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The development of pre-service teachers' pedagogical content knowledge (PCK) through CoRe design

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Abstract. This study investigated the pre- service teachers to design Content Representation (CoRe) for particular chemistry topics and the content of their CoRe reflect the components of pedagogical content knowledge (PCK) as identified by Magnusson et al (1999). In this research, the participants demonstrated their PCK through the process of design a CoRe, teaching in the classroom and discussion with the researcher during interviews. The result show that the preservice teachers' ability in creating lesson plans according to CoRe. They implemented the PCK lesson plans to actual classroom. It was found that the pre-service teachers had better understanding and practice of blending of pedagogical knowledge and content knowledge together that supported them to be confidence in integrating of chemistry contents and the aforementioned five components of PCK (knowledge of goal and purpose of teaching science, knowledge of instructional strategies for teaching science, knowledge of science curriculum, knowledge of assessment in science and knowledge of learner and learning to their classroom practices).
Keywords: Content Representation (CoRe), Pedagogical Content Knowledge (PCK), Pre-service teachers

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INTRODUCTION

Shulman (1986) defined PCK as the amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding and as a specific category of knowledge which goes beyond knowledge of subject matter to the dimension of subject matter knowledge for teaching. Beginning from 1983, Shulman outlined that within the category of pedagogical content knowledge has concluded for the most regularly taught topics in one's subject area; the most useful forms of representation of subject matter*;* the most powerful analogies, illustrations, representing and formulating the subject that make it comprehensible to others; the most understanding of what make the learning of specific topics be easy and difficult; and the most knowing conceptions and preconceptions that students of different ages and backgrounds bring with them into classroom (Shulman, 1986). PCK was mentioned and described as an important factor of teachers' ability.

Science teachers should not only have good subject matter knowledge and passion of teaching, but should also possess pedagogical knowledge to motivate and engage students to participate in learning. Shulman (1987) proposed a number of domains or categories to deal with the complexity of this knowledge base that experienced teachers draw upon. These categories include:

- Content knowledge
- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter
- Curriculum knowledge, with particular grasp of the materials and programs that serve as tools of the trade for teachers
- Pedagogical content knowledge that special amalgam of content and pedagogy that is uniquely that provide of teachers, their special from of professional understanding
- Knowledge of learners and their characteristics
- Knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts to the character of communities and cultures
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

This knowledge is sourced from scholarship in the content discipline of science, educational materials and structures, science education research and the wisdom of practice (Shulman, 1987)

Grossman (1990) has tried to remedy these various models and conceptions by distinguishing four general areas of teacher knowledge including general pedagogical knowledge; subject matter knowledge; pedagogical content knowledge (PCK); knowledge of context. Grossman explained knowledge-based for teaching that consists of general knowledge which is defined as knowledge concerning learning and learners, knowledge of general principles of instructions, knowledge related to classroom management and knowledge about the aims and purposes of education. Knowledge of context includes knowledge about school setting; for example, culture and knowledge of individual students.

PCK or pedagogical content knowledge was originally defined by Shulman (1987) as a category of teachers' professional knowledge, that is considered unique to each individual teacher, key to that teacher delivering content knowledge in a comprehensible from to learners and embedded in his/her classroom practice (Padilla et al. 2008). The intervention involved a novel use of Content Representations (CoRes), which the teacher educator had previously found very useful for helping pre-service teachers understand the nature of PCK. CoRes were originally developed by Loughran et al. (2004,2008) as diagrammatic representations of aspects of expert teachers' collective PCK related to the teaching of specific science topics, e.g., chemical reactions (see Table 1 for blank CoRe framework) to particular students.

Table 1. *Content Representation (CoRe) framework*

Year level :	Important science ideas/concepts for topic X		
Pedagogical questions/prompts	Big idea 1	Big idea 2	Etc.
1.What you intend the students to learn about this idea.			
2.Why it is important for students to know this.			
3.What else you know about this idea (that you do not intend students to know yet)			
4. Difficulties/ limitations connected with teaching this idea.			
5.Knowledge about students' thinking which influences your teaching of this idea.			
6.Other factors that influence your teaching of this idea.			
7.Teaching procedures (and particular reasons for using these to engage with this idea).			
8.Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).			

The purpose of CoRe is to help codify teachers' knowledge in a common way across the content area being examined and through this, to identify important features of the content that science teachers recognize and respond to their teaching of such content. Attached to CoRe are PaP-eR, with links to the aspects of this field that the PaP-eR bring to life by illustrating how such knowledge might inform effective classroom practice. A

PaP- eR offers a window into a teaching/ learning situation wherein it is the content that shapes the pedagogy. The PaP- eR is therefore linked to the CoRe to help to connect the practice seen with the understanding of that particular content. These links then illuminate the decisions underpinning the teacher's actions intended to help the learners better understand the content. The PaP-eRs are about teaching that content in that context and help to illustrate aspects of PCK in action. Importantly, one PaP-eR alone is not enough to illustrate the complexity of the knowledge around particular content. Including a collection of PaP-eRs attached to different areas of the CoRe is crucial in highlighting some of the different blends of elements that are jointly indicative of PCK in that field. The overlap, interplay and relationship between PaP-eRs in a content area are important in viewing the complex nature of PCK without any one PaP-eR being regarded as representing the nature of PCK itself. It is a schematic overview of how the CoRe and PaP-eRs are conceptualized both in terms of methodology and portrayal of PCK. The CoRe is based on explication of the "big ideas" of the particular content through responses to the prompts in column 1, and the PaP-eRs offer windows into some of these explications by representation in different forms (e.g., descriptions of classroom observations, teaching procedures, curriculum issues, students' alternative conceptions, and so on…)

The authors take the view that PCK development involves the transformation of other forms of knowledge (such as content knowledge, pedagogical knowledge and contextual knowledge) into knowledge for teaching (Abell, 2008). As a generated form of professional knowledge, PCK includes discrete categories of knowledge that are applied synergistically to problems of practice. While there is still discussion in the literature over the exact nature of these PCK categories, this study used the five components of an experienced teacher's PCK as identified by Magnusson et al. (1999) as determinants for gauging the nature and extent of any PCK development by the pre-service teachers. These components are as follows:

1) Orientations towards science teaching (that is, science teachers' knowledge of science and the nature of science, and beliefs related to their teaching goals and approaches)
2) Knowledge and beliefs about science curriculum
3) Knowledge of assessment in science (that is; what, how, and why to assess) which also influences a teacher's practice
4) Knowledge of students' understanding of science
5) Knowledge of instructional strategies

Purpose of the study

This study examines the nature of pre-service teacher's pedagogical content knowledge (PCK). The research objectives are expressed through the research question:

- Did the strategies enhance pre-service teachers' abilities to design a CoRe?
- To what extent did the content of CoRe reflect the components of PCK as identified by Magnusson et al. (1999)?

METHODOLOGY

This study was conducted within an interpretivist paradigm using a case study approach (Bryman 2008, Cohen et al. 2007) and action research design known as practical action research (Creswell 2005). The action research component involves a dynamic, flexible and iterative methodology, allowing the research to spiral back and forth between reflections about a problem, data collection and action. The methodology, as outlined by Creswell (2005), comprises a general spiral of generic steps that allows the researcher to pursue solutions to identified problems in collaboration with other researchers or mentors and to enter the spiral at any point appropriate to the particular action research project. The CoRe initiative arose as part of this ongoing action research.

To contribute to the trustworthiness of the research process (Guba and Lincoln 1989) particular attention was paid to strategies that would maximize the quality of data gathering and processing within the constraints of the study. For instance, while the representativeness and typicality of the finding might be compromised by the small sample size, strategies such as prolonged engagement and triangulation (Cohen et al. 2007; Guba and Lincoln 1989; Patton 1990), help to promote the dependability, confirmability and credibility of the study. Participant observation, semi-structured interviews by a fellow researcher and analysis of documents such as course planning notes and reflective journals were utilized to reduce the likelihood of researcher bias (Erickson 1998) and produce sufficient evidence to allow convergence (Bell 1999; Keeves 1998).

Participant

The participant in this study was 34 per-service teachers who were learning in Teaching Chemistry course. Teaching Chemistry course is bachelor of Education Program and subject in a specific subject and is a major subject course. The course description is principles of chemistry instruction, chemistry learning management, learning materials for developing understanding of chemistry concepts, chemistry learning assessment, chemistry syllabus designing, teaching chemistry for developing higher-ordered thinking, analysis of problems in chemistry instruction and chemistry laboratory in higher secondary school. All pre-service teachers had undertaken the preliminary exercises introducing them to PCK and the CoRes and PaP- eRs in the Teaching Chemistry course. As stated earlier the process of scaffolding CoRe construction began in earnest after the first teaching practice. The activities were as follows:

Research phase 1: Investigation the current understanding of pre- service teacher' s pedagogical content knowledge.

An open- ended questionnaire was used to survey about understanding of pre- service teacher's PCK in providing of teaching and learning activities. There are 2 parts of questionnaire. Part 1 asking about general demographic characteristics of pre-service teacher participants in terms of gender, age, educational background. Part 2 consisted of 5 open-ended questions asking about understanding and practice of pre-service teachers of PCK on providing of learning activities in chemistry.

Research phase 2: Development the understanding of pre- service teacher' s PCK and ability in creating the lesson plans using the PCK training program.

The objectives of this research phase are 1) to enhance the understanding of pre-service teacher's components of PCK, 2) to enhance the pre-service teachers' ability in creating lesson plan of learning activity related to content representations (CoRes), 3) to enhance the pre- service teachers' ability in creating lesson plan of learning activity in accordance with PCK and 4) to examine the understanding of pre-service teacher's components of PCK after participation in PCK training program. There were 3 sub-research phases.

Research phase 2.1: Development of training activities to enhance pre-service teachers' understanding of PCK and ability to create lesson plans of learning activities according to Content Representation (CoRe).

Arranged the PCK workshop training activities to pre-service teachers' in order to enhance the development of pre- service teachers' understanding of PCK. Four plans of activities were implemented throughout the workshop. These PCK activities were 1) Knowledge of PCK,
2) Science curriculum and analyzing science curriculum, 3) Scientific Inquiry and 4) Brainstorming to write CoRe (Content Representation).

Research phase 2.2: Enhancement pre-service teachers to construct Content representations (CoRes)

The pre- service teacher participated in the training workshop of PCK. Researcher implemented four plans of training activities using a small group discussion and brainstorming to enhance the development of understanding of PCK and Content Representation. They were required to construct their own CoRes using CoRes template on a topic of teaching chemistry.

Research Phase 2.3: Construction of PCK lesson plans according to CoRes

The researcher briefly presented and summarized Content Representations (CoRes) and Pedagogical and Professional experience Repertoires (PaP-eRs) to be used in construction of PCK lesson plans by indicating the congruency between content and learning standards along with indicators to organize learning activities.

The pre-service teacher participants were asked to collaborate in creating PCK lesson plan according to big ideas based on their Content Representations (CoRes) and Pedagogical and Professional experience Repertoires (PaP-eRs). They brainstormed to analyze learning standard indicators in curriculum and together designed learning activities based on CoRes along with PaPeRs.

Research Phase 3: Implementation of PCK lesson plans to actual classroom

Pre-service teacher participants implemented their PCK lesson plans of learning while the researcher and their colleagues observed their actual teaching activities aimed to improve or revise individual lesson plan. The researcher took note and recorded classes observation as well as interviewed pre- service teacher participants and student participants. Pre- service teacher participants had to work in group. In doing so, the first member was a leader to implement PCK lesson plan , the other group observed teaching approach and recorded results of observation then shared reflective discussion after completing each lesson plan for group members to improve the teaching and learning in the same topic. Focus group discussion was organized after finishing each lesson plan of learning activity to discuss and share idea about the environment of

teachinglearning and problems in teaching as well as to brainstorm in order to improve or revise the rest of lesson plans to suit the contexts of school and students. After finishing all designed PCK lesson plans, pre-service teacher participants assessed their groups of students' learning achievement.

Data Analysis and Interpretation

As this study concerned with understanding the meaning that the participants ascribe to particular experiential activities, a thematic analysis approach (Braun and Clarke 2006) proved to be most useful for data analysis. The analysis initially used a deductive approach by coding the data from the CoRes, reflective statements and the group interview in relation to explicit themes provided by the theoretical framework of the study, i.e. the five components of PCK as identified by Magnusson et al. (1999). This coding of data within set themes facilitated identification of the nature and extent of the pre-service teachers' PCK development over the period of the study.

Evidence of the acquisition, expansion and integration of these components into their classroom teaching and rhetoric by the pre-service teachers would support the use of collaborative CoRe design as a tool on practicum. The study also used an inductive approach in attempting to answer the two research questions related to the contribution the professional dialogue between pre-service teachers and their associate might make to the pre-service teachers' PCK development. Thus, Data were also coded in relation to the two research questions.

RESULTS AND DISCUSSION

Results of research phase 1: Investigation the current understanding of pre-service teacher's pedagogical content knowledge.

The understanding of pre-service teacher's pedagogical content knowledge for each of five components (i.e. orientations towards science teaching in terms of knowledge of goals and purposes of teaching science, knowledge of instructional strategies for teaching science, knowledge and beliefs about science curriculum, knowledge of assessment in science, and knowledge of students' understanding of science) was incomplete, therefore they were unable to integrate all five components of PCK into their teaching accordingly and appropriately. Pre-service teachers' lack of awareness in setting purposes and goals of science teaching and learning to promote attitude toward science, appreciation in science, recognition the importance of science. Pre- service teachers were aware of an effectiveness of management of teaching and learning activity based on scientific inquiry but they still involved giving teacher-centered lectures not learner-centered of learning with pre-specified content knowledge based on content knowledge in curriculum rather than providing teaching and learning activities according to needs and interests of students. In addition, pre-service teachers did not see the importance of prior knowledge of the students and did not know how to design teaching and learning activities appropriately for content knowledge. A lack of knowledge of assessment in science in assessing the progress of students' learning outcome was also contributed to incomplete understanding of pre-service biology teacher's pedagogical content knowledge.

Results of research phase 2: Development the understanding of pre-service teacher's PCK and ability in creating the lesson plans using the PCK training program.

Result of Research phase 2.1: Development of training activities to enhance pre-service teachers' understanding of PCK and ability to create lesson plans of learning activities according to Content Representation (CoRe).

The researcher developed four topics of training plans to be used in training workshop to enhance pre-service teachers' understanding of PCK and ability to create lesson plans of learning activities according to Content Representation (CoRe). The researcher engaged pre-service teacher participants in four plans of activities. They were: 1) Knowledge of PCK, 2) Science curriculum and analyzing science curriculum, 3) Scientific Inquiry and 4) Brainstorming to write CoRes (Content Representations).

Results of research phase 2. 2: Enhancement pres-ervice teachers to create Content Representations (CoRes).

The pre-service teacher participants were required to brainstorm to write Content Representations (CoRes). They created a table of CoRes of "Chemistry" topic. The topic was divided into six big ideas: 1) big idea 1 was "The structure of polymer" 2) big idea 2 was "Molecular shape of covalent", 3) big idea 3 was "Polymer Products", 4) big idea 4 was

"Electrochemical Cell", 5) big idea 5 was "Electroplating", 6) big idea 6 was "Factors affecting the rate of chemical reactions".

Results of research phase 2.3: Construction of PCK lesson plans according to CoRes

After participation in workshop session, the researcher found that pre-service teacher participants were able to work together with each other in creating lesson plans of learning activities using Content Representations and Pedagogical and Professional experience Repertoire approach. They were required to collaboratively complete the activities in 3 prototypes lesson plans and to reflect their learning by writing journal.

Overall results of research phase 2, pre-service teachers revealed the improvement of teachers' understanding of PCK. Multiple sources of data were collected using individual interview, classroom observations, lesson plans, reflective journal writing, video recorder, written CoRes, written PaP-eRs, and focus group discussion.

Before participation in the training workshop of PCK, pre-service teachers lacked of content knowledge in some specific topics of chemistry and lecture was used as instructional strategy to convey knowledge to students. Their actual teaching was not congruent with and contradicted to their understanding of knowledge of goal and purpose of teaching science, knowledge of instructional strategies for teaching science, knowledge of science curriculum, knowledge of assessment in science and knowledge of learner and learning to their classroom practices.

After they participated in the PCK training program, pre-service teachers understood more about the goals of teaching and learning science (i.e. scientific knowledge, science process skills, and scientific attitudes), learning standards, and the school science curriculum. They realized the importance of the students' prior knowledge and individual differences of learning styles as well as different chemistry conceptions. Their lesson plans were congruent with their learning goals and purposes. They designed learning activities based on the school science curriculum and the science curriculum framework with an emphasis was placed on scientific inquiry based learning and context of learning. They gained knowledge of students' roles in scientific inquiry (i.e. introduction of lesson, investigation, and conclusion). They encouraged the students to design their own investigation by providing questions, hands-on and minds-on investigation, and materials for learning. Their students were able to formulate their questions on their own to investigate. They encouraged their students to think and perform hands-on activity as well as challenged them to apply chemistry knowledge into their daily lives. The students were encouraged to conduct investigation or experiments based on their interest. They became aware of the roles of teachers (i.e. coach, motivator, facilitator, and classroom manager). They motivated their students to learn chemistry as active and minds-on investigations. All three in-service biology teachers focused on the inquiry based learning with an emphasis was placed on scientific knowledge, science process skills, and scientific attitudes in accord with the National Science Curriculum Standards.

Results of research phase 3: Implementation of PCK lesson plans to actual classroom.

When the pre-service teacher participants brought their understanding of PCK integrated into their actual teaching, it revealed that pre-service teachers had developed their understanding and practice of PCK for constructing lesson plans of teaching and learning activities. Pre-service teachers indicated that after they participated in the PCK training program, they had better understanding and practice of blending of pedagogical knowledge and content knowledge together that supported and enabled them to be more confident in integrating of biology contents, knowledge of goal and purpose of teaching science, knowledge of instructional strategies for teaching science, knowledge of science curriculum, knowledge of assessment in science and knowledge of learner and learning to their classroom practices.

CONCLUSION AND IMPLICATIONS

From the perspective of the pre-service teachers in this study, the findings suggest that CoRe design could be a useful tool in helping to stimulate the move from novice teacher to experienced expert teacher. The pre-service teachers valued most about their experience with this tool were the following: their associate teachers' interest in collaborative CoRe design and preparedness to share their expertise; the use of CoRes as a focus for authentic professional discussion with their associate teachers; and the opportunity to develop their PCK through associate teacher input into CoRe design. The potential of the CoRes to initiate and mediate ongoing professional dialogue between veteran and novice teachers seems to lie in their structure.

To create a Core required the designers to: identify and justify key content ideas for learning, identify prior learning, common misconceptions and learning difficulties and contextual factors that may impact on the learning, determine future learning, devise appropriate instructional and assessment strategies.

The results indicated that before participation in the training workshop, preservice teachers lacked of content knowledge in some specific topics of chemistry and lecturing was mainly used as instructional strategy to convey knowledge to students so that their teaching methods were not congruent with five components of PCK. After they participated in the PCK training program, preservice teachers understood more about chemistry contents and the five components of PCK. They realized the importance of the students' prior knowledge and individual differences of learning styles as well as different chemistry conceptions. They focused on the inquiry based learning with an emphasis was placed on scientific knowledge, science process skills, and scientific attitudes in accord with the National Science Curriculum Standards.

The results of the implementation of PCK lesson plans to actual classroom. It was found that pre-service had better understanding of PCK and they were able to blend pedagogical knowledge and content knowledge together that supported and enabled them to be more confident in integrating of chemistry contents and the aforementioned five components of PCK (knowledge of goal and purpose of teaching science, knowledge of instructional strategies for teaching science, knowledge of science curriculum, knowledge of assessment in science, and knowledge of learner and learning to their classroom practices).

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