Int. J. Educ. Stud. 03 (02) 2016. 45-54

Available Online at ESci Journals

International Journal of Educational Studies

http://www.escijournals.net/IJES

UNCOVERING THE DEVELOPMENT OF CONTENT KNOWLEDGE, PEDAGOGICAL KNOWLEDGE AND PEDAGOGICAL CONTENT KNOWLEDGE: PROSPECTIVE TEACHERS' PERCEPTIONS

Sabah Akhtar, Faiza Shaheen*, Saima Bibi

University of Education, Bank Road Campus Lahore, Pakistan.

A B S T R A C T

The purpose of the current study was to compare the perceptions of prospective teachers with respect to their Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) in the subject areas of mathematics, science, English and Social Studies. Census sampling was used to take 189 prospective teachers from two teacher education institutes (Institute I= 101, Institute II= 88) in this cross sectional survey type study. The analysis of questionnaire data showed that no significant difference was found in CK of prospective teachers in all subject areas. Significant differences were found in PK and PCK in the subject areas of English, Science and Mathematics whereas, for the subject of Social Studies, this difference was not observed in the prospective teachers of both institutes. Findings of the study suggest that teacher education programs should be aligned with the appropriate model for pre-service teacher education meant for the improvement of CK, PK and PCK in the English, Science, and Mathematics with more focus on Social Studies.

Keywords: Content Knowledge, Pedagogical Knowledge, Pedagogical Content Knowledge, Pre service elementary teachers.

INTRODUCTION

Giving priority to content knowledge, pedagogical knowledge, or to base teaching on the mixture of these two, has long been remained a concern in the literature of teacher education. The review of the documents of National and International professional standards for teachers clearly indicate common expectations from teachers of varied levels: these expectations are command of subject matter, skills of delivering the content effectively, planning instruction, classroom management skills, assessment skills, creating learning environment, knowledge of how children construct knowledge. The combination of appropriate extent of CK, PK, and PCK makes teachers effective as well as competent. The underlying reason to conduct this study is to assess the ability of prospective teachers. The extent to which education institutes are developing required skills among prospective teachers. It has been established through the literature that lack of any component of this knowledge endangers teachers becoming proficient (Cogill, 2008; Parkay & Standford, 2008; Carlsen, 1987).

Subject matter knowledge or content knowledge has been defined by Graber (1999) as knowledge of content of each subject e.g. mathematics, science, or biology; knowledge of actual subject matter that is to be learned or taught (Kohler, 2011). Teachers must know the central facts, concepts, theories and procedures within a given field (Shulman, 1986). Research studies (e.g. Leinhart & Greeno, 1986; Leinhart & Smith, 1985) showed that knowledge of subject is very important to teaching. Quality of teaching varies with the quality of teachers' understanding of the content being taught (Steinberg, Haymore, and Marks, 1985; Carlsen, 1987). Teachers need to be prepared to apply new teaching and learning practices along with deeper understanding of the content they plan (Parkay & Standford, 2008). Effective teachers teach content to the students in a wider context of the world, relating material not only to academic subjects but

* Corresponding Author:

Email: fizjanjua@gmail.com

also to their real life (Bloom, 1984).

Research from the National Center for Research on Teacher Education indicated that teachers do not understand their subjects in a way that enables them to explain important concepts to students. According to Ball (1990) when prospective teachers were asked to explain the mathematical sentence they could not do so even with mathematics majors. Kennedy (1989) expressed a similar problem that when given a problem that required selecting a singular or plural verb, many prospective teachers, as well as many majors, were unable to explain the concept of subject/ verb agreement and how it applied to the sentence. Training teachers in the pedagogy of explaining cannot work if teachers do not properly understand the content they are supposed to teach.

It is also important for teachers to expand their content knowledge of subjects because content does not only increase in volume but also change in character over time. The methods of inquiry include a set of assumptions, rules of evidence, or forms of argument that are or can be employed by those who contribute to the development of the discipline. McDiarmid, Ball, and Anderson (1989) are of the view that teachers of all grade levels and subjects may need to understand fundamental concepts and values within the subjects they teach. Teachers must be equipped with the ways of inquiring about the subjects. Wlson, Shulman, and Richert (1987) quote a secondary teacher who says he needs 150 different ways of knowing his subject in order to meet the needs of diverse groups of students in class. There is need to improve our teacher education programs because we need to prepare such teachers who understand the relationship between pedagogy and different kinds of knowledge (McDiarmid, Ball, and Anderson, 1989). We need teachers who can organize subject matter meaningfully, know its methods of inquiry, and to see its significance to everyday life.

Kennedy (1989) says that teacher education has long been rested on the assumption that subject matter and pedagogy are separate bodies of knowledge. Subject matter is normally taken for granted in teacher education courses, as both faculty and students assume that the students already know their subjects.

Pedagogy has been defined by Watkins and Mortimer (1999) as “any conscious activity by one person designed to enhance the learning of another”. Leach and Moon (1999) expand further on what may define pedagogy by describing a Pedagogical Setting as “the practice that a teacher, together with a particular group of learners creates, enacts and experiences”.

The meaning of pedagogy while using it in the process of teaching is complex that includes other factors like learner’s role, interaction between teachers and learners and practice that further involves school environment, a teacher’s place or position in the school, prior experience of teaching, teacher training and teacher’s own experience of learning (Cogill, 2008). Whereas Shulman (1987) views pedagogical knowledge as broad principles and strategies of classroom management and organization that appear to transcend subject matter.

Brown and McIntyre (1993) provide ten qualities proposed by pupils that create good teaching:

- Creation of a relaxed and enjoyable atmosphere in the classroom
- Retention of control in the classroom
- Presentation of work in a way that interests and motivates
- Providing conditions so that pupils understand the work
- Making clear what pupils are to do and achieve
- Judging what can be expected of a pupil
- Helping pupils with difficulties
- Encouraging pupils to raise expectations of themselves
- Development of personal mature relationships with pupils
- Teachers’ personal talents
- Considering how planning interacts with the management of classes and lessons
- The management of lesson introductions
- Managing question and answer sessions.
- Building the confidence and trust of pupils

The involvement of students in learning and part of knowing the ways through which learners or students learn also include in teaching process (Cogill, 2008).

According to Shulman (1987) general pedagogical knowledge means aspects about pedagogy in general regardless of the content knowledge teachers are to be specialised in.

Knowledge about the processes and practices or methods of teaching is referred as pedagogical knowledge. Some components that include classroom management skills, teaching strategies, evaluation techniques, and also the nature of the audience or students are included in the

concept of pedagogical knowledge.

Chai and Tsai (2013) defined pedagogical knowledge as the Knowledge about the students' learning, instructional methods, different educational theories, and learning assessment to teach a subject matter without references towards content. Knowledge about pedagogy is somewhat particular in selecting/using appropriate teaching techniques, tools or methods that best facilitate and suit to the teaching and learning process regardless of the specific content command of teachers.

Several factors together contribute to make teaching process effective including knowledge of subject matter, knowledge of students, knowledge of the cognition of students and knowledge of teaching and decision making etc. (Turnuklu & Yesildere 2007). It is well acknowledged in the literature of teaching effectiveness that having knowledge of content and students is not only necessary to ensure students' understanding of the content being taught instead the knowledge about teaching itself and techniques and strategies to be followed remain equally necessary. According to Turnuklu and Yesildere (2007) that relating previous knowledge of students while teaching a specific topic /lesson also assure that students will understand properly. This skill is also expected from teachers to practice.

Pedagogical knowledge encompasses all of the above mentioned required skills essential for effective teaching. Lee (2010) defined pedagogical knowledge as the knowledge of how to teach or transfer that knowledge to the concerned learners. The knowledge of students and teaching is pedagogical knowledge. Possessing the knowledge related to content to be taught to the students is necessary to have but transferring that knowledge to the students in understandable ways is also crucial.Sound pedagogical knowledge helps the teachers to select the appropriate teaching tools, skills and techniques that are used specifically to teach certain content in order to make the topic understandable to the students. It also helps teachers to manage classroom activities and time (Kilic, 2005; Abbitt, 2011). Having the knowledge about different strategies does not suffice the pedagogical knowledge whereas knowledge related to students; class room management, planning, and students' assessment are also included in pedagogical knowledge.

For the purpose of effective teaching a blend of subject knowledge and pedagogical knowledge is required. The pedagogical knowledge helps the teacher to select the appropriate instructional strategies that ensures the understanding of the content being taught to the students (Lee, 2010).

The findings of a research study explore the need of pedagogical knowledge of teachers that PK enables the teachers to relate, present and teach the content effectively by using a blend of content knowledge as well as best suited technique for the transition of that subject matter.

Teachers with a strong command over subject matter would be comparatively more proficient to satisfy students' queries and complexities and making the content more comprehendible to students. But content knowledge and teachers' expertise on handling the classroom problems, and command on pedagogy does not work as isolated compartments. Rather a blend of both of the components formulates another component essential to develop in teachers that will make teaching effective in terms of enhancement in students' learning (Lee, 2010). Kennedy (1998), in the support of pedagogical content knowledge, quoted an example of a boy who knows the way of the store but is unable to give directions to any person to get the way to the store. Same is the case of the teachers who in spite of having enriched content knowledge face difficulty in delineating issues to students.

Knowledge of content and knowledge of teaching is termed as pedagogical content knowledge (PCK) by Schulman (1995: 130) describes pedagogical content knowledge as 'the ways of representing and formulating the subject that makes it comprehensible to others', 'an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons'.

If we base PCK on Shulman's (1987) notion, teachers must possess command over and must have competency on presenting the content to learners (Parker & Heywood, 2000). Pedagogical content knowledge includes the knowledge of the subject matter, what the contents of the particular topic or the subject includes in it, the historical and philosophical roots of this content knowledge, its rationale and principle, what are the sources to approach the modern trends and emerging issues related to those contents with a competency to transmit this enriched knowledge to the learners making it more comprehendible. Moreover, Pedagogical content

knowledge consists of presenting the augmented knowledge that is more powerful pedagogically, becoming adaptive while presenting in class according to the background and mental level of the students and the environment in which it is being presented (Yurnuklu & Yesildere, 2007).

An, Kulm and Wu (2004) made their contributions in pedagogical content knowledge by describing its three components i.e. knowledge of content, knowledge of curriculum and knowledge of teaching, interwoven with each other and the absence of one of the components will negatively affect teachers' performance and ultimately students' learning. Grouws and Schultz (1996) explain that PCK includes, but is not limited to, useful presentation, unifying ideas, clarifying examples and counter examples, helpful analogies, important relationships, and connection among ideas. Leinhardt (1986) pointed out that both content and pedagogical knowledge is the requirement of a successful teacher. PCK is inter mix of three components i.e. knowledge students conceptions and misconceptions, knowledge of specific teaching strategies, and knowledge of content elaboration (Smith & Neale, 1989).

A number of research studies have been conducted to improve pedagogical content knowledge of different subject areas for in service teachers (Daehler & Shinohara, 2001; Stacey et al., 2008) worked on exploring pedagogical content knowledge in mathematics.

Few of the studies were found for PCK developed among prospective teachers. For an instance, McDuffy (2004) to explore Mathematics PCK in two pre-service teachers developed during the program of studies and reported less level perceived level in the end. Smithey (2006) found in his study that science teachers were inadequately prepared in involving students to approach the solutions of encountered learning problems during teaching learning process.

Researchers found that professional development that is much concerned to the development of PCK leads to the improved teachers' performance and better students' learning (Hill, 2008).On the other hand, lack of teachers 'pedagogical content knowledge leads to students' poor performance, misconceptions and complexities (Lee, 2010).

Participants: One hundred and eighty nine (189) prospective teachers enrolled in two years elementary teacher education programs were taken by using census sampling technique. It provided a true measure of population due to having no sampling error. Demographic information involved the gender, institution, and semester. Out of all participants (N=189), 53% belonged to one institute (N=101) and the rest of 47% (N= 88) were from the other teacher education institute. Gender wise distribution of participants was 92% female (N=174) and 8% males (N=15). The data showed that overall 51.3% (N=97) prospective teachers were at the initial stage i.e.1st semester and 48.6% (N=92) were at the stage near completion i.e.4th semester of two teacher education programs.

Table 1. Frequency distribution of participants with respect to institutes.

Institutions	N	Percent
Institution 1	101	53%
Institution 2	88	47%
Total	189	100%

Table 2. Frequency distribution of participants with respect to semester.

Semester	N	Percent
1st Semester	97	51.3%
2nd Semester	92	48.6%
Total	189	100%

Table 3. Frequency distribution of participants with respect to gender.

Gender	N	Percent
Females	174	92%
Males	15	8%
Total	189	100%

Instrument: For the current study a questionnaire of Pre service teachers' knowledge of teaching and technology developed by Schmidt, Bran & Thompson and Koehler Mishra & Shin in the year 2009 was used. Out of seven sub scales of the instrument, the three sub-scales such as Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) were used for the current study. The major reason of selecting the instrument is that it was particularly designed for prospective teachers of early childhood, and elementary teacher education programs.

Reliability reported by Schmidt et al, 2009 for each subscale was CK (α= .84), PK (α = .84), and PCK (α = .85). In the current study, reliability of three selected subscales was calculated with 30 pre service elementary teachers, and was found as CK (α = .80), PK (α = .76), and PCK (α = .74). The overall alpha coefficient for PCK was calculated .86 therefore showing an acceptable amount of reliability

for 23 selected items of the original instrument.

Data Analysis: The study aimed at exploring the development of CK, PK, and PCK among prospective teachers of elementary teacher education programs in the subject areas of English, Mathematics, Science, and Social studies.

First dimension of analysis was to find out the difference of perceived level of PCK of prospective teachers at the initial stage of teacher education program and of those at the stage near completion, within each institute by applying t-test for independent sample.

Secondly the levels of PCK as perceived by senior (4th semester) prospective teachers studying at two different teacher education institutes was explored by categorizing PCK score into three categories i.e. high, average, and low.

Looking into data more deeply, the difference of prospective teachers' perceived level of Content Knowledge (CK), Pedagogical Knowledge (PK) and overall PCK in each subject area was identified and compared institution wise by applying t-test for independent sample. Another concern of the study was to determine the influence of gender on the overall perception of PCK among senior (4th semester) prospective teachers by applying t-test for independent sample. Difference in the mean scores of PCK of prospective teachers was calculated across the variables such as institute, program, and gender.

RESULTS

Table 4. Comparison of the perceived level of PCK of two pre service teacher education programs.

	Variables	N	Mean	d*f*	t-value	Sig.
Institute 1	Semester 1	53	77.40	99	-4.988	.000***
	Semester 4	48	86.71			
Institute 2	Semester 1	44	77.55	86	2.821	.006**
	Semester 4	44	80.39			

*: $p < .05$; ** $p < .01$; *** $p < .001$

The results shown above clearly indicate a significant difference between the perceived level of PCK of prospective teachers at the initial stage of teacher education program (M= 77.40) and of those at the stage near completion (86.71) of institute 1. Similarly, the mean score of PCK of senior prospective teachers was higher (M= 80.39) than their juniors (Mean = 77.55) in other institute.

Table 5 Mean difference of senior prospective teachers' PCK score with respect to institutes.

Variables	N	Mean	d*f*	t-value	Sig.
Institute 1	48	86.75	90	-2.543	.015*
Institute 2	44	80.39			

*: $p < .05$; ** $p < .01$; *** $p < .001$

The analysis of senior prospective teachers' perceived PCK scores (as indicated in Table 5), from both teacher education institutes, points out a significant difference (α=.015), where the mean score of institute 1 is higher (M= 86.75) than of institute 2 (M= 80.39).

Prospective teachers' perceived level of PCK provided researchers a closer lens to look into their differences in the practices of both institutes. Criteria for categorizing PCK score is given below:

Table 6. Criteria for categorizing PCK scores.

PCK score	Level
35 to 82	Low
82 to 89	Average
Above 89	High

Table 7. Perceived Level of prospective teachers' PCK with respect to institutes.

Institutes	High	Average	Low	Total
I	22 (45.8%)	17 (35.5%)	9 (18.7%)	48 (100%)
II	12 (27.3%)	14(31.8%)	18 (40.9%)	44 (100%)

The development of PCK was calculated and found comparatively high (45.8 %) among prospective teachers of institute I than that of institute II where fewer prospective teachers (27.3 %) meet this level. 35.5% from institute I and 31.8 % prospective teachers of institute II were found in between high and low levels. Considerably higher percentage (40.9%) of prospective teachers of institute II were on low level (18.7%) than of institute I.

Table 8. Mean difference of prospective teachers' PCK in English, Science, Math, and Social studies across the institutes.

		Variables	N	Mean	d*f*	t-value	Sig.
English	CK	Institute 1	48	10.95	90	1.679	.097
		Institute 2	44	11.77			
	PK	Institute 1	48	28.73	90	3.985	.000***
		Institute 2	44	25.39			
	PCK	Institute 1	48	44.44	90	3.526	.000***
		Institute 2	44	39.98			
Science	CK	Institute 1	21	11.10	63	.710	.504
		Institute 2	44	10.68			
	PK	Institute 1	21	27.95	63	2.164	.024*
		Institute 2	44	25.39			
	PCK	Institute 1	21	44.14	63	2.661	.007**
		Institute 2	44	39.82			
Mathematics	CK	Institute 1	05	10.60	23	1.137	.185
		Institute 2	20	9.15			
	PK	Institute 1	05	29.40	23	2.042	.034*
		Institute 2	20	24.20			
	PCK	Institute 1	05	43.80	23	1.819	.014*
		Institute 2	20	36.70			
Social Studies	CK	Institute 1	24	11.25	37	1.187	.252
		Institute 2	15	11.87			
	PK	Institute 1	24	28.92	37	1.783	.129
		Institute 2	15	26.87			
	PCK	Institute 1	24	43.88	37	.966	.340
		Institute 2	15	42.40			

*: $p < .05$; ** $p < .01$; *** $p < .001$

For further analysis of data only senior (4th semester) prospective teachers were considered. The reason of this was that the study focused on investigating the development of PCK among prospective teachers of a well-developed teacher education institute and comparing it with the PCK level of relatively less developed institute.

The analysis of perceived level of PCK (sub scales CK and PK, and overall PCK) of senior prospective teachers shows that there was no significant difference in CK in all four subject areas i.e. English (α=.097), Science (α=.504), Mathematics (α=.185), and Social studies (α=.250) of both institutes. It is also evident from the results that significant difference was found in PK in three subject areas i.e. English (α=.000), Science (α=.024), and Mathematics (α=.034) whereas the difference was insignificant for the subject of Social studies (α=.129).

While comparing the students of both institutes on overall PCK scores, significant difference was found in the subject areas of English (α=.000), Science (α=.007), and mathematics (α=.014) but it was not found significant in Social studies (α=.340).

Table 9. Mean difference of prospective teachers' overall PCK score with respect to gender.

Variables	N	Mean	d*f*	t-value	Sig.
Male	15	85.53	90	.784	.440
Female	77	83.35			

*: $p < .05$; ** $p < .01$; *** $p < .001$

PCK with respect to gender was found insignificant (α=.440) with the slight difference of mean score for male (M= 85.53) and female (M= 83.35). The result shows that gender does not significantly influence the development of PCK.

DISCUSSION

The place of pedagogical content knowledge in the essential knowledge basis for effective teaching has been widely acknowledged. The blend of content knowledge

and pedagogical knowledge provide us another lens to look deeply into the competencies of pre service and in service teachers.

One major finding of the study indicates that beginning prospective teachers (1st semester) and seniors (4th semester) from both teacher education institutes were significantly different in the development of PCK. The higher score of 4th semester students on PCK is an indication that their teacher education program course experiences positively influenced with this respect. Development is gradual and time taking process and development of PCK is deeply rooted in a teacher's daily tasks, it covers both theory learned during teacher preparation program as well as experience gained from ongoing school tasks. It takes considerable amount of time to prospective teachers to be rich in the repertoire of professional knowledge and skills of teaching. Kind (2009) views in similar lines that expert teachers are not born with PCK. So throughout two years of their course work experiences they study the courses of educational psychology, educational assessment, classroom management, guidance and counseling, teaching methodologies, teaching of English (as compulsory), opt teaching of Science, Teaching of Social studies, Teaching of Mathematics etc and are engaged in a range of activities including presentations, lesson planning, and they go through micro teaching sessions, and teaching practice for the minimum time duration of one month. Resultantly they develop in pedagogical content knowledge as the findings of the study show that senior prospective teachers of both universities were higher in this construct than that of their junior counterparts.

The comparison of the perceived level of PCK of both universities revealed that senior prospective teachers studying in an already well established teacher education institute perceived themselves more competent with respect to PCK than those from relatively less developed or developing teacher training institute. Among many factors associated with PCK development two are teachers' personal background and the environment. Kind (2009) mentioned three commonly found factors contributing the growth of PCK among novice teachers i.e. good command on subject matter knowledge, experience of teaching in classroom, having self confidence and provision of supportive environment where collaboration is encouraged. For newly emerging and developing teacher training program holders it is a big challenge to facilitate teacher educators with training for appropriately modeling PCK. Because literature supports that the knowledge and experience of teacher educators influence the knowledge of their students (Kilic, 2010). There might be difference in the expertise of teacher educators with respect to putting student teachers into the activities supportive for PCK development.

The results of the study also showed that in English, Science, and Mathematics the prospective teachers of both institutes were on equal level of CK. This is generally assumed in teacher education programs that teacher education candidates bring sufficient amount of content knowledge at the time of entry that is why subject specific content knowledge is not offered to them in teacher education program courses. Two years pre service teacher education programs in our context are also based on the same assumption. The almost same perceived level on CK shows that the practices of both institutes are same regarding CK.

On the other hand significant differences in the development of PK in English, Mathematics, and Science were found between senior students of both universities. Pedagogical knowledge is the in depth knowledge about the processes of teaching and learning or methods of teaching and learning. PK requires an understanding of cognitive, social and developmental theories of learning and how they apply to students in the classroom; classroom management, lesson plan development and implementation student evaluation techniques or methods used in the classroom; the knowledge of altering strategies according to the need of students for evaluating their understanding. Research on pedagogy has focused on the application of general pedagogical practices in the classroom, isolated from any relevant subject matter. However, several researchers (e.g., Ball & McDiarmid, 1990; Magnusson, Krajcik, & Borko, 1993) have rekindled the discussion about the importance of teachers' content knowledge in learning to teach. Teachers with deep knowledge of PK understand PCK i.e. 'knowledge of pedagogy that is applicable to the teaching of specific content" (p.14). According to Schulman (1987, p. 15), PCK is "the ability of a teacher to transform content backgrounds in a classroom context" (Handbook p. 64). Teacher education students develop in PK as they go through the courses of classroom management, assessment, learning theories etc. The practical nature of course assignments and field tasks help them to enhance in PK. These aspects might

not be as implemented (conceptually as well structurally) in a university emerged a decade ago as in the other pre established institute.

The overall development of PCK in English, Science, and Mathematics was higher among the students of pre established institute. Understanding teachers' practices with respect to PCK may be helpful in refining their professional learning. There is need to develop and apply appropriate model for teachers development. Some models are available in literature of teacher education, specifically meant for PCK development of pre- service science teachers (Corchran, DeRuiter, & King, 1993; Sakofs et al., 1995). For example the reform initiatives in science provide a guide for some teacher educators to develop models of science teacher development (Bell & Gilbert, 1996; Cochran, DeRuiter, & King, 1993; Cochran, King, & DeRuiter, 1993; Magnusson, Krajcik, & Borko, 1993; Sakofs et al., 1995).

IMPLICATIONS

This study provides the insight into what prospective teachers of two teacher education institutes perceive about their competencies with respect to CK, PK, and PCK of different subjects teachers need to teach at elementary level. Pre – service teacher education program holders might benefit with the results of the study in a sense that they can view the effectiveness of program for PCK development from the lens of student teachers' self-perception. This study did not include the perceptions of course instructors of prospective teachers. Difference between first semester and fourth semester was used to conclude PCK perceptions, acute picture of PK can be studied during teaching practice in third semester. Further, deeper research studies are needed to explore the reasons of low perceived level of PCK. The difference of this level can be gauged with regard to the differences in the structural and conceptual orientations of these pre service teacher education programs. Moreover intervention studies may be designed to enhance PCK in the subject of English, Science, Mathematics and Social studies. Teaching practice activities should be observed with the angle of PCK.

REFERENCES

Abbitt, J. T .(2011). Measuring technological pedagogical content knowledge in preservice teacher education: a review of current methods and instruments. *Journal of Research on Technology in Education, 43*(4), 281-300.

An, S., Kulm, G. & Wu, Z. (2004). The pedagogical content knowledge of middle school, mathematics teachers in China and the U.S. *Journal of Mathematics Teacher Education, 7*, 45–172.

Ball, D. L. (1990). The mathematical understandings that preservice teachers bring to teacher education. *Elementary School Journal*, *90*, 449-466.

Ball, D. L., & McDiarmid, G. W. (1990). The subject-matter preparation of teachers. In W. R. Houston, M. Haberman, & J. Sikula (Eds.), *Handbook of research on teacher education* (pp. 437–449). New York: Macmillan.

Banks, F., Leach, J., & Moon, B .(1999). *New understandings of teachers' pedagogic knowledge.* In J. Leach and B. Moon (Eds) *Learners and Pedagogy.* London: PCP.

Bell, B., & Gilbert, J. (1996). *Teacher Development: A Model From Science Education* . East Lansing, MI: National Center for Research on Teacher Learning.

Brown, S., & McIntyre, D .(1993). *Making Sense of Teaching.* Buckingham: Open University Press.

Carlsen, W. S. (March). *Why do you ask? Effects of science teacher subject matter knowledge on teacher questioning and classroom discourse*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Chai, C. S., Koh, J. H. L., & Tsai, C. C .(2013). A Review of Technological Pedagogical Content Knowledge. *Educational Technology & Society, 16* (2), 31–51.

Cochran, K., DeRuiter, J. & King, R. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education*, *44* (4), 263-272

Cogill, J .(2008). Primary teachers' interactive whiteboard practice across one year: changes in pedagogy and influencing factors. EdD thesis King's College University of London. Available at www.juliecogill.com

Daehler, K., & Shinohara, M. (2001). A complete circuit is a complete circle: Exploring the potential of case materials and methods to develop teachers' content knowledge and pedagogical content knowledge of science. *Research in Science Education, 31,* 267-288.

Graeber, A. O. (1999). Forms of knowing mathematics: What preservice teachers should learn. *Educational Studies in Mathematics, 38,* 189–208

Grouws, D., & Schultz, K. (1996). Mathematics teacher education. In J. Sikula (Ed), *Handbook of Research on Teacher Education* ,2nd edition (USA: Macmillon).

Hill, H. C. (2008). Unpacking pedagogical content knowledge: conceptualizing and measuring teachers' topic specific knowledge. *Journal for Research in Mathematics Education, 39*(4), 372-400.

Kennedy, M. M. (1989). *Challenging the myths about teacher preparation*. Paper presented to the Office for Educational Research and Improvement, Washington, DC.

Kennedy, M. M. (1998). Education reform and subject matter knowledge. *Journal of Research in Science Teaching, 35,* 249-263.

Kilic, K. (2009). Pedagogical content knowledge of preservice secondary mathematics teachers. Unpublished doctoral dissertation, Graduate School, The University of Georgia.

Kind, V. (2009) 'Pedagogical content knowledge in science education: potential and perspectives for

Kohler, M. J. (2011). *Technological pedagogical knowledge*. Retrieve from http://mkoehler.educ.msu.edu/tpack/technological-pedagogical-knowledge-tpk/

Lee, J. (2010). Exploring kindergarten teachers' pedagogical content knowledge of mathematics. *International Journal of Early Childhood, 42,* 27-41. doi: 10.1007/s13158-010-0003-9

Leinhardt, G. (1986). Expertise in Mathematics Teaching. *Educational Leadership, 43,*(7), 28-33.

Leinhart, G. and Smith, D. (1985). Expertise in math instruction: Subject matter knowledge. *Journal of Educational Psychology*, *77*, 241-271

Leinhart, G., and Greeno, J. G. (1986). The cognitive skill of teaching. *Journal of Educational Psychology*, *78*, 75-95.

Magnusson, S., & Krajcik, J. S. (1993). *Teacher Knowledge and Representation of Content in Instruction about Heat Energy and Temperature* . East Lansing, MI: National Center for Research on Teacher Learning.

McDiarmid, G. W., Ball, D. L., and Anderson, C. W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In M. Reynolds (Ed.), *The knowledge base for beginning teachers*. Elmsford, NY: Pergamon.

McDuffy, A. (2004). Mathematics teaching as a deliberate practice: An investigation of elementary preservice teachers' reflective thinking during student teaching, *Journal of Mathematics Teacher Education, 7,* 33-61.

Parker, J., Heywood, D. (2000). Exploring the relationship between subject knowledge and pedagogic content knowledge in primary teachers' learning about forces. *International Journal of Science Education, 22*(1), 89-111.

Sakofs, M. (1995). Developing a Teacher Development Model: A Work in Progress. *Journal of Experiential Education, 18*(3), 128-132.

Schmidt, D., Baran, E., Thompson, A., Koehler, M.J., Shin, T, & Mishra, P. (2009, April).*Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers.* Paper presented at the 2009 Annual Meeting of the American Educational Research Association. April 13-17, San Diego, California.

Shulman, L. S. (1986a). Paradigms and research programs in the study of teaching: A contemporary perspective. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 3-36). New York: Macmillan.

Shulman, L. S. (1986b). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and Teaching: Foundation for the new reform. *Harward Education Review, 57* (1), 1-22.

Shulman, L. S. (1995). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Smithey, J., & Davis, E. A. (2004). Preservice elementary science teachers' identity development: Identifying with particular images of inquiry. In Y. B. Kafai, W. A. Sandoval, N. Enyedy, A. S. Nixon & F. Herrera (Eds.), *Proceedings of the 6th International Conference of the Learning Sciences, ICLS2004*. Mahwah, NJ: Lawrence Erlbaum Assoc.

Stacey, K., Helme, S., Steinle, V., Baturo, A., Irwin, K. & Bana, J. (2001). Preservice teachers' knowledge of difficulties in decimal numeration, *Journal of Mathematics Teacher Education, 4,* 205-225.

Steinberg, R., Haymore, J., and Marks, R. (1985). *Teachers' knowledge and structuring content in mathematics*. Paper presented at the annual

meeting of the American Educational Research Association, Chicago.

Turnuklu, E. B., & Yesildere, S. (2007). The pedagogical content knowledge in mathematics: perservice primary mathematics teachers' perspective in Turkey. *Content Knowledge*, *1,*1-13.

Watkins, C., &Mortimer, P .(1999). *Pedagogy: What do we know?* In Mortimer P (Ed) (1999). *Understanding pedagogy and its impact on teaching.* (pp 1-19). London: Chapman.

Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teachers' thinking. London: Cassell Educational Limited.