on this factor.

Figure 5

Factor Array (Model Sort) for Factor 3

Least Identify With			Neutral			Most Identify With		
-4	-3	-2	-1	0	+1	+2	+3	+4
29	16	34	21	26	28	23	31	33
25	30	27	14	24	6	19	17	13
20	4	32	2	22	5	9	8	12
		10	1	18	3	7		
				15				
				11				

Table 5

Factor 3 Most Identify With and Least Identify with Statements

Score	Card	Statement
+4	s12	An effective element of professional development is providing a mentor to new teachers.
+4	s13	Effective professional development includes time to collaborate with peers.
+4	s33	A prerequisite of effective professional development is that one must have good reason to believe that the change being introduced is itself of value.
+3	s8	Effective professional development includes follow-up and support for transfer of learning to the school or classroom.
+3	s17	Effective professional development exposes teachers to actual practice than to descriptions of practice.
+3	s31	Establishing a collaborative culture among colleagues is an element of effective professional development.
-3	s4	Effective professional development invests in the change process to impact student knowledge and skills.
-3	s30	Effective professional development integrates examination of student learning using multiple sources of evidence.

-3	s16	An effective element of professional development for teachers is to conduct differentiated sessions based on career stages, with specialized training for aspiring, new, and experienced teachers.
-4	s20	State and national conferences are an effective form of professional development.
-4	s25	Effective professional development includes an analysis of student work samples.
-4	s29	Effective professional development is embedded in the specific content of the student curriculum.

Factor 4: Feedback and Follow-up

Factor 4 has an Eigenvalue of 2.08, and three participants loaded significantly on Factor 4, representing 17.6% of the participants and 12.25% of the study variance. Figure 6 shows the model factor array. In looking at the participants that loaded significantly on Factor 4, four were science teachers, and one was a math teacher. Table 6 looks at the six highest and lowest-scoring statements for this factor.

This factor defines the importance of teachers being provided with constructive feedback and sufficient follow-up as teachers transfer their new skills and knowledge to the classroom (s11: +3; s8: +4). PD should focus on a few concepts at one time (s23: 4+). Teachers value a collaborative culture where time is provided for them to work together (s31: +4; s13: +3).

Participant P54 described how, when being observed, she normally receives minimal feedback. However, she recently participated in a professional learning opportunity that included in-person classroom coaching. She stated, “It was wonderful to have someone sit in my classroom and push me...having someone there to give feedback and reminders stops you from going to that instinctual part of your brain as easily and helps you to break old habits.” She also recently taught as part of a Lesson Study conference. She described this opportunity by stating, “Teaching in front of a room full of teachers allowed many eyes and minds to provide me feedback.” Similarly, when it comes to follow-up, participant P22 stated, “I have found it very helpful to have some sort of support to follow up with even if it is just the email of the presenter to ask more in-depth questions later.” She discussed how it is “nice” to be able to clarify questions.

Feedback and follow-up naturally occur in teachers’ reflective interactions and collaboration with peers. Participant P02 stated that “collaboration with peers is synonymous

to implementation and follow through”; and “if the people receiving the PD cannot reflect and ask questions to their peers, they could feel insecure about trying to implement the new ideas.”

Statements ranking low on factor 4 include s33, s26, and s16 (all -4), and s34, s27, and s19 (all -3). Participants on this factor felt that, without follow-up, book studies and university courses are not effective means of providing PD (s26: -4; s27: -3). Participant P02 shared, “Some of the university courses I took over the years did not prepare me for life in the classroom.” She also shared, “Book studies are good, but most often they what *[sic]* is learned hardly transfer to the classroom. If it does, there is little to no follow-up.”

Statement s16 centered around providing differentiated sessions based on career experience, focusing on the premise that novice teachers may require more support at a more basic level. Participant P54 wrote, “We gain a lot from working together with [teachers from] various backgrounds and levels of experience.”

Compared to participants on other factors, two participants on this factor, P22 and P54, both ranked s33 at -4, suggesting that it might not always be necessary to know the value of a particular PD opportunity in advance of a session. Participant P22 shared, “Just because the idea is great, doesn't mean it ends up having value to the intended audience.” Similarly, participant P54 said: “I did a QFT [Question Formulation Technique] workshop a couple years ago...I had no idea what QFT was...but I learned a lot and immediately implemented QFT effectively.” With appropriate feedback during a session and follow-up after a session, either with colleagues or the PD facilitator, teachers can come to value new information presented in a session that they did not recognize as valuable to their practice in advance.

Figure 6

Factor Array (Model Sort) for Factor 4

Least Identify With			Neutral			Most Identify With		
-4	-3	-2	-1	0	+1	+2	+3	+4
33	34	32	22	24	28	30	17	31
26	27	29	18	20	15	25	13	23
16	19	7	21	14	5	10	11	8
		1	4	6	2	9		
				12				
				3				

Table 6***Factor 4 Most Identify With and Least Identify with Statements***

Score	Card	Statement
+4	s8	Effective professional development includes follow-up and support for transfer of learning to the school or classroom.
+4	s23	Effective professional development should only focus on a few concepts at one time.
+4	s31	Establishing a collaborative culture among colleagues is an element of effective professional development.
+3	s11	An effective element of professional development is providing constructive feedback on instructional practice.
+3	s13	Effective professional development includes time to collaborate with peers.
+3	s17	Effective professional development exposes teachers to actual practice than to descriptions of practice.
-3	s27	Effective professional development for teachers is university courses.
-3	s34	Professional development should be primarily school based and integral to school operations.
-3	s19	An effective element of professional development is the inquiry process.
-4	s26	Professional Learning Community book studies are an effective form of professional development.
-4	s33	A prerequisite of effective professional development is that one must have good reason to believe that the change being introduced is itself of value.
-4	s16	An effective element of professional development for teachers is to conduct differentiated sessions based on career stages, with specialized training for aspiring, new, and experienced teachers.

In conclusion, Factor 4 considers feedback and follow-up as essential components of PD. While individualized feedback is highly beneficial, sometimes that is not feasible. Collaboration with peers may provide that necessary feedback and follow-up. Ranking low

with the participants on this factor were PD related to university courses and book studies, due to the often-limited transferability of knowledge and skills to their classrooms. Participants on this factor also noted that sometimes unexpected value could come from PD opportunities.

Consensus Statements

Sometimes, all participants will rank a particular statement very similarly, and therefore they do not distinguish between two pairs of factors. Statements, in these instances, are referred to as consensus statements (Watts & Stenner, 2012). Our analysis identified two consensus statements (see Table 7). Participants seemed to be neutral in regards to the effectiveness of observing other teachers. Ranking very high for the participants, however, was the importance of establishing a collaborative culture among colleagues. As shown above, this idea has ranked highly on and shared by multiple factors (Figure 7).

Table 7

Consensus Statements across Four Factors of the 34-item Q set

Statement	Factor			
	1	2	3	4
(s15) Effective professional development focuses on curriculum and instruction.	0	0	0	1
(s13) Effective PD includes time to collaborate with peers.	3	3	4	3
(s31) Establishing a collaborative culture among colleagues is an element of effective professional development.	3	4	3	4

Note: a “Consensus Statements were those that do not distinguish between ANY pair of factors” (Watts & Stenner, 2012, Appendix Table A2.14).

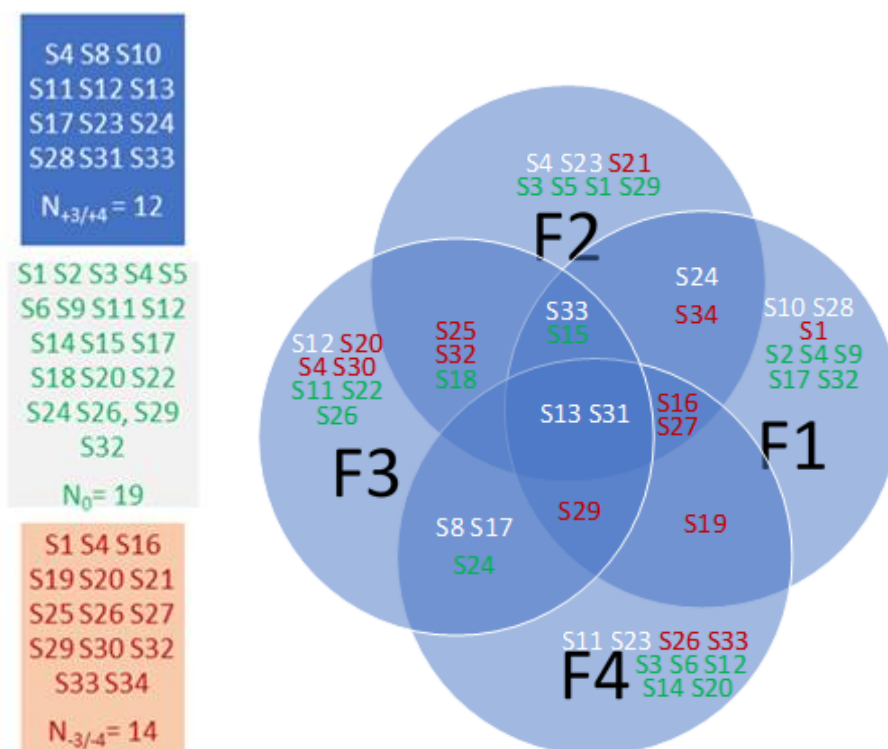
Discussion

Teachers' Perceptions of Characteristics of Effective PD

Through this study, four critical and overlapping factors were discovered about what this group of science and math teachers perceived about the characteristics of effective PD. Visualizing this overlap helps interpret the factors and understand how each factor relates to one another, as well as to andragogy. Figure 7 highlights the four factors and how the statements loaded on each factor. Factors are defined by distinguishing statements between pairs of factors (Watts & Stenner, 2012).

Figure 7

Overlapping Statements Structure of Four Factors [Red for -3/-4; White for +3/+4; Green for Neutral]



Note. Four items, S11S12 S17 S24, shared by +3/+4 and Neutral; One item, S33 shared by +3/+4 and -3/-4; Five items, S1 S20 S26 S29 S32, shard by -3/-4 and Neutral; One item S4 was ranked -4 in F3, +4 F2, and 0 F1.]

The first aspect centers Factor 2 around statement 4, which indicates PD that includes a focus on student learning is important to teachers. Ultimately, changes to practice that are made should positively impact student learning outcomes (Guskey & Yoon, 2009; Lakshmanan et al., 2011; Sample McMeeking et al., 2012). Teachers are looking for ways to meet the needs of all learners and therefore are looking for strategies and models that will improve practice (Gore & Rosser, 2020; Spatz et al., 2019). Coming through firmly on this factor was statement 33 which stated, “A prerequisite of effective PD is that one must have good reason to believe that the change being introduced is itself of value”. Important here is the idea that teachers have limited time to test things that may or may not work (Saka, 2013). They are interested in practices that show prior success in teaching (Wayne et al., 2008) and lasting effects in classrooms (Spatz et al., 2019).

As indicated through statements 10 and 13, teachers want opportunities to collaborate with peers (i.e., “staff collaboration” in Darling-Hammond, 2020; “coaching and expert support” in Spatz and colleagues (2019, p. 162); “collaborative environments with peers” in

Herro and colleagues (2019, p. 187), and “cross-grade/subject observation and collaboration” in Gore and Rosser (2020, p. 9). By collaborating with other educators, teachers can form a network to support each other through changes in practice (Herro et al., 2019), which also “lifted teachers’ expectations of students, as well as their views of colleagues and motivation to collaborate” (Gore & Rosser, 2020, p.10). They can share successes and challenges and provide feedback and suggestions for one another “contextualized in teachers’ classrooms” (Herro et al., 2019, p.187). Districts can leverage the power of collegial teacher communities to enhance the learning teachers are doing (Darling-Hammond, 2020). Much can be gained by both teachers and the district by fostering collaborations as these tend to be low-investment ways for teachers to further their pedagogical and content skills (Murray, 2010), and results in better-functioning schools (Darling-Hammond, 2020).

For an effective change in practice, there needs to be ongoing learning and support for teachers. Here again is the idea that teachers can provide ongoing support for one another, if space is made for this to occur (Desimone et al., 2009; Jeanpierre et al., 2005; Spatz et al., 2019). Also important to ensure the transfer of learning to the classroom is providing the opportunity for teachers to model actual practice rather than just learning about it (Loughran, 2013). This modeling often cannot occur in a one-time meeting, and therefore efforts need to be made to support implementation, as participant P21 shared.

Finally, teachers seek constructive feedback and follow-up as they implement change in their classrooms (Darling-Hammond et al., 2017; Herro et al., 2019). Teachers desire follow-up sessions to support their implementation of new practices (Main et al., 2015). Teachers then can ask questions, share their progress, and receive feedback on their actions. Teachers in this study have suggested that time with other teachers is valuable to them, and peer support can also provide an excellent opportunity for the necessary feedback (Fetters et al., 2002).

Connections to the Core Adult Learning Principles and The Four Extracted Factors

In considering the factors extracted in this study and looking at the factor interpretations, connections can be made to the six core adult learning principles from Knowles and colleagues (2015). Table 8 represents how the factors and principles map with one another for this study. In helping to connect the two, additional information was incorporated to provide a more holistic view; namely, the seven criteria of PD presented by Spatz and colleagues (2019) and the five core criteria of PD by Lindvall and colleagues (2021).

Principle 1: Learner's Need to Know

This core principle considers the what, why, and how, and specifically that “adults need to know why they need to learn something before undertaking to learn it” (Knowles et al., 2015, p. 43). Statement s33 was ranked highly on three out of four extracted factors (F1, F2, F3 in Figure 7), emphasizing the importance that teachers want to know that any change being introduced through PD has value related to their practice (Main et al., 2015; Gore & Rosser, 2020; Spatz et al., 2019). Often teachers seek PD related to their current needs, yet do not have a supportive structure to help with learning and implementation (O’Toole & Essex, 2012). Therefore, to support teacher learning and integration of new knowledge and skills, ongoing support of sustained duration [B7] that provides coherence with the teachers' current practice (Spatz et al., 2019) and identifies needs [A2] would be beneficial (Lindvall et al., 2021).

Principle 2: Self-Concept of the Learner

This core principle focuses on the idea that adults are seen and treated by others as being capable of self-direction and are responsible for their own decisions (Knowles et al., 2015). If teachers are inhibited in the learning process by the design of a PD opportunity, then self-directed learning is limited (O’Toole & Essex, 2012). Providing teachers opportunities to collaborate [B3] (Spatz et al., 2019) and [A4] (Lindvall et al., 2021) with peers (F1) indeed allows space for teachers to rely on self-direction to move them forward in their learning. Statement s24 also loaded highly on two of the four factors (F1, F2), suggesting that as part of this self-direction, teachers need space and support to think through their learning (Loucks-Horsley & Matsumoto, 1999).

Principle 3: Prior Experience of the Learner

Knowles and colleagues (2015) describe this principle in terms of the “greater volume and a different quality of experience from that of youths” (pp. 44). They go on to discuss how there may be a broader range of differences in adult learners compared to youth learners due to varying experiences (Knowles et al., 2015). For example, some teachers may have access to many more and varied learning opportunities, as suggested by teachers in this study. It may be helpful to survey participants in advance to get a grasp of their level of knowledge about the topic being taught to ensure the needs of all teacher learners are being met (Drake et al., 2014). Continuous learning [F3; B7; A5] is essential to consider with this principle as schools' populations become more heterogeneous in their makeup (Ball & Ladson-Billings, 2020). Practices based on past experiences may need updating to meet the needs of changing populations.

Principle 4: Readiness to Learn

The thinking behind this principle is that adults are prepared to learn those things that apply to their current needs and what they must do to cope with their present situation (Knowles et al., 2015). Statement s23 ranked highly on two factors (F1, F4), suggesting the importance placed by teachers on PD being directly related to the work that they do. This PD should model actual practice (s17), again supported by teachers on two factors (F3, F4) and PD criteria [B4] suggested by Spatz et al. (2019). Such learning would be best sustained over time [A5] to integrate new teaching practices into their current work (Darling Hammond et al., 2017; Lindvall et al., 2021; Spatz et al., 2019).

Principle 5: Orientation to Learning

In principle 5, adults are task-centered or problem-centered and learn new knowledge and skills when presented in real-life situations (Knowles et al., 2015). Teachers that loaded on Factors 3 and 4 spoke about how learning by practice is better than reading about it (s17). Teachers may require ongoing support [B7] (Spatz et al., 2019) beyond the PD opportunity, again highlighting the overlaps of Factors 3 and 4. Transfer of learning is supported by teachers engaging in actual practice. Mentoring and coaching whereby feedback can be provided [B6] (Herro et al., 2019; O'Toole & Essex, 2012; Spatz et al., 2019) to support the active transfer of learning [A3] (Darling-Hammond et al., 2017) into classroom practice

Principle 6: Motivation to Learn

The idea that adults are responsive to external motivators is covered by this principle. Knowles and colleagues (2015) lists external motivators such as better jobs, promotions, and higher salaries as examples of external motivators (p. 47). For teachers, this motivator may be a requirement to maintain teaching certification(s) and to meet PD re-licensing standards (Darling-Hammond, 2020). Sometimes, teachers want to learn for their own purposes, with the motivation coming from the desire to improve student learning outcomes [Factor 2]. This finding is well aligned with the content-focused PD [A1] and [B1] of Lindvall and colleagues (2021) and Spatz et al. (2019), respectively.

Intrinsic motivation of the teachers may predict the success of a PD opportunity (Lynch et al., 2019). Factor 2's Participant P13 shared, "As a teacher, learner, and observer of human nature, I have found that when we are motivated to learn something, we are relentless in pursuit of it. Motivation is an enormous predictor of how effective [a] particular PD will be." Sometimes, what is motivating enough is providing time and space for teachers to use their new curricular resources (Spatz et al., 2019) to collaborate with others, resulting in a positive change in attitude (Gore & Rosser, 2020, p. 9). Overall, based on the factors for this study,

improving student content-based knowledge through improved pedagogical practice is a great motivator for teachers to pursue the “lasting effect on classroom practices” (Spatz et al., 2019, p. 174).

Table 8

Mapping of Four Teacher PD Factors with Three Principal PD Factor and Six Core Adult Learning Principles

Principal Professional Development Factor	Teacher Professional Development Factor	Core Adult Learning Principle (Knowles et al., 2015)	Seven Criteria (Spatz et al., 2019)	Five Core Criteria (Lindvall et al., 2021)
f2: Collaborate	F1: Collaboration with peers	LP2: Self-concept of the learner	B2. Incorporate active learning B3. Supports collaboration	A4. Collective Participation
-	F2: A focus on student learning	LP6: Motivation to learn	B1. Is content focused	A1. Content Focus,
f1: Sustained over time	F3: Ongoing support	LP1: Learner’s need to know; LP3: Prior experience of the learner; LP4: Readiness to learn; LP2; LP5	B4. Uses models of effective practice B5. Provides coaching and expert support B7. Is of sustained duration	A5. Duration
f3: Collaboration and follow-up	F4: Feedback and follow-up	LP5: Orientation to learning	B6. Offers feedback and reflection	A2. Coherence

			B7. Is of sustained duration	A3. Active Learning
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Comparing Teachers' and Principals' Perceptions of Characteristics of Effective Professional Learning

In our study, four factors were extracted. These factors included (F1) A focus on student learning, (F2) Collaboration with peers, (F3) Ongoing support, and (F4) Feedback and follow-up. In comparison, the study conducted by Brown and Militello (2016) provided three extracted factors, including (f1) Sustained over time, (f2) Collaborate, and (f3) Collaboration and follow-up. There is reasonable similarity across the two studies, and hence, the two groups of participants surveyed. The factor that stands out the most is the addition of the focus on student learning that was extracted from the teachers (Capobianco et. al, 2021). The surveyed teachers kept coming back to this idea of a higher purpose in participating in PD. Improved student outcomes help to satisfy the why for doing PD. The remaining factors and the comments provided between the principals and the teachers are fairly aligned. This coherence should probably not be a total surprise as principals have taught in the past and likely participated in teacher PD. Not covered in this study, but it seems often the “one-size-fits-all” mismatch comes when the content backgrounds of administrators facilitating PD do not match up with the content subject areas of the teachers receiving PD (Patton et al., 2015).

Limitations

There are multiple limitations inherent to this study. First, we focused on science and math teachers. While this is a clearly defined population, they are not likely representative of all related STEM disciplines (e.g., engineering and technology). In a similar way, these teachers were located in one geographical location. Teachers from other geographical locations globally may offer additional insights into perceived effective characteristics of PD. Likewise, demographics were not considered as confounding factors in this study, meaning that we did not examine potential differences based on gender and ethnicity. Rather, teachers represented a more homogeneously White population of males and females across institutional locations.

Conclusion

The creation and facilitation of PD for teachers is a huge undertaking that requires many resources (e.g., time, finances, and materials). The effectiveness of PD for teachers is

something researchers have spent a great deal of time studying. The result has been defining numerous items and creating several lists that purport to be the characteristics of effective PD. This study set out to obtain teachers' perceptions of one list of characteristics that both synthesized previous PD work and appeared to overlap with findings science and math PD literature (Brown & Militello, 2016).

Participating science and math teachers in this study most identified with those characteristics of effective PD that included a focus on student learning, incorporated collaboration with peers, provided ongoing support, and allowed for feedback and follow-up. While only 17 teacher participants were included in this study, the results should be considered significant when considering their perceptions of the characteristics of effective science and math PD. This is especially true since this group of teachers has participated in a significant amount of professional learning (at least 50 hours per year over four years).

The characteristics of PD that the teachers identified were examined through the lens of andragogy, or adult learning theory. Using the six core adult learning principles (learners need to know, self-concept of the learner, prior experience of the learner, readiness to learn, orientation to learning, and motivation to learn), the characteristics identified by science and math teachers as elements of effective PD do align well with the core principles of andragogy (Knowles et al., 2020).

In comparing teachers' perceptions with previous work (i.e., Brown & Militello, 2016), the one significant difference was the addition of improved student outcomes resulting from teachers' participation in PD. This idea came through very strongly on a couple of the extracted factors in this study. Beyond this one difference, many similarities existed between the perceptions of the two groups on this particular Q sample.

Future research will continue to focus on the characteristics of effective PD. It is crucial to ensure the Q set is truly representative of all of the characteristics of PD that have been identified. Considering the Q set that was used for the Brown and Militello (2016) study was intended for use with principals, there may be additional characteristics not considered that should be included for teachers, and perhaps items that should be excluded. Additionally, future research will look more closely at the associations between the characteristics of effective PD in the literature and adult learning theory. Facilitators of PD may need to consider the learning styles and motivations of adult learners in the design of their PD opportunities.

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