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The development of teachers' pedagogical content knowledge in teaching biology

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Abstract

This paper examines the development of biology teachers' pedagogical content knowledge (PCK). All participants were provided with PCK training activities to improve their understanding of PCK and ability in creating lesson plans according to content representation (CoRe). Research instruments used in this study were open-ended questionnaire, semi-structure interview, lesson plans, CoRe and pedagogical and professional-experience repertoire. The results of the PCK training programme indicated that before participation in the training workshop, three biology teachers lacked content knowledge in some specific topics of biology so that their teaching methods were not congruent with five components of PCK. After the PCK training programme, the three biology teachers understood more about biology contents and the five components of PCK. They realised the importance of the students' prior knowledge and individual differences of learning styles as well as different biology conceptions. They focused on the inquiry-based learning in accord with the National Science Curriculum Standards.

Keywords: Pedagogical content knowledge (PCK), content representations (CoRes), biology teachers, experience teachers.

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1. Introduction

Influential factors affecting such science education reform are the knowledge and competency of teachers which play an important role in supporting the emergence of science education reform and science curriculum instructional management objectives which can assist people to develop their science knowledge. In the context of Thailand, the Office of the National Education Commission (ONEC) (2001) and the Institute for the Promotion of Teaching Science and Technology (IPST) (2004) pointed out that knowledgeable and competent science teachers should have a sophisticated deep and well developed professional knowledge base to support the different competencies of learners. However, 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 suggested that pedagogical content knowledge (PCK) is made up of the attributes a teacher possess that help her/him guide students towards an understanding of specific content, such as industrial design, in a manner that is meaningful. He argued that PCK included 'an understanding of how particular topics, problems or issues are organised, presented and adapted to the diverse interests and abilities of learners and presented for instruction' (Shulman, 1987).

PCK was also seen as '…knowledge of the transformation of several types of knowledge for teaching (including subject matter knowledge), and that as such it represents a unique domain of teacher knowledge' (Magnusson, Krajcik & Borko, 1999). In addition, PCK is a unique knowledge processed only by individuals within the profession of teaching, and consequently, the concept of PCK is useful to help teachers' understandings of what teachers know, what teachers ought to know and how they might develop it (Baxter & Lederman, 1999; Park, 2005). Magnusson et al. (1999) conceptualised pedagogical content knowledge for science teaching as consisting of five components: 1) orientations towards science teaching (since teacher's knowledge and beliefs related to their teaching goals and approaches will influence their classroom practice), 2) knowledge of curriculum, 3) knowledge of assessment (since what is to be assessed, how and why, also influences a teacher's practice), 4) knowledge of students' understanding of science and 5) knowledge of instructional strategies.

PCK supports science teachers' theoretical and practical knowledge and abilities about science, learning and science teaching. Teachers' PCK helps them to make decisions about content and activities, how to interact with students, and select assessments for understanding students' abilities and attitudes. In addition, PCK helps teachers address the particular interests, knowledge and skills of their students, build on their questions, and employ teaching and learning models relevant to classroom science teaching. Loughran, Berry and Mullhall (2006) also provided a clear definition when he indicated that PCK is an academic construct that represents an intriguing idea. It is an idea rooted in the belief that teaching requires considerably more than delivering subject content knowledge to student, and that student learning is considerably more than absorbing information for later accurate regurgitation. PCK is the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhance student understanding. Geddis (1993) argued that science teachers with well-developed PCK are effective teachers because they realise the importance of students' understanding of science concepts and were able to utilise a range of effective and appropriate teaching methods and instruction strategies to develop students' science concepts.

2. Purpose of the study

This study aims to improve the in-service high school biology teachers' understanding of PCK and ability to create lesson plans of learning activities according to content representation (CoRe) through participating in the PCK workshop training programme. The specific objectives of this study were

1. To investigate high school biology teachers' current understanding of pedagogical content knowledge.
2. To develop the PCK training activities to improve in-service high school biology teachers' understanding of pedagogical content knowledge and ability in creating lesson plans according to CoRe.
3. To investigate the high school biology case teachers' understanding and practice of PCK.

3. Methodology/experimental design

This study constitutes a report of case-study method used to look at how mentor science teachers conceptualised their own PCK that impacted their teaching practice. According to Merriam (1998), this research method is the best vehicle for providing 'intensive descriptions and analyses of a single unit or bounded system such as an individual, programme or group' (p. 19). By employing case-study methods, our intent was to represent the teachers' understanding of the situation and share their meaning with all involved in the research.

3.1. Participant

The participants in this study were biology teachers who were teaching at the secondary school level (grade 10). To protect her privacy, she was given pseudonyms of Ms. Somsri, Ms. Sopha and Ms. Malee

A case study of Ms. Somsri

Ms. Somsri's background: Ms. Somsri is 29 years old. She is an experienced biology teacher with 5 years of teaching experience as a leading teacher. She taught biology for 15 hours per week. She also taught general science at Grade 7 for 3 hours and was responsible for classroom counselling. In this study, classroom observations were conducted with a class of Grade 10 students.

A case study of Ms. Sopha

Ms. Sopha's background: Ms. Sopha is 34 years old. She is an experienced biology teacher with 10 years of teaching experience as a leading teacher. She taught biology for 12 hours per week. She also taught general science at Grade 7 for 3 hours and was responsible for classroom counselling. In this study, classroom observations were conducted with a class of Grade 10 students.

A case study of Ms. Malee

Ms. Malee's background: Ms. Malee is 26 years old. She is an experienced biology teacher with 2 years of teaching experience as a leading teacher. She taught biology for 15 hours per week. She also taught general science for the 7th Grade students for 3 hours and worked as classroom counsellor. In this study, classroom observations were conducted with a class of Grade 10 students.

3.2. Data Collection

Qualitative method was mainly used in this study. There were three research phases. Survey research was employed in Research phase 1: Investigation of the current understanding of high school biology teacher's PCK; one-group pretest–posttest design was used in Research phase 2: Development of the understanding of high school biology teacher's PCK and ability in creating the lesson plans using the PCK training programme, which was a workshop session for professional development training teachers. The researcher developed four topics of training plans to be used in training session for 2 days workshop to enhance teachers' understanding of PCK and ability to create lesson plans of learning activities according to CoRe. The researcher engaged teacher participants in four plans of activities. They were: 1) Knowledge of PCK, 2) Science curriculum and analysing science curriculum, 3) Scientific inquiry and 4) Brainstorming to write CoRes. After teacher participants finished

brainstorming to write CoRes, they created a table of CoRes of 'Cell division' topic. The cell division topic was divided into five big ideas as big idea 1: Types of cells of living organism, big idea 2: Cell structure, big idea 3: The importance of cell division on living organisms, big idea 4: Mitosis, big idea 5: Meiosis. Classroom observation was used in Research phase 3: Implementation of PCK lesson plans to actual classroom.

The pseudonyms used to represent the high school biology teachers' names were Ms. Somsri, Ms. Sopha and Ms. Malee. They were selected to be included in case study of content knowledge of biology and PCK knowledge, both before and after participation in the PCK training programme. Along with each case of teacher was indicated background and development of PCK in teaching biology. Understanding and practicing of PCK were analysed according to the five components of PCK: orientations towards science teaching (knowledge of goals and purposes of teaching science), knowledge and beliefs about science curriculum, knowledge of assessment in science, knowledge of students' understanding of science and knowledge of instructional strategies. Research instruments in this study were open-ended questionnaire about understanding of high school biology teachers' PCK in providing of teaching and learning activities, semi-structure interview, lesson plans, CoRe and pedagogical and professional-experience repertoire (PaP-eR). Data were mainly analysed qualitatively.

4. Results and discussion

Understanding and practice of PCK after participating in the PCK training programme

4.1. Understanding and practice of orientations towards science teaching (knowledge of goals and purposes of teaching science)

Ms. Somsri realised the importance of the nature of science in providing objective in teaching and learning. When she observed Ms. Sopha's classroom with the researcher, it was found that Ms. Somsri had knowledge of scientific methods very well. She understood learning outcomes in all three aspects: scientific knowledge, scientific process skills and scientific attitudes.

Ms. Sopha's understanding of knowledge of goal and purpose for teaching science was good. She focused on encouraging students' learning concerning the student's understanding of scientific knowledge in terms of science process skills and scientific attitudes. With regard to Ms. Sopha's lesson plans in a topic of the mitosis division, Ms. Sopha wanted students for learning science to cover the three aspects: scientific knowledge, scientific process skills and attitude towards science or scientific mind.

Ms. Malee understood that the learning outcome of student and purpose of science teaching should cover the biology content, science process skills and science attitude. Ms. Malee explained, 'My topic of teaching was mitosis division. I provided the opportunities for the students to work in groups. I allowed them to investigate about the stages of mitosis division. They planned to investigate the shape of chromosome. They were able to indicate the shape of chromosome as stage of mitosis'. She realised the importance of the nature of science in teaching science. The students should learn and integrate the nature of science in their studying.

4.2. Understanding and practice of knowledge of instructional strategies for teaching science

Ms. Somsri had learned about management of teaching and learning which focused on the learner-centered guided by the theory of self-knowledge construction or constructivist teaching strategies (i.e., inquiry approach). She felt that after participating in the PCK workshop, she had better understanding of pedagogical knowledge that being used in constructivist teaching strategies. She had learned how to make introduction to arouse students' interest and engagement to participate in learning activity, to conclude a lesson and to connect between learning activity in science lessons.

She focused on student thinking and their interest which was very important for student-centered teaching approach. Ms. Somsri also aroused students' interest and curiosity by showing pictures, real model and scientific replica; telling stories; reading news; and providing interesting situation to students.

Ms. Sopha understood that she should investigate or ask student's prior knowledge in the lesson before introduction of the lesson by discussing and posing questions in class. The information derived from interview and lesson plan showed that Ms. Sopha motivated student's curiosity and enthusiasm by posing questions and asking for answers. She used the main question to ask students for covering their prior knowledge. She promoted student's curiosity by using the video tape about growing of bean tree and the mitosis division. She provided an opportunity for students to write about the content of mitosis that they have learned before including the content that they would like to learn.

Ms. Malee understood that she should motivate student's interest in teaching at the engagement stage or introduction stage of the lesson. Ms. Malee planned to motivate student's interest by using video tape of the mitosis division. They discussed about the video tape of the mitosis division. The researcher found that her understanding of knowledge of instructional strategies for teaching science was congruent with her actual practice. She explored student's prior knowledge about the concept of structure of cell. She prepared the worksheets to students. She assigned the worksheets to students and discussed with students. When the students completed the worksheet, Ms. Malee and students discussed the question in the worksheet together. Ms. Malee focused on hand-on activity. She provided the interesting activity to students. The students conducted their own experiment.

4.3. Understanding and practice of knowledge and beliefs about science curriculum

Ms. Somsri focused on the importance of the National Education Act of 1999 in relation to the Basic Education Core Curriculum of 2008 and the Science Curriculum Framework provided by the Institution for Promotion of Science and Technology. In the focus group discussion, Ms. Somsri shared her understanding about how school science curriculum was developed for science teaching. The students in secondary school learned science based on learning standards in science curriculum. She demonstrated her understanding of the science curriculum including the goals of teaching and learning science, learning standards. As shown in her lesson plan, she wrote the learning standards in science curriculum in her lesson plans. She designed the objectives of learning that were in accordance with learning standards.

Ms. Sopha's understanding and practice of knowledge and beliefs about of science curriculum was good. She understood about the goals of teaching and learning science based on the National Education Act of 1999, the Basic Education Core Curriculum of 2008 and the Science Curriculum Framework provided by the Institute for the Promotion of Teaching Science and Technology which specified aims of learning science. She understood that teaching and learning of biology should be depended on learning standards in the science curriculum framework.

Ms. Malee understood that the National Education Act of 1999 was related to the Basic Education Core Curriculum of 2008, and the Science Curriculum Framework. She shared her understanding of school science curriculum that it was developed for science teaching. The students in secondary school have to learn science according to the learning standards specified in the Basic Education Core Curriculum of 2008. She showed her understanding of knowledge and beliefs about science curriculum that science curriculum comprised the goals of teaching and learning science, learning standards. She wrote the learning standards related to biology concept in her lesson plan.

4.4. Understanding and practice of knowledge of assessment in science

Ms. Somsri developed her knowledge of assessment in teaching in terms of understanding of students' learning and assessment methods. She recognised goals and purposes in teaching and

learning science according to the Science Curriculum Framework. With regard to Ms. Somsri's instructional practice, she developed the test for assessing the students' learning achievement in science. She provided space below question for students to write their reasons to explain, 'Why did they choose that choice as the best answer'?

Ms. Sopha had developed her knowledge of assessment in science. She had knowledge of student learning and methods of assessment. The student's learning outcomes should be covered all three aspects: science content, science process skill and scientific mind or attitude towards science. Students should develop their inquiry process skills and scientific mind or attitude towards science. The assessment of student's learning was ongoing process throughout learning and teaching activities.

Ms. Malee developed her knowledge of assessment. She indicated that the goals and purposes of learning science were to understand scientific concepts, scientific process skills, creative thinking, ability to solve problems and scientific minds. She thought that the teacher should not assess students by using only multiple choice test. The teacher should use the written test and oral test for assessing the students' learning. This method helped the teacher to assess the student's understanding.

4.5. Understanding and practice of knowledge of students' understanding of science

Ms. Somsri realised the importance of students' prior knowledge and individual differences in classroom teaching. She understood that the students had different science conceptions. She understood about student learning. She recognised that science teaching should be flexible and suitable for student grade level and their learning styles and she designed her lesson plan consisted of various activities for students. She realised the individual differences of students. In Ms. Somsri's lesson plan, she provided opportunities and activities for students to work in groups and investigate on their own. Ms. Somsri acted as consultant and facilitator for students when they had problems or question. Ms. Somsri used various teaching methods in classroom. According to Ms. Somsri's classroom, she used inquiry-based teaching, cooperative learning and problem solving as teaching strategies in her lessons.

Ms. Sopha realised the importance of students' prior knowledge and learning. She noted that student learning was important in classroom teaching. She motivated students to share ideas using prior knowledge for learning about the structure of cell. In her understanding, students should have basic conceptions in the characteristic of cell. She understood that teacher had multiple roles in classroom. She mentioned that the main purpose of teacher's role was to improve student's learning of biology concept and to design the activities using inquiry teaching approach.

Ms. Malee had knowledge of the student's prior knowledge. She realised that students had prior knowledge before learning biology. The understanding of students' pre-existing knowledge was important for teaching profession. She had better knowledge of students' understanding of science. She knew about the series of biology concepts in secondary school. So, she was able to identify the biology concepts that students should learn as a pre-requisite for some specific biology concepts. She provided an opportunity for the students to work in their group.

5. Conclusion

Before participation in the training workshop of PCK, three in-service high school biology teachers lacked in content knowledge in some specific topics of biology 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 programme, three in-service high school biology 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 realised the importance of the students' prior knowledge and individual differences of learning styles as well as different biology 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 biology 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 biology 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. Three in-service biology teachers tried to link and correlate new knowledge to student's prior knowledge at the end of teaching hours.

When the teacher participants brought their understanding of PCK integrated into their actual teaching, it revealed that three in-service high school biology teachers had developed their understanding and practice of PCK for constructing lesson plans of teaching and learning activities. A case study of three in-service high school biology teachers indicated that after they participated in the PCK training programme, 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 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.

6. Recommendations from research results

Organisation of teaching profession should adopt and adapt these training activities of this research as the training programme for the professional development of teachers to understand the pedagogical content knowledge The participants should be teachers from similar school context or same school along with similarity of subjects to be taught in order to jointly construct lesson plans of learning activities based on CoRe including PaP-eR and share discussion of classroom observation for the better performance of teaching. Teachers should be provided an opportunity to work collaboratively and involve in every stage of teaching (i.e., co-planning stage, co-teaching stage and co-evaluating stage). Moreover, an important way for the development of teaching profession, the professional development should be created according to teachers' needs and problems regarding their actual teaching in real situation. The professional development should help the science teachers to integrate all components of pedagogical content knowledge (i.e., know how to integrate content knowledge, teaching knowledge including setting goals for teaching science, method of teaching science, learners and learning, curriculum and assessment and evaluation of learners' learning) into their teaching. The development of science teacher's knowledge should develop for long-term collaborative work.

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