The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2014

Volume 1, Pages 101-105

ICEMST 2014: International Conference on Education in Mathematics, Science & Technology

CONCEPTUALIZATION OF PEDAGOGICAL CONTENT KNOWLEDGE (PCK) FOR TEACHING MATHEMATICS IN UNIVERSITY LEVEL

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The aim of this study is conceptualization of pedagogical content knowledge (PCK) in the field of teaching mathematics in university level. This is a qualitative research which has done in mathematics discipline in Iranian higher education system. The data of this research were gathered through semi structured interviews with some PhD mathematics students and professors. They were analysed through coding and making themes. Data analysis showed that we could explain concept of PCK in a model with 4 main elements and 3 themes which influenced on that.

STATEMENT OF PROBLEM

Teaching and teacher's knowledge have always been a controversial field of study in education. Pedagogical content knowledge(PCK) is a familiar concept for researchers which first has introduced by Shulman(1985) as a "missing paradigm" in this field of study. Shulman(1987) described PCK as a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. Although, PCK is an interesting concept which has absorbed many eyes, its nature is complicated. Besides, many research have been done about PCK in school level mathematics and specially school mathematics teachers education, but little has been done in mathematics education in university levels. While we know school mathematics teachers themselves have learned mathematics in universities. Moreover, not only mathematics students in university level, but also many students in other disciplines are learning mathematics and all these persons would be parents, teachers and members of society who will influence on mathematics education for future generation. Therefore, mathematics education in higher education level would effect on culture of mathematics education in university. Thus, the problem in this study is: what does PCK for teaching mathematics in university level mean?

THEORETICAL FRAMEWORK

The term of PCK is inherit Dewey's(1916-1964) that teachers must learn "psychologize" their subject matter for teaching to rethink disciplinary concepts and topics to make them more accessible to students(Counts, 1999).

After introduction of PCK many researchers tried to work on that concepts. One of the most influential researchers was Grossman (1988) who introduced two overarching categories: General and Specific PCK. These categories were later modified by Fernandez-Balboa & Stiehl (1995) to generic and specific. Specific PCK is particular to instruction of a specific subject or content area; and Generic PCK is common to instruction all content areas or subjects. Generic PCK refers to the fact that every discipline in higher education could have a concept of PCK. It means mathematics as a discipline has its PCK and surely this Generic PCK consist of Specific PCK, emerged from different subjects and content area. Grossman (1990) also described four categories embodied in PCK:

- Knowledge about the purposes for teaching a given subject matter (subject matter issue);
- Knowledge about the students' understandings about the content (students issue);
- Knowledge about the order in which subject matter should be presented (curricular issue);
- Knowledge about the instructional strategies useful for teaching content (pedagogical issue).

- Selection and peer-review under responsibility of the Organizing Committee of the conference

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LITERATURE REVIEW

One of the initial studies about PCK in higher education has been done by Fernandez Balboa & Stiehl(1995). The aim of their research was to study the generic nature of PCK in higher education. To this aim they studied incorporated purposeful sampling of 10 professors from five different colleges (i.e., Arts and Sciences, Business, Education, Health and Human Sciences, and Visual and Performing Arts) at a university in the U.S.A. Data were obtained from personal phenomenological interviews. They analysed the data utilizing the method of constant comparison looking for themes that linked the reflections of the participants. The results of this study showed that although initially their reference framework for analysing generic PCK was based on the four components outlined by Grossman(1990), a few important differences with regards to these components emerged from their analysis. These components include knowledge about: the subject matter, the students, numerous instructional strategies, the teaching context, and one's teaching purposes.

Counts(1999) did a research with two purposes: to contribute to a broader conceptualization and understanding of the development of general PCK in college level teaching by generalizing Shulman's(1987) and Grossman's(1988) model of PCK to college professors and to describe how a professor's PCK was constructed. He applied a case study research on a physics professors and gathered data through semi structured participant interviews and supportive data sources. Analysis of data was by analytical induction. Results showed five major themes emerged that reflected the professor's PCK: knowledge of the purpose of teaching, knowledge of students as learners, knowledge of human communications, knowledge of curriculum and course design and knowledge of positive learning environment. Therefore these findings disclosed that the PCK conceptualization of this study was in a large congruent with Shulman and Grossman's models.

Major and Palmer(2001) described several significant aspects of faculty PCK drawing on qualitative methods at a private university in the southern United States. They found out student learning is the heart of PCK. The focus of faculty PCK is that they must consider their students, how students will learn, and what difficulties they might have in learning. To help their students learn, then, faculty members need several kinds of knowledge about student learning. They must understand who their learners are, being responsive to differences that may arise from culture, family experiences, and learning styles and processes. Faculty members must figure out what students know and believe about a topic. They must also consider how learners are likely to engage and process new ideas. They need to think about how students learn different kinds of material for different purposes. And they must decide which kinds of learning are important for different contexts. Faculty members need to be able to identify the strengths and weaknesses of different learners and develop knowledge to work with students who have specific learning disabilities or needs.

METHODOLOGY

This research is a qualitative research. Data gathered mainly from two universities in Iran. These universities were selected among comprehensive universities. They were both prominent universities in field of mathematics and both were somehow engaged in mathematics education knowledge. One of them was the pioneer of development of mathematics education as a discipline in graduate education level. The other had a big history in mathematics teacher education and also was established with the aim of training mathematics university teachers in the era of shortage of mathematics university teachers and quantitative development of mathematics discipline in higher education in Iran. Besides, they both have high influence on education of future mathematics university teachers in Iran since they educate many students in graduate level in mathematics. Therefore, It was believed that these universities were good indicators of mathematics university education in Iran.

The respondents of this study were 19 PhD students and 8 professors in mathematics discipline which were selected from these two universities. Professors and PhD students were sources of data since it was assumed that they could explain about their experiences both as students and teachers. They selected both in pure and applied mathematics and they were on a spectrum from juniors to seniors both in PhD students and professors. Data were gathered mainly through semi structured interviews about experiences of teaching from respondents. They were analysed through coding and making theme(Creswell,2008). The process of gathering data has continued until the saturation of findings from analysis of data. In total, 19 PhD students and 8 professors cooperated in this research.

RESULTS

PCK in this study could be explained in 4 main and 3 contextual themes. First theme is "mathematics syntactic knowledge". Two sub-themes have been found which would explain this theme. Respondents in this research said the main thing in teaching mathematics is encouraging students to learn mathematics and it is based on explaining what the "application of the mathematics concept" is? Analysis of data showed that application has two means for them: application in the real world, application in other disciplines and application in mathematics. Furthermore they said that they would try to make connections between students' knowledge and mathematical content through focusing on the "main idea behind a mathematics problem".

Therefore not only mathematics professors should know mathematics concepts, theorem and formula, but also they should be aware of applications of mathematics concepts and main idea behind it. To have these two knowledge, a mathematics professors should know the evolution of concepts in a coherent network and this leaded us to to conceptualize mathematics syntactic knowledge for this theme. Mathematics as a discipline has two structures: substantive structure in mathematics which refers to concepts, theorem, and formula and... in mathematics and syntactic structure in mathematics which refers to the methods of how the concepts of mathematics would be develops (Schwab, 1964).

Second theme is "knowledge about students". We found out two sub-themes which would explain this theme. One important thing that respondents referred was to know what is the "major" of their students is and which "grade" are they. Since mathematics would be taught for students in different majors (for example engineering, science, humanities, mathematics and ...), professors should engage with students with different *disciplinary culture*. One of the respondents in this study said:

When I am teaching, I would try to find problems which are related to their majors. For example in chemistry students class, I would try to find what the application of this concepts is in the chemistry and try to find or make problems and examples related to them.

The other respondent said:

Most engineering students would like to see the application of mathematics concepts, especially mechanically and physically applications. But in humanities, like a management student would like to know what is the application of mathematics concepts in management. In mathematics, students would see themselves as the specialist of mathematics and you could teach pure theorem and talk about the historical evolution of mathematics concepts in the mathematics body of knowledge. But this is boring for engineering or humanities students.

Respondents also referred that teaching is different in undergraduate or graduate student. One of them said:

Teaching in graduate level is like surfing in a large ocean because you have to introduce a broad variety of concepts to make students find different research questions. But in undergraduate level you have to teach like swimming in a deep river.

The other sub-theme related to this theme is to encounter with "students' misconceptions and learning difficulties" which was explained by Shulman(1986,1987) too.

Third theme was "knowledge about mathematics curriculum planning". The first sub-theme which resulted in this theme was "knowledge about mathematics problems". Since the main component of mathematics content is problem, many respondents introduced this kind of knowledge. They revealed that they should have knowledge about problems which encourage students' interest to learn mathematics. To do that one of the respondent said:

I would try to find problems which are the historical problem in the mathematics and try to make students in a natural context to engage with that problem and create the concept.

The other respondent said that he uses interdisciplinary problems and the other one told us she uses problems which seems complicated but the solution of them are easy and needs consideration.

After finding the elements of content, professors should integrate these elements and problems to "make a coherent and meaningful content". To do that, analysis of data showed they would try to make the content related vertically and horizontally.

About horizontal relationship, most respondents explained they would try to follow teaching a concept with a starting point of its story and to introduce why this concept is important and how this was created in the beginning and what the evolution of this concept is. They also explained they would help the students to work independently with the new concept gradually. About the vertical relationship, one of the respondents explained:

We have numerical analysis in 3 levels: bachelor, M. Sc and PhD. The goal of this subject is error analysis, but in bachelor we want to find a point, in M.Sc we would try to find a line and in PhD we want a function. To work on that, we need general mathematics analysis knowledge in bachelor, real analysis knowledge in M.Sc and functional analysis knowledge in PhD.

The last sub-theme of this theme is "to make the content appropriate with students". In this sub-theme analysis of data defined two approaches: some of respondents would design the content based on the formal intended curriculum and then try to make it appropriate for students. Minority of respondents would start with students. They concentrate on the main idea and concepts of lesson and let the students to make limit of content.
The forth theme is "knowledge about creating an influential teaching-learning environment". This theme has 7 sub-theme. The first one is "knowledge about different representation approaches" like teaching from intuition to abstract, problem based teaching which starts from an unknown position, connected to application world and many different strategies in teaching. The second one is "knowledge about how to say and how to write". Since one of the most important tools in representation in a mathematics classroom is writing, it is really important to know how to write mathematics. One of the respondents introduced this sub-theme in his professor's teaching:
He knew how to use the board to make connection between concepts. For example he cleaned board but let to remained some central concepts, explanation or theorem. Afterwards, while we were in the middle of a problem and we did not know how to continue, he referred to that concept or explanation or theorem on the board and highlighted central concepts which helped us to solve the problem. He was really professional to use the board. It is like an art in teaching mathematics.

The third sub-them is "knowledge about how to engage students in teaching-learning mathematics". One of the respondents said:
Learning by doing is the nature of learning mathematics, so students should be engaged in this process actively otherwise they would not learn simply.

In relationship with this sub-theme, we found out the forth one as "knowledge about giving feedback to students" and evaluate their learning which make them engaged in teaching-learning process in mathematics classroom.

The next sub-them was "knowledge about using information communication technology(ICT) in teaching". Analysis of data announced that professors use ICT in two approaches: using from the general aspects of ICT like using Power point to make abstract concepts more visual and also using specific mathematics software like Matlab or Mathematica. One of the respondents explained:

One of the problem in teaching matrices to students is that they are afraid of working with huge matrices. So I use Matlab software to make an environment for students to work with them and this reduces their fear from working with those matrices.

The sixth sub-theme is "knowledge about using aesthetic sense in teaching". Most of respondents referred to body language as one component of this sub-theme. One of them believed that professors should be like actors on the scene. More, using some jokes, cartoons, poems, autobiographies of mathematicians and animations also were introduced by respondents. The last sub-theme of this theme is "classroom management". The respondents referred to the proportional relationship between students and professors as one component in this sub-theme. Also time management has been referred as the other component.
Analysis of data also showed 3 contextual themes which influence on PCK: "nature of subject", "professor's features" and "terms of learning atmosphere".
The nature of subject influences on teaching-learning of that. In this study respondents referred to two main nature for mathematics subjects: pure in subjects like algebra or analysis and applied in subjects like numerical analysis and general mathematics. Professor's features, both inherent(like appearance, voice, gender, …) and acquisitive(like moral aspects, enthusiasm, hard working, ...) also consequences on teaching-learning mathematics. Furthermore, terms of atmosphere of learning, both physically and socio-culturally would influence PCK. Physically terms means the size of classroom, number of students, technological terms in class and so on which seem to be obvious. Socio-cultural terms are more complicated and it could be explained through three sub-themes. The first one is socio-cultural beliefs about teaching-learning mathematics. It means that what the society think about and need from mathematics professors? One of the respondents explained:

When I was a young professor, it was a belief about mathematics professors to teach without looking on the book or handout. It took me long time to memorize whole the content in my mind. Also when a teacher made mistake, students thought that he is illiterate. But now society beliefs have changed and it is a better situation. But expectations now is to solve whole the problems…

Many of respondents referred to that there is a belief about the professor's reputation: the more famous, the better teaching.
The second one is educational institution's requirements. In Iran we have some governmental universities and free universities named Islamic Azad University. The difference between them is that governmental universities are supported with government but in Islamic Azad universities, students should pay for learning. Respondents of this study referred that these two academic systems needs different approaches in teaching-learning mathematics. One of the respondent said:

It is totally different to teach in which kind of universities. If I want to teach in governmental universities I need a higher level of content and I know I could even fail all the students of a class when they are not qualified to pass it. But in Azad universities I could not fail them because university wants me to pass them above a minimum line of being failed. And I should select easier content. So in governmental universities right is with professor unless the opposite of that would be proved but in Azad universities right is always with students unless the opposite of that would be proved.

More we found out should consider educational institutional culture in teaching because even in governmental universities we have different kinds of universities, for example: polytechnics and comprehensive ones which each of them has its requirements.

The last sub-theme was the terms of students. Many respondents admitted that because of the development of higher education in Iran and increase of interest to technical and engineering majors, basic sciences especially mathematics gets less demand. Therefore better students in high schools would be registered in engineering majors. Mathematics students are usually those who are not interested in that. And in other majors, especially humanities there is a belief between students that they are not good at mathematics so they would reject to learn it. Because of these situations, students who are learners in mathematics classroom are not enthusiastic to learn that and this would influence on teaching-learning mathematics.

REFERENCES

Counts, M. C.(1999). A case study of a college physics professor's pedagogical content knowledge. PhD dissertation of the Gorgia State University.

Creswell, J. W. (2008). Educational research. Pearson Education International.

Fernandez-Balboa, J. & Stiehl, J. (1995). The generic of pedagogical content knowledge among college professors. *Teaching and Teacher Education*. 11(3). 293-306.

Grossman, P.L. (1998). A study in contrast: Sources of pedagogical content knowledge for secondary English. Unpublished PhD dissertation. Stanford University.

Grossman, P.L. (1990).The making of a teacher: teacher knowledge & teacher education. New York: Teachers College Press.

Major, C. H. & Palmer, B. (2002). Faculty knowledge of influences on student learning. *Peabody Journal of Education, 77(3), Pp 138-162.*

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

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*. 1-22.

Schwab, J. (1964). Structure of the disciplines. In G. W. Ford and L. Pugno (Eds.), *The structure of knowledge and the curriculum.* Skokie, IL: Rand McNally.