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Mathematics Teacher Learning Preferences: Self-Determination Theory Implications for Addressing Their Learning Needs

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Abstract
Participant perceptions of the effectiveness of the Middle School Project Partnership (pseudonym) professional development course strategies were evaluated using Q Methodology. Factor analysis of participant sorts of a Q set developed from interviews and observations yielded three teacher types, with one group preferring social activities, the second preferring activities promoting deeper understanding, and the third preferring autonomy in their learning. These teacher types are consistent with the basic needs identified in Self-Determination Theory which is commonly employed as a theory to explain motivation associated with positive outcomes in the field of education. Participant types did not differ by gender, course location, teaching experience, or scores on measures of teacher conceptual understanding of mathematics. Findings indicate that professional development activities should be varied to meet the learning needs of teachers, which tend to differ based on the range of teachers' self-determination to engage in the professional learning activities. Teachers appeared to interact with course strategies and activities in a manner that met underlying needs for learning. Therefore, collecting this type of information from teachers could be used to design training in ways that will lead to increased self-efficacy and enhanced experiences for all teachers. Future research is necessary to explore the possible connection between self-determination theory and teacher outcomes as designing teacher development activities and strategies using a theoretical framework for motivation might strengthen existing approaches and outcomes including retention and fidelity to instructional approaches.
Keywords: Self-Determination Theory, Professional Development, Middle School, Learning Preferences

1. Introduction

The last 20 years have called for a reconceptualization of the types of professional development offered to teachers (Desimone, 2009; Heck, Banilower, Weiss, Rosenberg, 2008), yet, for the great majority of public school teachers, it continues to involve attendance at half day or day-long workshops that provide lecture or presentations that promote specific classroom suggestions or interventions (Corcoran, 2006). The ability of these workshops to offer the high quality, content-focused and in-depth learning opportunities for teachers recommended by the National Council of Teachers of Mathematics (2000) is doubtful. Despite limited empirical support for proposed lists of essential characteristics (Heck, Banilower, Weiss, Rosenberg, 2008), current achievement trends and extant research on professional development of mathematics teachers (see Desimone, 2009; Loucks-Horsley Stiles, Mundry, Love, & Hewson, 2010; Pando & Aguirre-Munoz, 2018) support the need for professional learning to be designed to support four interconnected outcomes for teacher professional learning: enhancement of teacher pedagogical content knowledge (PCK), enhancement of quality teaching for all students, development of leadership capacity, and establishment of (or participation in) professional learning communities that would be maintained well after a specific professional learning event and drive teacher learning over the course of their teaching careers. Thus, in addition to challenging teachers to forge new, flexible organization and collaboration with the focus on student outcomes (Loucks-Horsley et. al., 2010), long-term, sustained commitment on the part of teachers and school leadership is necessary to produce the necessary changes in teacher practice that are needed to achieve learning and professional practice goals (Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009).

If sustained engagement in professional learning is needed to both increase teachers' content knowledge and transform that knowledge to effective teaching for all students, it is important to examine teachers' perceptions of professional learning activities to determine the extent to which the learning activities support their motivation to engage in such prolonged activity (Crawford, 2017). Thus, the purpose of the present study was to evaluate the perceptions of teachers involved in a three-week long, graduate level mathematics course designed to increase their conceptual mathematics knowledge as well as provide them with effective strategies for enhancing their students' mathematics self-efficacy. The use of Q methodology was utilized to determine what activities teachers viewed as most important to their learning and whether distinct groups of teachers emerged to represent distinct learning preferences.

1.1 Research on Teacher Perceptions of Professional Development

Like all professions, an integral part of effective teaching requires the continual deepening of knowledge and skills (Shulman & Sparks, 1992; Hill & Ball, 2004; Hill, Ball, & Schilling, 2008). Teacher perceptions of professional development activities are important to examine because they provide information regarding factors that influence enhanced knowledge and skills (e.g., Crawford, 2017; Garet, Porter, Desimone, Birman, & Yoon, 2001; Desimone, Porter, Garet, Yoon, & Birman, 2002), help maintain interest in staying in the profession (e.g, Bouwma-Gearhart, 2010; Evelein, Korthagen, & Brekelmans, 2008), as well as help maintain interest in continued professional development opportunities (e.g, Stevens, Aguirre-Muñoz, Harris, Higgins, & Liu, 2013; Wagner & French, 2010). Most of the research in this area investigates which aspects of professional development are associated with instructional change. For example, Garet et. al., (2001) conducted a study to examine what professional development activities are associated with positive teacher outcomes. They found that development opportunities that focused on content knowledge, active learning (e.g., examining student work and feedback on teaching), and coherence (e.g., linking to other activities and building on teachers' prior knowledge) with other learning activities were significantly associated with teacher perceived positive change in knowledge and practice. Additionally, these core elements were influenced by specific structural features, including the form of the activity, the level of collective participation of teachers from similar groups, and the duration of the activity. A follow-up longitudinal study (Desimone et. al., 2002) provided additional evidence that content focus, active learning, and coherence are most associated with teachers' perceived instructional change. Although self-reported data on instructional change is limited in terms of providing reliable data on actual teacher practice, teacher perceptions of professional development activity can offer important information about how professional development should be structured to maintain teachers' engagement over an extended period of time, particularly when the content is difficult or if teachers' engagement is motivated by external factors. That is, examining teachers' perceptions can also shed light on aspects of the professional development activity that limit or facilitate teachers' motivation to enhance their knowledge and skills.

For example, Stevens et. al. (2013) found that active learning contributed to teachers' self-efficacy, an individual's perceived capabilities to learn and perform at a given level (Bandura, 1997), and self-determination to engage in prolonged professional development. Self-determination applied to professional learning refers to teachers' internal drive to pursue professional learning opportunities for the genuine interest in deepening their content knowledge and improving teaching practice to meet the needs of students. This study is important in that it provides some guidance in addressing aspects of motivation that is largely absent in the professional development literature. Stevens et. al. (2012) found increases in both self-efficacy and self-determination as a result of the design of the professional learning experience. The encouragement of choices, promotion of individual agency, and availability of instructors across time positively impacted teachers' self-efficacy to use what was learned in the training and self-determination information in practice and to continue engaging in long-term professional development. If we accept that meaningful change in teacher practice is necessary to achieve current learning reform goals and this change will inevitably involve activities that some teachers may not find inherently interesting or enjoyable, addressing structural and contextual features of the professional development environment that motivate or discourage teachers' active involvement is important to examine. Moreover, past research has demonstrated that self-efficacy is predictive of individuals' choice to engage in a task, effort, as well as persistence in the face of difficulty (Bandura, 1997; Schwarzer & Schmitz, 2004). In addition, research on the impact of teachers' self-efficacy on student outcomes has consistently shown that teachers high in teaching efficacy will work hard to ensure that all students learn, set high expectations for all students, and focus on mastery of the content (rather than passing the test) (Stevens et. al., 2013). Finally, teachers with high teaching efficacy are more likely to experiment with new teaching strategies, even if they are difficult to implement (Hami, Czerniak, & Lumpe, 1996).

Perhaps if all teachers had high self-efficacy beliefs, professional development efforts would be more successful in producing instructional change. Unfortunately, the reality is that the great majority of professional development has not had such an impact (Crawford, 2017). Teachers differ in their levels of self-efficacy; therefore, even professional development characterized as high quality could yield varying degrees of impact for distinct groups of teachers. How can teacher training be organized to engage all teachers at high levels for a prolonged period of time? How could teachers be encouraged to engage in difficult tasks if they have low teaching efficacy?

Self-determination theory (SDT) offers some helpful (theoretical and empirical) responses to these questions. Self-determination refers to the causes of individuals' choice to engage in activity in addition to contextual factors that impact development, performance, and well-being (Ryan & Deci, 2000). In this way, SDT provides a differentiated approach to motivation by "considering the perceived forces that move a person to act… . By articulating a set of principles concerning how each type of motivation is developed and sustained, or forestalled and undermined, SDT … recognizes a positive thrust to human nature and provides an account of passivity, alienation, and psychopathology" (Ryan & Deci, 2000 pp. 69). In other words, SDT can be used to examine teacher motivation and how it affects their everyday decisions and their growth tendencies (Ryan & Deci, 2000)

The differentiation in motivational approach is possible by addressing basic needs identified by SDT that are thought to underlie human behavior: relatedness, competence, and autonomy. Relatedness refers to the need to belong to a group; competence refers to the need to feel competent and perform well in interactions with others; autonomy refers to the need to feel a sense of control in the environment (Ryan & Deci, 2000). Although we did not set out to test the degree to which SDT predicts ongoing engagement in professional development, our work with mathematics teachers through the Math Science Project (MSP) has caused us to consider the range of teachers' self-determination to engage in the professional learning activities when structuring professional learning environments. This program is described next.

1.2 The MSP Partnership (Pseudonym)

The MSP Partnership (MSPP) project focused on providing rich professional enrichment opportunities for select middle school math teachers in a large, predominately rural region in Texas. The MSPP activities focus on three desired mathematics teacher attributes:

1. Having a deep conceptual understanding of the mathematics taught in middle school,
2. Possessing the mathematics knowledge for teaching that is required to teach mathematics effectively in the middle school, and
3. Having the ability to teach mathematics effectively to, and enhance the mathematics self-efficacy of, the culturally and socially diverse student population in West Texas.

A core component of the MSPP project is the development of graduate level mathematics courses delivered during the summers at the partner institutions for selected middle school mathematics teachers in the respective regions. Each course covered a particular mathematics topic (e.g., algebraic structure for the particular course considered in this study) taught in grades 6 to 8 and is offered at four different partner institutions of higher education.

The MSPP design (described below) is consistent with recommendations for extended time and duration of teacher development as well as collaboration. Participants were inducted into one of two cohorts, each of which studied together over a period of three years. Participants attended one three-week long, hybrid course in each of three consecutive summers, participated in a MSPP scheduled day-long conference during the regular academic year, and interacted with peers online using a social networking platform. The focus on deep conceptual understanding of mathematical content taught at the middle level is also tied to professional development recommendations as well as the MSPP emphasis on active learning.

The research questions addressed here include:

(1) What activities do teachers view as most important to their learning? Do distinct groups representing prevalent perceptions of learning preferences emerge in this process?

(2) Do teachers representing each of the prevailing perceptions differ on key background characteristics (math background, years teaching experience, and gender) or on gain scores in mathematics knowledge for teaching?

2. Method

Participants' views of the various teaching strategies and materials were evaluated utilizing Q methodology. Q methodology allows for the study of participants' perceptions, which falls into the qualitative research domain. However, because these perceptions are rank ordered and factor analysis is then utilized to organize participants' perceptions into categories, the quantitative aspects of Q methodology make it a mixed methods approach. With an emphasis on discovery rather than reasoning, Stephenson (1953) was the first to describe Q methodology. More recently, Brown (1993) has advocated for its use in the social sciences and the technique has been utilized in education to investigate teachers' beliefs about discipline (Rimm-Kaufman & Sawyer, 2004), inclusion (Berry, 2010; Zambelli & Bonni, 2004), and teacher training preferences (Stevens et. al., 2009).

2.1 Participants

The *P-set*, or the group of participants who complete the Q sort (McKeown & Thomas, 1988), included 65 teacher participants of the MSPP. Brown (1980) recommended that each emerging factor should represent the perspective of at least 4 to 5 participants; therefore, 40 to 60 participants, although small for most correlational designs, is an appropriate sample size for Q methodology. Because the goal was not generalization but representation of individuals' perspectives of their learning, additional subjects add very little once the different points of view have been identified. "The objective in Q-methodology is to be able to describe typical representations of different viewpoints rather than to find the proportion of individuals with specific viewpoints" (Akhtar-Danesh, Baumann, & Cordingly, 2008).

Of the 65 participants, 82.8% were women (n = 53) and 15.6% were men (n = 10). Two persons failed to report their gender. Participants reported teaching an average of 10.46 years; however, the standard deviation of 7.35 indicated a wide range of experience. One individual reported teaching less than one year, whereas another reported teaching 32 years. Similarly, participants reported teaching mathematics for an average of 9.26 years (*SD* = 6.59), with a minimum report of 0 years of teaching mathematics and a maximum report of 27 years.

2.2 Professional Development Content & Activities

The content for the first MSPP hybrid summer course was centered on the topic of algebraic structure of the rational number field and was developed by the principal investigator for the project who is a senior mathematician with 37 years of experience teaching mathematics to pre- and in-service K-12 teachers. In addition to the mathematics content, participant teachers also received training in self-efficacy building. Teachers were provided with reading material and assignments prior to and at the conclusion of the face-to-face portion of the course. Content and activities are described next.

2.2.1 Math content

The first course began with the presentation of natural numbers from the point of view of Bertrand Russell's idea of number classes (Russell, 1956) and proceeded with the concept of addition as a binary operation on the natural numbers. Commutativity and associativity of addition followed immediately. The concepts of additive identity and additive inverse were introduced leading to the group of integers. Multiplication of integers was defined, again with the properties of commutativity and associativity following immediately. The distributive property of multiplication over addition was shown and led to the ring of integers.

The multiplicative identity and the concept of multiplicative inverse were introduced, leading to the meaning of a fraction. The possible physical meanings of fractions were discussed and the definitions of multiplication and addition of fractions were presented. The concept of equivalent fractions was explored along with the concept that multiplication and addition are well defined (independent of the choice of equivalence class representatives). Again, commutativity, associativity, and the distributive property were addressed.

The division algorithm was discussed and the decimal representation of rational numbers investigated. The meaning of an infinitely repeating decimal was obtained via the geometric series and the derivation of the formula $\sum_{k=0}^{\infty} r^k = \frac{1}{1-r}$. The course ended with a discussion of the Least Upper Bound Principle and the existence of irrational numbers (the real number field).

2.2.2 Self-efficacy Content

The self-efficacy component of the workshop was conducted during a three-hour long session on the second week of the face-to-face portion of the course. This component of the course aimed to build teachers' understanding of the role of self-efficacy in student mathematics achievement and in providing them with an implementation approach to incorporate feedback to students that develops students' mathematics self-efficacy. Thus, teachers were presented with a brief background of self-efficacy, how it is distinguished from self-esteem, the sources of self-efficacy that can be used as targets for self-efficacy-minded feedback, as well as the implications of self-efficacy on teaching practice. Although teachers did not practice self-efficacy oriented feedback in the context of mathematics instruction, multiple case studies were presented and discussed illustrating the application of the approach to teachers.

2.2.3 Processes

To facilitate participant teachers' thinking of how to apply the course content to their teaching practice, a case study was developed and discussed with participants. The case utilized in this study presented a middle level student's explanation of his solution for the addition of two fractions. As such, it was designed to elicit teachers' content knowledge, their ability to identify student misconceptions as well as engage in critical reflection. Introducing a second student who was persuaded by the first to model the first student's solution, the case also offered an opportunity to explore and develop teachers' sensitivity to student needs (content and self-efficacy) as well as an ability to provide pedagogically sensitive mathematical feedback to the student (Briza, Nardi, & Zachariades, 2007).

In addition, teachers were provided time to develop individual and group mathematical models, reflecting course content topics. For example, when asked to provide a model for the integer 5 and the additive inverse of 5 (5+(-5) = 0), one group of teachers suggested letting 5 represent 5 dogs and letting -5 represent 5 bones. Another group pointed out that putting 5 dogs with 5 bones resulted in no bones, but still left 5 dogs remaining. After a little consultation, the first group corrected model by letting 5 represent 5 hungry dogs.

2.3 Measures

2.3.1 Mathematics Background

To assess mathematical background, teacher participants were asked to report specific mathematics courses taken in college (e.g., college algebra, pre-calculus, calculus, trigonometry, statistics, analytic geometry, linear algebra, differential equations). Participants were assigned one point for each course type taken and these points were added to create a total score. An average of 3.63 (SD = 2.50) was calculated, with a minimum of 0 and maximum of 8.

2.3.2 Mathematics Knowledge for Teaching

Participants completed parallel forms of three Mathematical Knowledge for Teaching (MKT) scales to measure their MKT. The three scales were used to assess knowledge for teaching Number Concepts and Operations, Algebra, and Geometry (Schilling & Hill, 2007) and have undergone extensive validation (e.g., Hill, Dean, & Goffney, 2007; Schilling, 2007) indicating their relationship with student outcomes (Hill, Ball, Blunk, Goffney, & Rowan, 2007; Hill, Rowan, & Ball, 2005) and high quality mathematics instruction (Hill, Blunk, Charalambous, Lewis, Phelps, Sleep, & Ball, 2008; Hill, Ball, Blunk, Goffney, & Rowan, 2007). The 2007 Middle School Number Concepts scale is comprised of 30 items for form A and 32 for form B, the 2005 Middle School Geometry scale is comprised of 19 items for form A and 23 for form B, and the Middle School Algebra scale is comprised of 33 items. Raw scores were converted to item response theory (IRT) scale scores provided by the test developers, which are given in standard deviation units. Due to the lack of a nationally representative normative sample, test developers have cautioned against reporting mean MKT scores and have instead advocated using IRT gains calculated from pre- and post-test comparisons. Only IRT gain scores were used in the present study.

2.4 Procedures

Teachers were asked to complete the MKT measures prior to participation in the first summer course. Course observations and interviews with teachers with varying degrees of engagement in course activities were conducted to develop the universe of statements, referred to as the concourse, relevant to the MSPP summer course (see Kallay, 2007). A Q-set, or list of representative statements representing participant perspectives, was created from the concourse to eliminate redundancy, and included 53 items. Q-samples typically include 20 to 100 statements (Watts and Stenner, 2005) and vary depending on the concourse as well as the practical issue of the ability of participants to sort the statements in the time available. The Q-set includes opinions about participants' interactions with course activities, such as "Reading assigned journal articles provided necessary background for the course," as well as statements regarding strategies relative to their learning and self-efficacy development, such as "Receiving verbal feedback from peers about my performance helped to build my mathematics self-efficacy."

At the end of the two-week face-to-face portion of the course, teacher participants were asked to sort the statements to reflect their learning preferences. Each participant received a set of 53 cards with a Q-set statement and a number randomly selected from 1 to 53 and assigned to each item (the card sets were identical). Participants were asked to first sort the cards in three piles: the pile to the left including those statements with which they did not agree, the pile to the right including those with which they did agree, and the pile in the center including those about which they felt neutral. After participants completed the card sorting, they were asked to fill in a distribution pyramid in accordance to their degree of opinion about each item. A forced distribution was utilized, which required participants to assign each item to only one location on the distribution that ranged from -7 to 7. Because participants were expected to have clear, well-articulated opinions about the workshop activities due to their experience in education and likely frequent participation in similar learning environments, the shape of the distribution pyramid was flatter to allow for greater differentiation between expressions of agreement and disagreement. Figure 1 shows the number of statements allowed within each position of the forced distribution.

Participants also completed the parallel versions or equated forms of the MKT measures at the end of course. The MKT measures (pre- and post-tests) were distributed as PDF documents via e-mail and completed independently by participants within a three-day time frame. Participants were instructed to delete their MKT files immediately upon e-mail submission. IRT gain scores were calculated by subtracting the pre-test from the post-test.

3. Results

The Q sorts of the 65 participants were entered into Stricklin and Almeida's (2004) PCQ Software for analysis. Correlation coefficients for each pair were calculated to compare the manner in which individual participants sorted the statements for each Q set. Centroid Factor Analysis was conducted to identify the number of factors present in the data. That is, factor analysis was utilized to group participants who sorted the Q-set items in a similar manner. Varimax rotation was employed to rotate the number of factors revealed using the eigenvalue greater than one method. A cutoff of .35 was used to determine significant factor loadings (Table 1 provides the factor matrix showing defining sorts). Normalized factor scores for each factor were then reviewed as well as factor arrays, arrays of differences between factors, and distinguishing statements for each factor. This information was then considered in light of participants' reported characteristics.

Table 1. Table of Q Sort Factor Loadings

Sort ID	Factor 1	Factor 2	Factor 3	h^2
20	**.65**	.21	.27	.55
14	**.62**	25	-.08	.47
24	**.60**	.09	-.32	.48
20	**.56**	.21	-.34	.48
8	**.55**	.23	-.17	.39
56	**.54**	.21	-.18	.37
16	**.51**	.16	-.34	.40
62	**.50**	**.49**	-.19	.53
15	**.49**	-.21	-.24	.35
64	**.49**	-.12	-.19	.29
4	**.47**	.08	-.10	.23
19	**.45**	**.45**	-.16	.43
28	**.45**	.04	-.33	.32
23	**.45**	.09	-.20	.26
54	**.45**	-.03	.00	.20
3	**.43**	.13	-.15	.23
10	**.43**	-.05	-.17	.22
50	**.42**	-.17	.00	.20
26	**.41**	.07	**-.40**	.33
11	**.39**	.28	.22	.28
52	**.36**	.20	-.08	.17
34	.33	.31	.04	.21
43	.33	.16	-.06	.13
66	.29	-.08	-.09	.10
17	.22	.13	-.06	.07
25	.03	**.72**	-.34	.64
12	.01	**.66**	-.07	.44
36	-.05	**.64**	-.06	.41
13	.21	**.56**	-.07	.37
31	.17	**.54**	-.15	.34
33	-.10	**.53**	-.09	.31
38	.22	**.48**	-.22	.33
32	-.07	**.47**	**-.42**	.40
6	**.37**	**.44**	-.04	.33
5	.10	**.43**	.11	.21
9	**.36**	**.41**	-.22	.35
37	.13	**.40**	.12	.19
51	.22	**.38**	**-.36**	.33
59	.11	**.38**	-.32	.26
63	.08	**.38**	-.20	.20
57	.08	.28	-.23	.14
30	.02	.27	-.22	.12
45	.00	.16	.07	.03
29	.25	.11	**-.68**	.54
39	.09	.07	**-.66**	.45
42	.24	-.04	**-.62**	.44
27	.17	.04	**-.60**	.40
49	**.38**	.06	**-.57**	.47
1	**.45**	.17	**-.53**	.52
46	.11	.00	**-.53**	.29
41	.32	-.03	**-.50**	.36
47	.24	.31	**-.49**	.40
35	.11	.25	**-.48**	.31
40	.22	.01	**-.48**	.28
44	.11	**-.37**	**-.47**	.37
18	.22	.03	**-.46**	.26
61	-.08	.31	**-.45**	.31
48	.25	-.01	**-.43**	.24
53	-.10	.20	**-.43**	.24
22	.24	.23	**-.42**	.29
2	.19	.03	**-.39**	.19
7	.06	-.01	**-.37**	.14
60	.17	-.06	-.27	.10
58	-.16	.06	-.26	.10
55	.04	-.03	.13	.02

3.1 Prevalent Perceptions of Course Activities and Learning Preferences

Factor analysis revealed the presence of three factors, which were interpreted to represent three distinct types of learners and appear to be consistent with the three key basic needs identified by SDT: relatedness, competence, and autonomy. Type 1, which was comprised of 18 participants, was named Relatedness; Type 2, comprised of 11 participants, was named Competence; and Type 3, comprised of 16 participants, was named Autonomy. Ten participants' sorts were confounded or did not fit into a single category. That is, their sorts fit more than one perspective. Ten other participants' sorts were not statistically significant.

3.2 Type 1: Relatedness

The relatedness group was comprised of 18 participants who received instruction at each of the four institutions of higher education, with 33% completing the course at university one, 11% at university two, 28% at university three, and 28% at university four. Similar to the composition of the total sample of participants, 14 (78%) were women and 3 (17%) were men. Type 1 participants reported an average of 10.78 (SD = 7.49) years teaching and 9.89 (SD = 7.15) years teaching mathematics. This group's mean mathematics background score was 3.06 (SD = 1.63), which indicates that the average participant in the relatedness group completed about three regular college level mathematics courses (e.g., college algebra, trigonometry, calculus, etc.).

Recall that relatedness within the SDT perspective refers to the need to belong to a group. Relatedness group participants expressed the opinion that they learned most when engaged in group activities, such as developing math models in groups (statement number 34: array position of +6, z-score of 1.50) and listening to mathematical examples provided by peers (26: +3, z = .84) especially when they were able to choose their own group (27: +3, z = 1.00) rather than depend on one organized by the instructor (28: -4, z = -1.27). This perceived benefit further extended to the participants' preference for working on course tests in groups (45: +7, z = 2.19) but appeared restricted to activities with little conflict. That is, relatedness group participants did not agree that engaging in (3: -2, z = -.69) or listening to debates (4: -3, z = -.92) about content helped to deepen their understanding. Finally, relatedness group participant sorts indicated that using the project provided laptop to access internet resources assisted their learning (30: +4, z = 1.19). Although the internet resources accessed could have been mathematics related, they could also have been social websites that facilitated interaction. For example, a MSPP Facebook page was created by participants early in the first course.

Despite this group's expressed proclivity for working with others rather than alone (51: -7, z = -2.17), their sorts indicated that this preference may be limited to interactions with peers. For example, relatedness group participants were distinguished from the competence and autonomy group participants in their belief that discussing math with instructors during lunch did not help them to develop their understanding (52: -5, z = -1.78). This suspected preference for working with peers may be explained by this group's belief that moving through content at the student level rather than instructor pace helped them to feel comfortable (32: +5, z = 1.37). The 10 items that distinguished the relatedness group participants from those grouped in the competence and autonomy groups are provided in Table 2.

Table 2. Items that Distinguish Relatedness (Type 1) Group Participants from All Others (Types 2 & 3)

Q-Set Item	Group Type		
	1	2	3
3. Participating in debates about content helped to deepen my understanding.	-2	3	4
7. Participating in lectures on mathematics self-efficacy helped me to understand its importance in teaching.	-1	3	6
26. Listening to mathematical examples provided by peers helped me to understand the content at a deeper level.	3	-2	-3
27. Working in a group of my choice provided the best opportunity for learning.	3	-5	-1
32. Moving through content at student rather than instructor pace helped me to feel comfortable.	5	-1	1
34. Developing math models in groups helped me to develop my understanding.	6	1	0
36. Developing math models that can be used with middle level students helped me to develop my understanding.	6	1	-1
46. Working on the test independently helped me to develop my understanding.	-6	1	7
51. Thinking about content at home helped me to develop my understanding.	-7	0	0
52. Discussing math with instructors during lunch helped me to develop my understanding.	-5	0	6

3.3 Type 2: Competence

The competence group was comprised of 11 participants who received instruction at three of the four institutions of higher education, with 18% completing the course at university one, 18% at university two, and 64% at university four. None of the competence group participants attended university three for course instruction; however, only 7 participants completed the course at this location. Similar to the composition of the total sample of participants, 9 (82%) were women and 2 (18%) were men. Teachers in this group reported an average of 10.18 (SD = 10.07) years teaching experience and 8.91 (SD = 7.62) years teaching mathematics experience. Their mean mathematics background score was 4.09 (SD = 3.30), which indicates that the average participant in this group completed about four regular college level mathematics courses (e.g., college algebra, trigonometry, calculus, etc.), but this number varied considerably among the group.

As stated previously, competence within the SDT framework pertains to the need to feel competent and perform well in interactions with others. Consistent with this inclination, competence group participant sorts revealed a preference for activities that required personal responsibility in processing and understanding content. For example, teachers classified in this group viewed assisting others with content as helpful in deepening their understanding (39: +7, z = .87). They preferred activities that required them to answer questions during class (11: +6, z = .85) and in small groups (15: +5, z = .76) as this strategy assisted in their development of understanding. Answering questions was also identified by competence group participants as helpful in building their self-efficacy (12: +3, z = .61; 16: +6, z = .81). Thus, teachers in this group appeared to take an active role in their learning, which was further evidenced by their preferences for listening to mathematics lectures (5: +5, z = .79), asking questions during class discussion (10: +4, z = .72), and taking their own notes (43: +4, z = .68).

Similar to the relatedness group participants, competence group participants viewed working on course tests in groups as effective in helping them to develop their understanding (45: +4, z = .61). However, teachers in the competence group may have found this activity helpful as it provided a forum for their processing and conceptual development of content in contrast to the relatedness group participants who seemed to prefer the strategy for its social and relationship benefits. This explanation is also supported by their preference for participating in debates (3: +3, z = .61), which suggests that competence group participants do not mind experiencing conflict if it promotes their learning. Finally, teachers in this group did not agree that working in a group organized by grade level (29: -4, z = -.58) or a group of their choice (27: -5, z = -.67) provided the best opportunities for learning. This suggests that their positive opinion of answering questions in groups was likely due to a focus on gains in competence rather than comfort level or social interaction. The 12 items that distinguished teachers in the competence group from those grouped in the relatedness and autonomy groups are provided in Table 3.

Table 3. Items that Distinguish Competence (Type 2) Group Participants from All Others (Types 1 & 3)

	Group Type		
Q-Set Item	1	2	3
5. Listening to lectures on mathematics helped me to learn the content.	-1	5	-4
7. Participating in lectures on mathematics self-efficacy helped me to understand its importance in teaching.	-1	3	-6
8. Listening to lectures that incorporate manipulatives helped me to learn the content.	0	-4	0
11. Answering questions during class discussion helped me to develop my understanding.	-1	6	1
16. Answering questions in a small group helped to build my mathematics self-efficacy.	2	6	-1
27. Working in a group of my choice provided the best opportunity for learning.	3	-5	-1
29. Working in a group organized by grade level provided the best opportunity for learning.	3	-4	4
30. Using the MSPP provided laptop to access Internet resources assisted in my learning.	4	-1	4
39. Assisting others with content helped to deepen my understanding.	1	7	2
40. Being asked about my comfort level (e.g., are you okay, how do you feel) made me feel comfortable.	1	-6	3
46. Working on the test independently helped me to develop my understanding.	-6	1	7
52. Discussing math with instructors during lunch helped me to develop my understanding.	-5	0	6

Type 1 = Relatedness; Type 3 = Autonomy

3.4 Type 3: Autonomy

The autonomy group was comprised of 16 participants who received instruction at each of the four institutions of higher education, with 38% completing the course at university one, 31% at university two, 6% at university three, and 25% at university four. Similar to the composition of the total sample of participants, 15 (94%) were women and 1 (6%) was a man. Autonomy group participants reported an average of 10.81 (SD = 6.48) years teaching and 8.75 (SD = 4.81) years teaching mathematics. Their mean mathematics background score was 3.38 (SD = 2.75), which indicates that the average teacher in this group completed about three regular college level mathematics courses (e.g., college algebra, trigonometry, calculus, etc.).

Consistent with autonomy (the need to feel a sense of control in the environment) as characterized by SDT, autonomy group participants identified independent and self-directed activities as those that best assisted their learning. These teacher participants perceived that working on the test independently (46: +7, z = 1.96) as well as developing math models independently (33: +5, z = 1.48) helped them to develop their understanding of the content. They also perceived that reading the assigned journal articles, another independent activity, provided necessary background for the course (1: +5, z = 1.40). Similar to the relatedness group participants, participants classified in the autonomy group identified using the MSPP provided laptop to access internet resources as helpful to their learning (30: +4, z = .98); however, for participants in the autonomy group, preference may have been more related to the autonomy that laptops provide in learning rather than the social connections that they can facilitate.

A preference for autonomous, self-directed activities in these participants was also supported by their high ranking of items related to informal discussion, which involved participants seeking out instructors (52: +6, z = 1.65) and peers (53: +6, z = 1.49) during lunch to discuss content. Furthermore, these participants rated items related to passive activity negatively. For example, autonomy group participants agreed that listening to lectures on mathematics (5: -4, z = -1.29) and listening to mathematical examples provided by instructors (25: -4, z = -1.30) did not help them to learn the content. In addition, autonomy group participants did not agree that listening to a review of the previous day's content helped them to understand the content (31: -7, z = -1.79). The 19 items that distinguished teachers in this group from those classified in the relatedness and competence groups are provided in Table 4.

Table 4. Items that Distinguish Autonomy (Type 3) Group Participants from All Others (Types 1 & 2)

		Group Type		
	Q-Set Item	1	2	3
1.	Reading assigned journal articles provided necessary background for the course.	-6	-5	5
6.	Listening to lectures on mathematics self-efficacy helped me to understand its importance in teaching.	0	2	-6
7.	Participating in lectures on mathematics self-efficacy helped me to understand its importance in teaching.	-1	3	-6
14.	Asking questions in a small group provided clarity for issues I didn't quite understand.	5	2	-5
15.	Answering questions in a small group helped me to develop my understanding.	2	5	-2
17.	Listening to the answers provided to address others' questions during small group discussion provided clarity for issues I didn't quite understand.	0	2	-4
22.	Writing reflections at the end of each class session helped me to develop my understanding.	-5	-6	2
25.	Listening to mathematical examples provided by instructors helped me to understand the content at a deeper level.	2	3	-4
27.	Working in a group of my choice provided the best opportunity for learning.	3	-5	-1
28.	Working in a group organized by the instructor provided the best opportunity for learning.	-4	-3	2
31.	Listening to a review of the previous day's content helped me to understand the content.	4	1	-7
33.	Developing math models independently helped me to develop my understanding.	-3	-1	5
38.	Being assisted with content by peers was more helpful than instructor assistance.	-2	-4	2
43.	Taking my own notes helped me to develop my understanding.	4	4	-2
45.	Working on the test with my group helped me to develop my understanding.	7	4	-5
46.	Working on the test independently helped me to develop my understanding.	-6	1	7
49.	Taking a specific perspective in a case study discussion helped me to develop my understanding.	-4	-7	2
52.	Discussing math with instructors during lunch helped me to develop my understanding.	-5	0	6
53.	Discussing math with peers during lunch helped me to develop my understanding.	-4	-1	6

3.5 Background Characteristics, MKT Gain Scores, and Learning Preferences

To investigate potential differences in background characteristics or mathematics knowledge between the groups that emerged from the Q sort activity, one-way analysis of variance was utilized for each continuous dependent variable (mathematics background, years teaching, and years teaching mathematics). As presented in Table 5, no statistically significant differences were found between learning preference groups and background characteristics (all p's > .05). In addition, chi-square tests were used to investigate differences in gender and university course location between the learning preference groups. Again, no statistically significant differences were found ($\chi 2(3) = 1.58$, $p = .66$ for gender and $\chi 2(9) = 13.63$, $p = .14$ for course location).

Similarly, no statistically significant differences were found in IRT gain scores between learning preference groups for any of the MKT scale gain scores (Table 5), including Number Concepts, Algebra, and Geometry (all p's > .05). That is, MKT growth was similar across participants from the three observed learning preference groups. Even though participants interacted with course strategies differently, learning preference was not associated with differences in their growth. Thus, it appears that the structural and process features of the MSPP course served the three learning preference groups equally well.

Table 5. Summary of ANOVAs for Teacher Background Characteristics and MKT Gain Scores

	Sum of Squares	df	Mean Square	F	p
	Years Teaching				
Between Groups	3.13	2	1.56	.03	.98
Within Groups	2597.19	42	61.84		
Total	2600.31	44			
	Years Teaching Mathematics				
Between Groups	9.31	2	4.66	.11	.90
Within Groups	1836.69	42	43.73		
Total	1846.00	44			
	Mathematics Background				
Between Groups	7.37	2	3.69	.58	.57
Within Groups	267.6	42	6.37		
Total	274.98	44			
	Number Concepts				
Between Groups	.022	2	.011	.032	.97
Within Groups	14.092	41	.344		
Total	14.113	43			
	Algebra				
Between Groups	1.145	2	.572	1.63	.21
Within Groups	14.376	41	.351		
Total	15.521	43			
	Geometry				
Between Groups	.25	2	.13	.45	.64
Within Groups	11.39	41	.28		
Total	11.64	43			

4. Summary and Analysis

The results of this study revealed that teacher participants of an intensive summer mathematics course perceived that different strategies benefitted their learning. Specifically, defining group characteristics appeared to be based on whether teachers preferred activities and strategies that facilitated underlying needs for learning as characterized by SDT: relatedness, competence, or autonomy. That is, teachers appeared to interact with course strategies and activities in a manner that met underlying needs for learning. Participants in the relatedness group favored activities that emphasized social interaction; participants in the competence group favored items that emphasized understanding; and participants in the autonomy group favored items that emphasized his/her ability to seek out learning opportunities. The following example illustrates these distinct learning preferences that emerged from the Q sort activity. Teachers in the autonomy group tended to agree that reading assigned journal articles assisted them in their learning; however, the relatedness and competence group participants strongly disagreed with this perspective. Reading independently is a self-directed and autonomous activity that requires no social interaction. Although one could argue that reading would promote one's competence, reading without discussion or further analysis can result in knowledge but not deeper conceptual understanding. Additional evidence of these distinct preferences involves the observed difference between the relatedness and autonomy group participants. These two groups both indicated disagreement in the utility in listening to lectures about mathematics to help them to learn content. In contrast, the competence group participants agreed that the mathematics lectures were helpful in their learning. Following the principles of SDT, the relatedness group participants likely disagreed with this perspective because listening to lectures does not typically promote opportunities for social interaction, especially peer to peer interaction, whereas the autonomy group participants likely disagreed because little autonomy and choice are typically available in this activity.

Despite these differences, participants from the three preference types did not significantly vary in characteristics, such as gender, background in mathematics, or the number of years teaching. They also did not differ depending on the university location where they completed the course. Most importantly, participants from the three preference types did not differ in their MKT gain scores from pre-test to post-test. This finding underscores past research showing that variation in course strategies and activities may be necessary to meet the varied learning needs of mathematics teachers. That is, the results do not suggest that any particular strategy or activity was perceived by all teachers to be most effective at influencing their learning and no participants of a particular preference type appeared to benefit more than any others in their learning. Therefore, variety in course strategy and activity seems necessary when considering the teacher participants' points of view. Variation in course structure and processes is more easily accomplished over an extended period of time than a day-long teacher development workshop, which in turn supports the need for extended professional development to enact teacher change.

5. Study Limitations

Q methodology also suffers from limitations. Just as deductive research approaches may be limited in their measurement, the concourse and resulting Q-set may not adequately represent the perspectives of teachers. The MSPP course was offered at four university locations, and although the course was taught using the same instructors and content materials, capturing all the learning strategies and activities perceived by participants in the Q-set was difficult and omissions may have occurred. Because the Q-set was developed entirely from participant interviews and observations rather than from existing preference types, future research is necessary to determine if similar types emerge in other samples. Therefore, both deductive and inductive methods are necessary for understanding the manner in which teachers interact with and benefit from teacher development.

Another limitation relates to the sorts that were not accounted for in the factor analysis. As indicated above, 10 participant sorts fit into more than one participant type. These sorts could be explained by participants who are motivated by more than one underlying need for self-determination. However, 10 additional participant sorts did not fit into any participant type and could not be explained. From a practical perspective, this finding may further emphasize the importance of selecting strategies and activities for professional development using a variety of different empirical and experience based recommendations.

Designers of professional development should also be alerted to the ordinal level of the present analyses. MSPP teacher participants were asked to rank order the degree to which they agreed with each Q-set statement. Rank ordering does not involve equal intervals between rankings. For example, two participants might rank their preference for developing math models in groups higher than their preference for developing math models independently. However, one participant may feel more strongly than the other about how much more she prefers developing math models in groups over developing them independently. Consequently, the possibility exists that participants may have enjoyed and benefitted from all the course strategies and activities, and their lowest ranked item could still reflect an activity or strategy that they preferred, albeit one they preferred the least in comparison to all others.

6. Discussion

Although generalization was not the purpose of the present study and the use of Q methodology was originally intended to inform and guide the project, the results provide insight for developers of teacher professional development especially when considered in light of existing research in the field. Most research investigating the value of various types of teacher development has used a reductionist approach (e.g., Stevens et. al., 2009; Garet et al., 2001). In these studies, teachers' ratings of professional development activities are reduced to a mean score that is used to represent the sample, which can then be used as an estimate for the population. Although generalization is an advantage, the inability to discover differences in teachers' learning preferences within situated professional development contexts is a disadvantage. "From the situative perspective, what appear to be general principles are actually intertwined collections of more specific patterns that hold across a variety of situations" (Putnam & Borko, 2000, p. 13). In addition, studies that do not include measures guided by the actual experiences of participants (e.g., items written based on participants' perceptions identified through interviews and observations) are limited to only the points and aspects of professional development identified by researchers. Detached objectivity in measurement does not recognize that professional development designers and instructors are a part of the context in which teachers are learning (Putnam & Borko, 2000).

The present study's inductive approach yielded three learning preference types that appear to be consistent with the basic needs identified in Self-Determination Theory which is commonly employed as a theory to explain motivation associated with positive outcomes in the field of education (e.g., Grolnick & Ryan, 1987; Miserandino, 1996; Ryan & Connell, 1989; Vallerand & Bissonnette, 1992). According to Ryan and Deci (2000), individuals can be either "proactive and engaged" or "passive and alienated" (p. 68) depending upon the social-contextual conditions they experience. If individuals are provided choices in their learning (autonomy), opportunities to feel they have mastered content (competence), and connections to others (relatedness), then engagement and motivation are encouraged. However, if these psychological needs are not met, then passivity and alienation will likely occur. This issue should be directly addressed in the context of extended and meaningful professional development. Engagement in complex content-based problem solving needs to be flexible enough to enlist the participation of a large group of teachers with varied learning preferences. The results of this study suggest that preferences for certain learning strategies and activities may be related to underlying needs for self-determination. Thus, addressing teacher content knowledge and years teaching experience alone, may not address all of their learning needs.

To meet teachers' leaning needs, Loucks-Horsely et al. (2010) encouraged considering variations found across individual teachers in their learning needs and experience teaching. Although the present results do not support considering experience teaching at the same level, at least based on years of experience alone, the findings emphasize the consideration of teachers' learning needs. When selecting teacher development activities, a variety in strategies and activities with multiple opportunities for social interaction (relatedness), deep understanding (competence), and self-direction (autonomy) should be developed. This is consistent with the recommendation of Loucks-Horsely et al. (2009) that single strategies should be avoided. Future research is necessary to explore the possible connection between SDT and teacher outcomes as designing teacher development activities and strategies using a theoretical framework for motivation might strengthen existing approaches and outcomes. When such an approach to the design of teacher development activities is taken, it may be possible to identify antecedents to teacher outcomes, such as persistence in continued professional development and self-efficacy profiles. Monitoring such antecedents may improve the impact of professional development on teacher subject matter knowledge, pedagogical content knowledge, and instructional quality.

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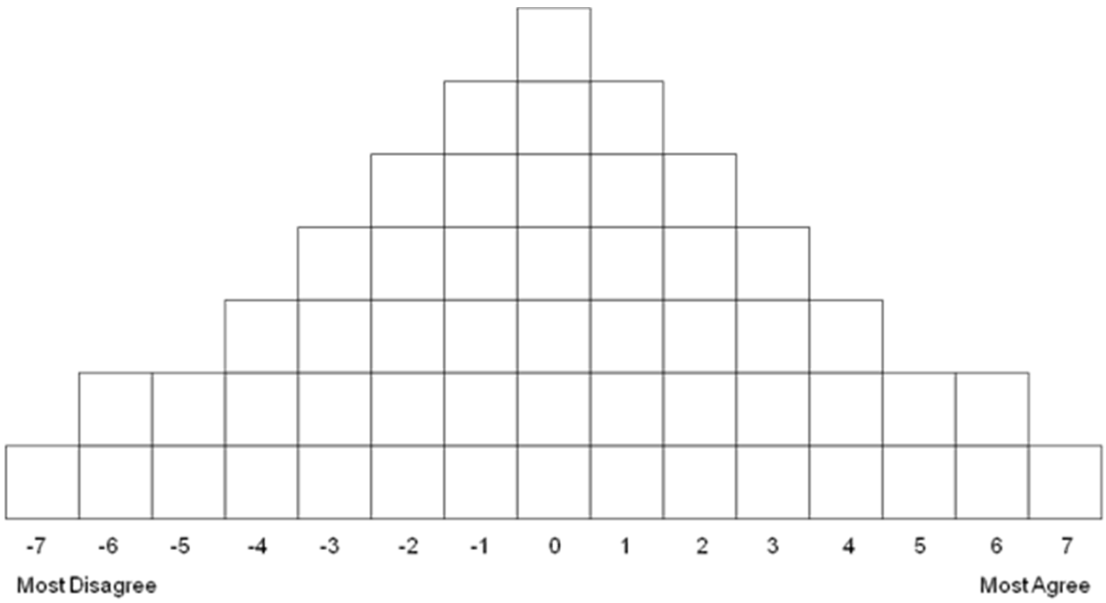

Figure 1. Forced frequency distribution