

# **THESIS**

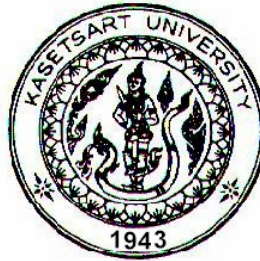
**A PROFESSIONAL DEVELOPMENT PROGRAM FOR  
LOWER SECONDARY SCIENCE TEACHERS'  
DEVELOPMENT OF PEDAGOGICAL CONTENT  
KNOWLEDGE IN GENETICS**

**POJCHANA MAGROOD-IN**

**GRADUATE SCHOOL, KASETSART UNIVERSITY**

**2008**





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**2008**



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**GRADUATE SCHOOL, KASETSART UNIVERSITY**

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**TITLE:** A Professional Development Program for Lower Secondary Science  
Teachers' Development of Pedagogical Content Knowledge in Genetics

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THESIS

A PROFESSIONAL DEVELOPMENT PROGRAM FOR LOWER SECONDARY  
SCIENCE TEACHERS' DEVELOPMENT OF PEDAGOGICAL CONTENT  
KNOWLEDGE IN GENETICS

POJCHANA MAGROOD-IN

A Thesis Submitted in Partial Fulfillment of  
the Requirements for the Degree of  
Doctor of Philosophy (Science Education)  
Graduate School, Kasetsart University

2008

Pojchana Magrood-In 2008: A Professional Development Program for Lower Secondary Science Teachers' Development of Pedagogical Content Knowledge in Genetics. Doctor of Philosophy (Science Education), Major Field: Science Education, Department of Education. Thesis Advisor: Assistant Professor Naruemon Yutakom, Ph.D. 298 pages.

The objectives of this research were: 1) to explore lower secondary science teachers' current practices, problems, and needs for teaching and learning in genetics, 2) to design a professional development program that served to guide the development of a professional learning experience for developing a teacher's genetics content knowledge (CK) and pedagogical content knowledge (PCK), and 3) to study the development of three Thai lower secondary teachers' genetics CK and PCK over the course of a professional development experiences.

The participants of this study were three lower secondary science teachers who participated in the PCK-based professional development program in the second semester of the 2006 academic year. The contents and activities in the program, emphasizing on 5E inquiry and reflective approaches, were included a five-day workshop, two seminars, and following-up in teachers' classrooms. To understand their development of teachers' CK and PCK, the grounded theory was guided for collection and analysis. An interpretive case study design guided the collection of qualitative data with a questionnaire, semi-structured interviews, concept interviews, teacher and researcher-generated narrative cases, researchers' field notes, teachers' journals, and lesson planning documents. Constant comparative analysis was used for analyzing those data and generated a theory of how lower secondary science teachers develop their CK and PCK in genetics.

The findings indicate that three teachers gained an understanding of many genetic concepts and their relationships and possessed few misconceptions about genetics following the professional development experience. They understood the strengths and weaknesses of representations and activities and also applied their understandings in practice. In addition, they planned and improved their lesson plans and teaching based on the 5E inquiry that relied on a student-centered orientation. Furthermore, they increased their knowledge of curriculum for organizing the genetic content in their lessons. However, two of the three teachers gradually developed their CK and PCK better than the other teacher. Many factors was influencing on their CK and PCK development. First, the activities regarding the development of genetic content knowledge and knowledge of representations and activities in the PCK-based PD program had a potential to help in-service science teachers develop their CK and PCK for teaching genetics. Especially, with hands-on 5E inquiry activities, discussing genetic concepts, examining the strengths and weaknesses of representations and activities, case discussions, reflection on knowledge on teaching, and collaboration with the research team gave them a better understanding of genetic concepts and their teaching. Second, teachers' knowledge of students' backgrounds, conceptions, and learning styles, impacted on planning and practicing in teachers' classrooms. Third, their personal characteristics, beliefs, and teaching experiences effected teachers' development of CK and PCK in genetics. As a result, the PCK-based PD program will be an effective professional development program for developing science teachers' PCK for developers, schools, IPST, pre-service science teacher education and researchers in the future.

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Student's signature

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Thesis Advisor's signature

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Pojchana Magrood-in  
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# **CHAPTER I**

## **INTRODUCTION**

### **Overview of the Chapter**

This chapter described the background of Thai education and teacher professional development. Then the rationales of the study are explained. In addition, the research objectives and research questions are described. The operational definition of terms is also explained. Finally, outlines of the remaining chapters of this study are concluded.

### **Background of Thai Education**

Education in Thailand has changed over time. According to the Office of Education Council (OEC) (2004), between 1220 and 1868 there was no formal education in Thailand. Children were educated in the temple, the King's palace and by the family. Children were offered non-formal education in agricultural and social skills in the context of the extended family. In the late 19<sup>th</sup> century, Western imperialism and the pressure of internal politics stimulated the monarchy to initiate educational reform. Under threat of western military power, many schools were established for commoners in 1884. A law on compulsory primary education was issued in 1921, guaranteeing every child a free primary education unit the age of 14. Then, in 1932, educational policies and plans were revised, extending compulsory education to five and six year olds. More recently, compulsory education was extended from six years to twelve years.

The educational system in Thailand increasingly needs improvement to meet the demands of a knowledge-based economy. According to OEC, (2004), education policy in the First National Education Development Plan (1961-1966) was directly linked to economic development. It focused on providing medium-and high-level

manpower needed for the country's growing economy. Later, educational policies were introduced to increase rural access to schooling, improve the administrative system of schools, and strengthen curricula and the learning process. Science, technology, and formal education were strongly emphasized, and the role of private education was encouraged. From 1992 to 1996, the education system was then expected to provide equilibrium between development in economic, social, and cultural aspects. It was also supposed to facilitate linkages between these aspects as well as creating harmony and mutual benefit the urban and rural sectors of the country. According to ONEC (2001), education from 1997 to 2001 was aimed at preparing the Thai people to cope with the rapidly changing world of the 21st century. This plan emphasized that the education system should facilitate the country's development process towards self-reliance, sustainability, and enhanced global competitiveness. From 2001 to the present, the goal of Thai education has been to provide the necessary skills and knowledge to prepare all individuals to become productive members of a "knowledge-based society" (OEC, 2004; ONEC, 2001, 2003). According to ONEC (1999), the ultimate aims of education in line with the National Education Act (NEA) (1999) are to transform Thai citizens into perfect human beings, having good health, wholesome minds, intelligence, knowledge, morality, good behavior and cultural life.

### **Background of Teacher Professional Development in Thailand**

In concert with the reform of educational policy, teachers were considered important. According to OEC (2001), (2003), from 1857 to 1891 teachers got informal teacher training in the palaces and temples. Later to meet the exigency of national reform (1892-1912), teacher' skills and knowledge of teaching were developed through teacher training institutes. The Project for the Production of Rural Area Teachers was carried out from 1913 to 1945. Efforts between 1946 and 1973 reflected the desire to produce teachers who met international standard, so teacher training was modeled on that of other countries. Between 1974 and 1991, educational reforms were enacted to enhance the quality of life and society. Teachers received training to attain Thailand's own educational identity through acceleration of

experimental decentralization of authority at the primary education level. From 1992 to 1996, teacher's development aimed at elevating the status of the teaching profession and enabling teachers to become highly respected professionals.

In educational reform efforts since 1997, the aim of education has been to produce high quality teachers based on the 1999 NEA and the 1994 teacher professional standards. According to the 1999 NEA, Teacher Standards mentioned in Julawattanapon (1999), and Pillay (2002), teachers develop their professional practice continuously. Through professional development experiences, teachers are able to provide subject matter and arrange activities in line with the learners' interests and aptitudes, bearing in mind individual differences. Teachers also receive training in thinking processes, management, how to face various situations, and the application of knowledge for obviating and solving classroom problems. In addition, they organize activities for learners to draw from authentic experience, drill in practical work for complete mastery, enable learners to think critically, acquire reading habits and a continuous thirst for knowledge. Furthermore, teachers always develop efficient media for teaching and learning. Moreover, they achieve, in all subjects, a balanced integration of subject matter, integrity, values, and desirable attributes. Teachers also report their students' qualitative development systematically, teachers act as good role models. Finally, teachers cooperate creatively with other persons in schools and communities.

In particular, according to the Institute for Promotion of Teaching Science and Technology (IPST) (2002), Thai science teachers are required for developing their knowledge and practice. Teachers should understand the nature of science and technology if they are to be able to apply science and technology knowledge in good way and attempt to develop their profession. In addition, teachers should provide learning processes for learners in line with the 1999 NEA, and belief that "...all learners are capable of learning and self-development, and are regarded as being most important" (ONEC, 2000: 12). Teachers have also to understand diverse pedagogies for developing learners' learning and authentic assessment for learning development. They should be able to create an environment in which learners to learn. Furthermore,

teachers should develop the curriculum, learning standards, and lesson plans in line with the community's needs and the students' potential. Moreover, teachers should have opportunities to cooperate with their community to organize students' education.

According to ONEC (1999), in order to meet the requirements of the current educational reform about teacher professional development, educational institutions and agencies should enable teachers to create the ambiance, environment, instructional media and facilities for learners to learn and be all-round persons. In addition, they should support teachers to use research as part of the learning process. Furthermore, they should facilitate both learners and teachers to learn together from different types of teaching-learning media and other sources of knowledge at all times and in all places and co-operate with parents, guardians, and all parties concerned in the community. Moreover, institutes should promote development of a system for teachers and educational personnel, including production and further refinement of this category of personnel, so that teaching will be further enhanced and become a highly respected profession.

Requirements for teacher professional development standards have led to reform of teacher education. According to ONEC (2003) and OEC (2004), teacher training occurs in two areas: the teacher training system and teacher education institutes. In the teacher training system for in-service teachers, School-based Training (SBT) in line with the 1999 NEA required that the teaching profession was developed on a continuous basis and that pedagogical practices were shifted away from teacher-centered towards learner-centered pedagogies. The School-based training (SBT) for in-service teacher development was launched in 4 pilot projects, namely the National Teacher Project, Master Teacher Project, Project on Research and Development on Models of School-Based Training and Projects to Support School-Based Training. Based on the results of a study (OEC, 2004), it was decided that SBT should be the new paradigm to guide the development of teachers and the teaching profession in Thailand. Furthermore, reforming in-service teacher training required all in-service teachers to have at least a bachelor's degree in education. Moreover, this reform stipulated that in-service teachers should have a post-graduate

certificate or a master's degree in teaching and that of in-service administrators of educational institutions should have a post-graduate certificate or a master's degree in educational.

Teacher education institutes are another aspect of the teacher training under reform in the current system. Teacher education institutions must develop conceptual frameworks that describe how faculty can meet the standards required through conducting action research in schools, training courses, and scholarships for studies in master's and doctoral degrees. Faculty and staff should accelerate the creation of new knowledge for teacher education and of new products for the provision of education.

In sum, for more than a hundred years, many Thai educational reforms have attempted to develop educational policies consistent with world. Nowadays, education should provide the necessary skill and knowledge to prepare all individuals to become productive members of a "knowledge-based society" (ONEC, 2001, 2003; OEC, 2004). Education in Thailand today aims to develop all Thai people into perfect human beings, having good health, wholesome minds, intelligence, knowledge, morality, good behavior and cultural life (ONEC, 2000). Thus, to ensure that teachers are prepared to address the requirements of the National education standards, teacher professional development standards have been stipulated. In addition, the educational institutes are attempting to provide teacher training programs for in-service teachers in order to develop their profession in line with this current educational reform.

### **Rationale for the Study**

Since the start of educational reform in Thailand, many institutes such as ONEC and IPST have designed teacher professional development programs. The programs aimed to assist in-service science teachers to develop their teaching skills and knowledge in ways that resonate with the educational standards. Based on the 1999 NEA (ONEC, 1999), and the Science and Technology Teacher Standards (IPST, 2002), teachers are responsible for their own professional learning and the maintenance of the teaching profession. Teachers will also need ongoing opportunities

to build their understanding in science knowledge, and skills and to promote their ability to be effective in classroom.

However, science teacher professional development in Thailand has not always led to successful outcomes in line with the standards (Julawattanapon, 1999). The training courses were not serving teachers' needs because the teacher professional development programs emphasized the design of intensive courses of 3 days to 2 weeks to develop teachers' knowledge of teaching and skills (Educational Supervision Unit, n.d.; IPST, 1997; Julawattanapon, 1999; Office of Human Resource Development Project Co-ordination, 1997; Pitiyanuwat, n.d.). In addition, much of professional development tends to involve traditional lectures that merely convey science content and emphasize technical training about teaching rather than decision making, theory, and reasoning (Julawattanapon, 1999; Pillay, 2002; Pitiyanuwat, n.d.). Evaluation of the Ninth National Education Development Plan revealed that 40 percents of the teachers had not attended any training courses and seminars (Julawattanapon, 1999; Pituyanut, n.d.). Furthermore, science teachers' needs were not met in the training institutes due to the nature of the knowledge and skills addressed (Educational Supervision Unit, n.d.; IPST, 2003) and limited funding and resources (Lee, Hart, Cuevas and Enders, 2004; Petchen, 2000). Moreover, there were no follow-up assessments to determine what teachers learned as a result of professional development or to assess the long-term effectiveness of the workshop or distance programs (Julawattanapon, 1999; Pitiyanuwat, n.d.; and Research Department of IPST, 2003).

In addition, Thai lower secondary science teachers needed to develop their knowledge and skills thorough professional development programs in many aspects continuously (Research Department of IPST, 2003). They needed knowledge of physics, chemistry and biology subjects, teaching methods, assessment, and writing lesson plans (Educational Supervision Unit, n.d.) as well as knowledge of action research and student-centered teaching (Julawattanapon, 1999). They also wanted knowledge of how to arrange strategies in line with the learners' interests and aptitudes, bearing in mind individual differences (Jurawattanapon, 1999).

Based on the pilot study that I did, in-service lower secondary science teachers expressed the desire to develop science knowledge about topics that were difficult for their students to understand. In addition, they desired pedagogical knowledge of how to teach science using student-centered approach, and how to teach for development of conceptual coherence and in way that students enjoy. In the area of assessment, they desired knowledge of authentic assessment strategies and how to assess students' learning in every biology topic taught in lower secondary schools. Furthermore, they wanted to develop understandings of how to construct teaching media in each of the topics.

As a result, based on the professional development literature and the findings of my preliminary study, Thai lower secondary science teachers needed to develop content knowledge in certain areas and also pedagogical knowledge about how to teach these topics in ways that lead to student learning. Specifically, they had difficulty in providing learning opportunities for student's understandings of science. They often also lacked knowledge of how to teach concepts in ways that promote student learning. In addition, although the majority of the teachers have several years of science teaching experiences, they desired to know exactly how to foster students' leaning in effective way. Thus what science teachers need is pedagogical content knowledge (PCK).

Pedagogical content knowledge (PCK) is an important concept for science education. Shulman first defined PCK as:

...Most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others (1986: 9).

Shulman viewed PCK is an important knowledge of knowledge bases for teaching. He later further defined PCK as being of:

... special interest because it identifies the distinctive bodies of knowledge for teaching . . . It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction . . . pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue (1987: 8).

Building on Shulman's notions of PCK, a number of researchers in science education defined PCK as consisting of knowledge of instructional strategies incorporating representations of subject matter and understanding of specific learning difficulties and student conceptions with respect to that subject matter (Carter, 1990; Cochran, DeRuiter and King, 1993; Geddis, 1993; Grossman, 1990; Smith and Neal, 1989; Tamir 1988; van Driel, Verloop and de Vos, 1998). PCK also is "...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 and Borko, 1999: 95). 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 what teachers know, what teachers ought to know, and how they might develop it (Baxter and Lederman, 1999; Park, 2005).

PCK is required as a knowledge base for expert teachers in educational reform documents. According to the National Research Council (NRC) (1996), IPST (2002), ONEC, (2000), 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, know 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. Furthermore, knowing the strengths and weaknesses of teaching and learning models, teachers are able to examine the relationship between

the science content and how that content is taught and learned (Halim and Meerah, 2002).

According to Lee, Hart, Cuevas, and Enders (2004), high quality professional development for science teachers should provide opportunities for teachers to develop deep and complex understandings of science concepts. It also should provide opportunities to develop PCK. According to Loucks-Horsley, Love, Stiles, Mundry and Hewson (2003), professional development programs can increase teachers' knowledge of content and PCK. Increasing teachers' content knowledge can be accomplished by immersing teachers in content classes as learners themselves. However, professional development for in-service teachers must include experiences that to put the science content they learn into the context of teaching (Darling-Hammond and McLaughlin, 1995; Garet, 2001; Liebman, 1995; Loucks-Horsley, Hewton, Love and Stiles, 1998; ONEC., 1999).

Based on professional development programs, numerous research studies have emphasized that PCK plays a vital role for solving problem of teaching science. PCK is critically influential in developing teachers' planning and actions (Clermont, Broko, and Krajcik, 1993, 1994; Geddis, 1993; Park, 2005; Veal, 1997, 2003; Zwmbal-Saul, Blumenfeld, and Krajcik 2000, 2003). It shapes teachers' learning of new instructional approaches and strategies (Jasti, 2005; Park, 2005). Teachers' PCK also influences student understanding in the particular topics (Geddis, 1993; Park, 2005; Halim and Meerah, 2002; van Driel *et al.*, 1998).

This study fills a gap revealed in science educational research on PCK. Most research on teachers' PCK in science education has focused on how beginning teachers learn to transform their knowledge of subject matter into a form appropriate for teaching (e.g. Adams and Krockover, 1997; Appleton (2003); Clermont *et al.*, 1993; Justi, 2005) on pre-service science teachers' PCK (e.g. De Jong, Ahtee, Goodwin, Hatzinikita and Koulaidis, 1999; Geddis, 1993; van Driel, de Jong and Verloop, 2002; Zembal-Saul *et al.*, 2000, 2002), and on direct expert-novice comparisons (e.g. Clermont *et al.*, 1994). There exists little research that deeply

investigates the in-service science teachers' PCK at the lower secondary school level in Thailand.

Even though there is a great deal of research on the development of secondary science teachers' PCK, there is limited amount of research on the development of teachers' PCK in particular topics of biology. Most researchers have focused on the development science teachers' PCK in chemistry teaching (e.g. Clermont *et al.*, 1993, 1994; Park, 2005; van Driel *et al.*, 2002; Veal, 2004), in physics teaching (e.g. Geddis, 1993; Halim and Meerah, 2002), and in both chemistry and physics (e.g., Jasti, 2005; Veal 1997). One study that did focus on biology (Veal 2003) attempted to understand how and why biology teachers teach evolution. In addition, little research has been done on the development of in-service science teachers' PCK at the secondary school level in Thailand (Worrachittanont, 2005).

Specially, Genetics has been recognized as one of the most important biological topics for Thai secondary students. According to the National Science Curriculum Standards (IPST, 2003) and National Science Education Standards (NRC) (1996), all secondary students should develop a level of understanding that will allow them to explain genetics phenomena that affect their daily lives.

Teachers and students consistently identify genetics as one of the most difficult of all science topics (Bahar, Johnstone, and Hansell, 1999; Kindfield, 1991; Stewart, 1982). In a pilot study, I investigated Thai lower secondary science teachers' perception of science content. They considered genetics to be the most difficult topic for teachers to teach and students to learn. They reported that they required much preparation and study to understand genetics concepts during their lesson planning; however, even after extensive preparation time, they did not fully understand the concepts. In addition, genetics concepts were viewed as abstract and complicated, making them difficult for understanding. The teachers were also not able to determine appropriate activities and teaching media to teach genetics concepts, or how to explain them in ways to ensure students' understanding. Furthermore,

because there is much terminology associated with the topic of genetics, both teachers and students felt confused during lessons.

There is little research that addresses teachers' understandings of genetics topics. However, using a questionnaire Finley, Stewart and Yorroch (1982), asked biology teachers what content in biology was both difficult and important for students to learn. They found that teachers placed protein synthesis, cell division, multiple alleles, chromosome theory of heredity, probability, Mendelian genetics, dihybrid crosses, and population genetics in the 15 items with the highest means for difficulty. Cell division, Mendelian genetics, chromosomes, and gene concepts were considered the most important concepts for students to learn. In addition, cell division, Mendelian genetics and the concept of chromosomes were considered as both important and difficult for students to learn.

In the Thai context, there are few studies about the teaching of genetic. Some researchers studied Thai secondary students' understanding of genetics topics. The findings revealed that students had some difficulties learning the concepts of heredity, multiple alleles, polygene incomplete dominants, and chromosomes (Ratanaroutai, 2006; Settapukdee, 2004; Sukpimontree, 1988).

Similarly, in studies outside of Thailand, genetics is viewed as difficult by students. Many researchers reported finding poor understandings of genetics among students of all levels (Ann and Kindfield, 1991; Bahar *et al.*, 2000; Brown, 1990; Lewis, 2004; Lewis, Leach and Wood-Robinson, 2000a, 2000b, 2000c; Moll and Allen, 1987; Oztap, Ozay and Oztap, 2003; Santos and Bizzo, 2005; Stewart, 1990, 1982; Tolman, 1982; Wood-Robinson, Lewis and Leach, 2000; Venville, Gribble and Donovan, 2005; Venville and Treagust, 1998). Researchers found that meiosis, gametes, alleles, genes, chromosome, phenotype and genotype, molecular genetic, genetic engineering, along with monohybrid and dihybrid crosses and linkages, and genetic disorders were concepts that students identified as ones with which they had difficulty.

Secondary school students were confused about relationships between the topics of cells, genes and genetic information (Lewis *et al.*, 2000a, 2000b; Wood-Robinson *et al.*, 2000). In addition, secondary students and college students had difficulty understanding the purposes and products of cell division (Lewis *et al.*, 2000c; Brown, 1990; Oztap *et al.*, 2003) and linking between chromosomes and genetic material, and relationship between the behaviors of chromosomes in cell division (Brown, 1990; Lewis *et al.*, 2000c; Oztap *et al.*, 2003). Furthermore, secondary students reported that there was no clear distinction between phenotypes and genotypes (Lewis, 2004). They also did not have a conceptual understanding of what genes and DNA are or what they do (Venville *et al.*, 2005). Secondary school and college students' knowledge of problem solving related to the concepts of monohybrid cross, dihybrid cross, co-dominance problems, and sex-linked inheritance was weak (Moll and Allen, 1987; Stewart, 1982; Tolman, 1982).

In summary, the research on lower secondary teacher's understandings of genetics suggested that many concepts of genetics are both difficult and important for students to learn (Finley *et al.*, 1982). The majority of Thai and international lower secondary science students revealed their misconceptions on such concepts (Brown, 1990; Lewis *et al.*, 2000a, 2000b, 2000c; Moll and Allen, 1987; Oztap *et al.*, 2003; Settapukdee, 2004; Stewart, 1982; Sukpimontree, 1988; Tolman, 1982; Venville, *et al.*, 2005; Wood-Robinson *et al.*, 2000). The present study aims to assist teachers to teach and students to learn genetics. In addition, this study will extend the knowledge base about the influence of professional development experiences on Thai lower secondary science teachers' knowledge of genetics and PCK related to genetics. Based on my preliminary study, Thai lower secondary science teachers need to construct understandings about content knowledge and pedagogical knowledge, teaching media, and strategies for assessing their student learning in genetics. Thus, professional development should be developed, implemented, together with follow-ups for developing teachers' content knowledge and PCK regarding genetics topics. PCK plays an important role in eliminating some problems associated with teaching science. Furthermore, it may ultimately help to empower teachers and enhance the status of teaching as a profession in line with the 1999 NEA and the Science and

Technology Teachers' Standards (IPST, 2002), and the National Science Education Standards (NRC, 1996).

### **Research Objectives and Research Questions**

This investigation had multiple purposes. The first was to explore the current practices, problems and needs of lower secondary science teachers about teaching and learning in genetics. Information from this part of the study was used to inform the study's second purpose, which was to design a professional development program to guide the development of a professional learning experiences for developing the teachers' CK and PCK. The third purpose was to study the development of three Thai lower secondary teachers' CK and PCK related genetics over the course of a professional development experiences.

The following research questions are addressed:

1. What are the current practices, problems and needs of lower secondary science teachers about teaching and learning in genetics?
2. What is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teacher develop content knowledge and pedagogical content knowledge regarding genetics?
3. How do Thai lower secondary science teachers' content knowledge and pedagogical content knowledge develop related to genetics over the course of a teacher professional development experiences?

## Definition of Terms

### 1. Professional Development

Professional development is a process of promoting Thai lower secondary science teachers' content knowledge and pedagogical content knowledge development. According to Loucks-Horsley *et al.* (2003), the process of professional development includes analysis of teachers' context, planning strategies, activities and context, implementing them and following-up their professions. In the Thai teachers' context, this study concerns the needs, curriculum, culture, background, prior knowledge of CK and PCK, and learning resources of genetics. In addition, the workshop, seminars, study groups, case discussion, collaboration with the research team including a scientist, two educators and a researcher are factors that will impact the development of teachers' CK and PCK. Professional learning experiences also use a set of activities based on inquiry and teacher reflection. In the implementing process, Thai teachers will participate in a five day workshop and two seminars for developing their CK and PCK. Three case studies will be followed-up their teaching in the real classroom

### 2. Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK) is lower secondary science teachers' knowledge that enables them to transform genetics content knowledge and knowledge of representations and activities he or she possess into forms that are useful for helping lower secondary science students comprehends genetics concepts.

#### 2.1 Genetic Content Knowledge (CK)

Genetic Content Knowledge is teachers' understanding of genetic ideas or concepts with commonly held views of a particular community (e.g., scientists), and in line with the sub-standard of Stand 1: Living things and living processes in the IPST Science Curriculum (IPST, 2003). Genetics concepts consist of concepts of:

genetic traits, dominant and recessive traits, chromosomes, genes, DNA, mitosis and meiosis, phenotype, genotype, mono-hybrid cross, Punnett squares, Mendel's laws, genetic diseases, and applied genetics.

## **2.2 Knowledge of Representations and Activities**

### **2.2.1 Knowledge of Representations**

Based on Magnusson *et al.* (1999), knowledge of representations refers to teachers' knowledge of ways to represent genetics in order to facilitate the students' learning. It is the teachers' knowledge of the relative strengths and weaknesses of representing particular genetics concepts. In addition it includes the teachers' ability to invent representations to aid their students in developing understanding of genetics concepts.

### **2.2.2 Knowledge of Activities**

Knowledge of activities refers to the teachers' knowledge of what activities can be used to help their students understand particular genetics concepts.

## **3. Lower Secondary Science Teachers**

The lower secondary science teachers are persons who are taught genetics for grade 7-9 students in the 2005-2006 academic years.

## Overview of the Study

In this chapter, according to educational reform documents from the literature and pilot of this study, lower secondary science teacher needed knowledge of science contents and how to teach these contents for students' understanding in genetics in line with the requirements of the reforms. In addition, professional development program should be provided science teachers develop their profession continuously. Furthermore, in the pilot of study and literature, genetics is the most difficult topic to teach and learn for teachers and students. As a result, this study involved the design of a professional development experience for helping lower secondary science teachers' development of CK and PCK in genetics.

In the chapter 2, professional growth and teacher change, teacher knowledge and reflection as research theoretical framework are delineated. In addition, professional development programs in science education are presented. Furthermore, the historical background and the concepts of pedagogical content knowledge are described. Furthermore, knowledge of genetics is discussed. Moreover, definitions of reflection, role of reflective practices and reflective tools are discussed through a comprehensive review of the relevant literature. Finally, professional growth in the aspect of current trends of professional development as well as the relationships between reflection and inquiry are discussed for promoting teacher knowledge in science education. In the chapter 3, the research methodology is described under the following topics: (i) grounded theory as methodological framework; (ii) descriptions of case study as a method; (iii) the research context of the study; (iv) participants of the study; (v) procedures of the study; (vi) data collection and, (vii) data analysis. Chapter 4 presents research intervention as process and results of the developmental phase of the study. Chapter 5 presents the findings of development of science teachers' CK and PCK. Finally, chapter 6 provides conclusion and discussions of the results and recommendations for the science teacher professional development program.

## **CHAPTER II**

### **REVIEW OF THE LITERATURES**

#### **Introduction**

This examination addressed the interrelatedness of three bodies of literature that inform the study of professional growth and teacher change, teacher knowledge, and reflective practices in the context of professional development in science education. In the first part, I describe professional growth and teacher change, programs of professional development designed for developing science teachers' knowledge and practices in general. In the second part, professional development program in science education is presented. In the third part, teacher knowledge is described. To understand Thai science teachers' knowledge, I describe characteristics of each type of teacher knowledge, particularly, the background and components of pedagogical content knowledge and teachers' knowledge of genetics concepts. I also review research about the development of science teachers' knowledge in context of professional development. In addition, reflective practices are considered an active process related to developing teachers knowledge. Definitions of reflective practices, reflection in the context of professional development experiences and reflective tools are explained for understanding how to promote reflective practices for Thai lower secondary school science teachers' development of PCK and content knowledge in the context of professional development experiences.

## **Professional Growth and Teacher Change**

### **1. Definition of Professional Growth and Teacher Change**

Professional growth is defined as changes over time in behavior, knowledge, images, beliefs, or perceptions of teachers (Kagen, 1992). According to Kagen (1992), growth consists of at least five components. First, teachers become more aware of what they know and believe about students and classrooms and of how their knowledge and beliefs change. Second, teachers reconstruct idealized and inaccurate images of students. Knowledge of students is used to modify, adapt, and reconstruct the teachers' image of self as teacher. Third, as the image of self-as-teacher is resolved, teachers' attention shifts from self to the design of instruction and then to students' learning. Fourth, teachers develop standardized routines that integrate instruction and management and grow increasingly automated. Fifth, teachers grow in their thinking about classroom problems and consider different problem-solving solutions.

Teacher change is defined as a highly personal process accomplished by the individual through experiences, emotions, cognitions, and behaviors over a period of time which transforms a teacher's values and beliefs (Prochaska, DiClemente and Norcross, 1997). Change comes from teachers being empowered to be better teachers (Scheidler, 1994). The evidence of change is the product (Scheidler, 1994). Change can be seen in new student performance, new school reform, new teacher practices, and so on (Boling and Martin, 2005; Scheidler, 1994). Change occurs when teachers' belief systems and core values concerning teaching and learning are modified (Boling and Martin, 2005).

In science education, change is often associated with a need to improve practice, content knowledge, and attitudes (Jeanpierre, Oberhauser and Freeman, 2005). According to Paris, Lipson, and Wixson (1983), the change process is evident through cognitive behaviors in three phases of learning: declarative, procedural, and conditional. The declarative level of understanding is the phase where teachers are

introduced to the strategies. Next, at the procedural level, teachers deepen their knowledge by experimenting with the strategies. Last, at the conditional knowledge level, teachers understand when a strategy should be used to achieve a certain purpose and evaluate the strategy's effectiveness in instruction.

Prochaska *et al.* (1997) described six change processes consisting of precontemplation, contemplation, preparation, action, maintenance, and termination. First, in precontemplation, teachers are unaware of a need for change. Next, in contemplation, teachers become aware of the problems and think of ways to change. In preparation, teachers begin to research ways to change. Then, in the action stage, teachers engage in the change process. In the maintenance stage, teachers assess and reflect on the change. Finally, in the termination stage, teachers have accepted the change so completely that they are advocates for the new concept.

In order to facilitate changes in teacher's behavior, knowledge, beliefs, or perceptions, teachers need to participate in a variety of professional development experiences (Gilbert, 1994). Ongoing change should occur continuously in all schools, generated by teachers as part of their own professional renewal (Gilbert, 1994). Professional development experiences should also be emphasized over time beginning with the relatively simple and moving to the more complex through stages (Burden, 1996). In addition, in development of teacher's professional growth, individual beliefs should not be ignored as a factor in decisions of change (Burden, 1996). Furthermore, teachers should learn to share their ideas, resources, and beliefs and to participate in the decision-making process in collaboration work (Bell and Gilbert, 1994; Scheidler, 1994). Moreover, teachers should have opportunities to respect and value what they know (Bell and Gilbert, 1994). Teachers should also learn by doing, reading and reflection, by collaborating with other teachers, by looking closely at students and their work, and by sharing what they see (Darling-Hammond and McLaughlin, 1995).

## **2. Effective Professional Development for Promoting Professional Growth and Teacher Change**

To provide teachers with experiences that allow them to change their knowledge and practices and grow professionally, effective professional development opportunities should provide valuable experiences for science teachers. The 1999 NEC describes several features of high quality professional development (ONEC, 1999). First, there should be collaboration among the people involved in programs, including teachers, teacher educators, teacher unions, scientists, administrators, policymakers, members of professional and scientific organizations, parents, and business. The content of professional learning experiences must also come from both inside and outside the learner and from both research and practice that recognize the developmental nature of the teacher's professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency. In addition, professional development should enable teachers to develop further expertise in subject content, teaching strategies, uses of technology, and other essential elements in teaching to high standards. Furthermore, professional development must be aligned with, and support, system-based changes that promote student learning. Finally, professional development should recognize the history, culture, and organization of the school environment.

Loucks-Horsley *et al.* (1998) proposed a set of seven principles from their review of the discipline-specific perspectives of professional organizations. First, effective professional development experiences are driven by a well-defined image of effective classroom learning and teaching. Professional development, for example, emphasizes an approach to learning that focuses on in depth understanding of core concepts and challenges students to construct new understandings. Second, effective professional development experiences provide opportunities for science teachers to build their knowledge and skill. For example, they help the teachers develop in-depth knowledge of their disciplines as well as pedagogical content knowledge. Third, professional development experiences use or model strategies that teachers will use with their students. For example, the experiences provide teachers ample time for in-

depth investigations, collaborative work, and reflection. Fourth, effective professional development experiences build a learning community. For example, the teachers learn continually and share together. Fifth, the experiences of professional development support the teachers in serving leadership roles, for example, as supporters of other teachers or as promoters of reform. Sixth, effective professional development experiences provide links to other parts of educational systems, such as district or school initiatives. Seventh, the experiences are continuously assessing themselves and making improvements to ensure positive impact on teacher effectiveness, student learning, leadership, and the school community. Other researchers (Darling-Hammond and McLaughlin, 1995; Garet *et al.*, 2001; Liebman, 1995) have echoed similar principles of effective professional development.

Furthermore, Tobin, Tippins, and Gallard (1994) discussed two essential factors for successful professional development for science teachers. First, connecting professional development efforts to teachers' previous knowledge base is important. Second, professional development needs to provide a supportive, long-term environment for change.

Moreover, Jeanpierre *et al.* (2005)'s project illuminated three characteristics of effective science professional development. These characteristics are opportunities for teachers to practice science process and research skills for developing deep science content and science process skills. The second is clear accountability requirements of teachers, where they demonstrate competency in a tangible and assessable way (i.e., a product of their learning is produced, which is accessed at specified standard of acceptability). The last is developers and providers of professional development experiences have high expectations for teacher learning and are able to facilitate multifaceted experiences that allow teachers to demonstrate their learning.

Contemporary, effective teacher professional development includes opportunities related to the contributions, needs, and developing knowledge of teachers themselves (Shapiro and Last, 2002). It should provide professional experiences to teachers by training, practice, and feedback (Abdal-Haqq, 1996). In

addition, effective professional development should enable teachers to engage in collegial sharing of knowledge and opportunities to draw on the expertise of others in the community (Wise, Spiegel, and Bruning, 1999). Moreover, effective professional development provides opportunity for reflection on their own experiences and on students' learning (Abdal-Haqq, 1996; Stallings, 1989 cited in Fullan and Hargreaves, 1992; Wise *et al.*, 1999). Professional development should also focus on teachers as learners and enable them to assess practices and incorporate constructivist approaches to learning. Furthermore, it should provide adequate time and follow-up support with multiple opportunities for interaction (Luft, 2001). Teacher professional development should link prior knowledge to new information (Fullan and Hargreaves, 1992). Finally, learners in professional development programs should be understand, empathetic, and warm. They should concentrate and be willing to participate and to put their knowledge into practice.

To promote teacher professional growth of knowledge and practice, this study aims to develop science teachers' knowledge of content and pedagogical content knowledge. Its ultimate purpose is to develop students' understanding of the science concepts and principles addressed in the Thai standards. Many features of effectived professional development based on the Thai NEA (1999), Loucks-Horsley *et al.* (1998, 2003), and the research of others (Abdal-Haqq, 1996; Darling-Hammond and McLaughlin, 1995; Garet *et al.*, 2001; Jeanpierre, *et al.*, 2005; Liebman, 1995; Luft, 2001; Tobin *et al.*, 1994) have been built into the workshop and follow-up that serve as the context for this study. The science teacher knowledge of subject content and pedagogical content knowledge in genetics should be developed through a process of collaboration among teachers, science educators and scientists and through reflection. The contents in the professional development program will be based on the teachers' needs and prior knowledge and addressed in the context of Thai educational reform.

## **Professional Development Programs in Science Education**

### **1. Context of In-Service Science Teacher**

Various professional development programs of teachers' professional development have been suggested worldwide in science education. The IPST (1997) designed a master teacher training program as a project of the School-Based Training (SBT) over five years (1997-2001). Its purpose was to extend master teachers' knowledge for training science, mathematics and computer teachers in local primary and secondary schools. In addition, IPST hoped that the in-service teachers could enhance their knowledge of contents, teaching methods, media production and assessment. The master teachers participated in an intensive 40-hour program. Then they trained in-service teachers systemically. They surveyed the teachers' needs, designed courses related to their needs, developed media and materials for the courses, evaluated the effectiveness of the course and followed up on teachers' success. The content of the course provided for the in-service teachers included subject matter and teaching in line with the curriculum and new knowledge in science, mathematics, and technology.

The Office of Human Resource Development Project Co-ordination, part of the Ministry of Education (1997), designed a 4-day workshop for master teachers about integrated science and mathematics teaching. The professional development design emphasized description, demonstration and practice. The Ministry expected that the master teachers would help in-service teachers bring their teaching and learning in line with science and mathematics integration. Petchen (2000) reported that the master teacher training program (1995-1998) influenced the master teachers' perspectives about aspects of teaching and learning process effectively. Furthermore, the in-service science and mathematics teachers changed their knowledge and attitudes toward the profession and were able to systematically organize their work. However, the master teachers reported some problems: they had insufficient time to develop other science teachers' knowledge of teaching science and mathematics. In addition, schools also lacked resources and funds for teacher professional

development. The masters teachers hoped that the new contents, materials, media and continue professional development programs would be supported by IPST in the future.

Another program designed by the IPST (2002) was a 12-day workshop to develop teachers' knowledge of science subjects. The content of the course included almost every science subject taught in lower secondary schools; it also included teaching strategies. The designers developed the program based on teachers' needs, implemented, the activities systematically, and evaluated the effectiveness of the programs. A total of 1,814 grade nine science teachers were surveyed about the teacher professional development programs in which they participated. The results revealed that 59.4 percent of the participants were satisfied their success because they could apply science knowledge in their classroom well. Among those surveyed 52.5% understood the objectives of the program clearly and 78.9 percent were pleased with the professional development experience.

The Office of Education Council (2001) designed a professional development unit. The unit was used to guide teachers' development in line with the criteria of the standards for long-term professional development. This unit was designed to support higher quality teacher performance in line with the National Teacher Qualification (NTQ). Another Expected outcome was the development of students' potential. The unit consisted of development of teachers' belief about teachers' spirit, development of teachers' performance in line with the teacher professional standards, and development of teachers' pride and appreciation for their careers.

According to the Research Department of IPST (2001), IPST developed Satellite Distance Teacher Professional Development Program. The program enabled teachers in distant schools to receive knowledge of science and mathematics teaching and learning in primary and secondary levels through T.V. or a satellite system. Teachers participated in the program over the course of one week or at the weekend. The Research Department of IPST (2003) surveyed the 168 experts and 704 participants who took part in the program and found that science teachers understood

the contents in the course better after completing the program. They needed the next teacher professional development program about new teaching methods, difficult contents, and new or model contents. In addition, they suggested that in the next program the contents in the course should reflect participants' needs. Furthermore, experts and participants had different view on the most appropriate time for professional development program, summer, every Saturday or one day a week. Moreover, the participants reported that they would be pleased to participate in other professional development programs related to teaching and learning development.

In Thailand, there has been professional development programs similar to those mentioned above to improve science teaching and learning according to the constructivist approach (Nopakoon, 2002; Jeeravipoolvarn, 2003; Jumpawan, 2004). The results showed that science teachers had more effective teaching and learning processes and were able to increase students' understanding in science after completing the program (Jumpawan, 2004; Nopakoon, 2002). The science teachers also further changed their beliefs and abilities concerning the nature of science and constructivism (Jeeravipoolvarn, 2003).

Some professional development programs have focused on inquiry-based learning. The model described by Jeanpierre *et al.* (2005) is based on an inquiry approach. Middle and high schools teachers from the same school districts implemented full inquiry skills into their science teaching practices. Five groups of teachers and students participated in the ecology research institutes over a 3-year period: one group in year 1, and two each in years 2 and 3. Each group attended two 1-week institutes during the summer the fall. During the time of two institutes, participants conducted two kinds of research, a scientist-directed project in which they monitored monarch butterflies and a group-designed independent inquiry project. They were engaged with the process of authentic inquiry throughout the program. During the program, each day focused on an ecology topic, a science process, a study system of the butterflies, science inquiry processes and a research project. In addition, teachers discussed inquiry teaching and classroom implementation, and reflected on how daily activities fit into key features of inquiry learning. Case studies of the

project showed that teachers changed based on implemented inquiry at different levels. One teacher increased confidence in his abilities to effectively do inquiry-based teaching. His students were able to investigate a variety of their own questions, developing hypotheses and experimental designs, carrying out research, and presenting their results in written and oral forums. Another teacher changed her practices by increasing use of inquiry. She changed her lab teaching, which had formerly been characterized by the “cookbook approach,” to incorporate more inquiry experiences over time. In addition to presentations by project staff on biology content, the participants had numerous opportunities to pose their own questions, investigate the answers, and use the field-based techniques. This study showed that teachers can improve their content understanding.

Inquiry-based learning was also the focus of Luft (2001), who designed a model of the Inquiry-Based Demonstration Classroom (IBDC), an in-service program for beginning and experienced science teachers. The study specifically explores how the program impacted the extended inquiry instruction of secondary science teachers in aspect of changes in behaviors and beliefs about inquiry instruction. Participants learned about a model of inquiry, utilized it in their classrooms, and examined and reflected upon their enacted lessons. Participants attended a one-day workshop that provided an orientation to inquiry-based science instruction. They then, participants engaged in an extensive five-day workshop in which they explored, experienced, and processed an extended inquiry cycle. Throughout the school year, while participants implemented extended inquiry cycles in their classrooms, they were engaged in various types of follow-up activities. They had opportunities to demonstrate their selected lessons to participants and staff and to get their feedback. In addition, the participants received feedback from the program director or program coordinator in a clinical supervision format about their implementation of the extended inquiry cycle. Furthermore, the participants reflected on the process of the entire IBDC experiences. Through the processes of the in-service program, the participants’ changed their behaviors and beliefs. The participants revised their perspectives about being science teachers and their views of inquiry instruction. For example, their conception of the teacher’s role shifted from that of an advocate to an entertainer. In addition, teachers

were able to plan and implement extended inquiry cycles in their lessons. Furthermore, teachers gained knowledge of teaching through observing, discussing and reflecting their practice with their peers.

Khourey-Bowers and Simonis (2004) designed a professional development program to enhance self-efficacy beliefs, content knowledge, and pedagogical content knowledge in chemistry education. Designed as an inquiry approach, the program had the following goals: to (a) provide instruction in fundamental chemistry concepts; (b) model the learning cycle through the use of exploration, concept development, and application; and (c) facilitate discussion of theories of learning to promote inquiry, teaching for conceptual change, and other child-supportive theories. The program was offered annually to in-service teachers of grades four through nine over a span of 10 years. Evaluation of the program indicated that it influenced achieving gains in personal science teaching, self-efficacy, chemistry content and pedagogical content knowledge. The researchers concluded that professional development that enhances personal science teaching self-efficacy and outcome expectancy should be recognized as essential to achieving scientific literacy for all students.

Case-based long term professional development for science teachers was the focus of a model by Dori and Herscovitz, (2005). This model was designed to develop pedagogical content knowledge in specific topics in chemistry and physics, as well as technology. This professional development program provided teachers with a series of weekly experiences for a period of three academic years. It included three types of enrichment: theoretical knowledge, content knowledge, and pedagogical content knowledge in the learning environment of the program. Teachers were engaged in planning activities, adapting cases to an appropriate activity, developing subject matter that involves cases, and applying it in class. First, the teachers as learners critically read the cases and posed question at various thinking levels. As teachers, they explored findings, editing existing cases or developing new ones, and adapted them to students at different academic levels. Second, to advance the teachers' ability to find out and develop new cases, they had to search for articles in popular science journals, daily newspapers and websites, sorting them into different subject matter

topics and adapting them for use by students at different academic levels. Third, the teachers used various considerations in choosing and adapting different teaching strategies to different topics to expose their students to a wide range of activities such as laboratory experiments, concept maps, and field trips. Fourth, as learners, the teacher experienced cooperative learning in small groups, with focus placed on the jigsaw method, group discussion, and brainstorming. Finally, following each project, the teachers were introduced to and experienced peer assessment, self-assessment of their own projects, and student evaluation in their classes. Throughout the 3 years of the program, the participating teachers went through major changes in their abilities to design high-quality case studies and related activities. In the final project, teachers developed case studies that were highly suitable for their students.

In the Collaborate–Enact–Reflect–Adapt model, suggested by Krajcik, Blumenfeld, Marx, and Soloway, (1994), teachers collaborated in order to construct meaning, enact new practices in the classroom, reflect on their practice and, eventually, adapt materials and practices. In their work, the middle school science teacher's attempts to understand and enact project-based instruction including a nontranscriptive, nonlinear approach grounded in constructivist theory were examined. The project aims to: (1) address authentic, real-world questions or problems that organize concepts and principles and diverse activities; (2) pose problems that represent students' emerging understandings; (3) allow students to engage in investigations; (4) involve students, teachers, and members of the larger community in collaboration as a community of inquiry; and (5) promote the use of cognitive tools including computing and telecommunication technologies. The teachers joined collaborative research teams to share and critique ideas, and to provide information related to their particular expertise. Teachers also participated as members of the university research community. Technology provided the context for establishing the collaboration between teachers and university staff. In addition, the teachers attended two university sessions that focused on helping them learn to use the schools' new computer lab. The results revealed that opportunities for collaboration and reflection supported teachers' development of new conceptions, strategies, and possibilities for enacting the features of project-based science. In

addition, work sessions and other collaborative opportunities with university staff and colleges enabled teachers to begin to link their new conceptions and strategies with the underlying constructivist premises of project-based science.

Howe and Stubbs (1996) designed the Constructivism/Sociocultural Model, which focuses on teachers' construction of their own knowledge of science content and of science teaching (pedagogical content knowledge or PCK). This model provided research scientists to work with science teachers and a science educator who acts as a facilitator and liaison. A scientist presented current research findings and theories (through a lecture with slides or video, a field trip, demonstration, or laboratory experience) in his or her field to a group of teachers. This activity was followed by teachers working in small groups, reflecting and brainstorming on ways that the information and the ideas presented by the scientist impact the development of curriculum material for their own students. Each day, the teachers developed a lesson plans that included three components: (a) involvement of all students in observation, experimentation, or another form of active learning; (b) cooperative learning; and (c) open-ended experiences. Teachers then shared their knowledge and materials with colleagues and form a network that encourages and supports their efforts. Designed for the developing two forms of teachers' knowledge including: content knowledge, and PCK, this model supported teachers' construction of knowledge in a supportive social context. In addition, teachers gained the power of professional growth when they had the freedom to make choices and to take responsibility for their own futures as professionals. Furthermore, many of teachers were more knowledgeable about science and more competent in teaching science. As teachers increased their knowledge and competence, they also gained their confidence and their beliefs.

## **2 Context of Pre-Service Science Teachers**

A program of collaborative inquiry and reflection was designed by Grunau, Pedretti, Wolfe, and Galbraith (2000) to answer two questions: 1) in context of the content presentation assignment, what problems can researchers focus on and attempt

to solve to make the teaching and learning process more meaningful for their pre-service secondary science students?, and 2) how can the researchers progress in their understanding of the reflective processes involved in their own collaborative efforts to inquire into and improve their professional practice?. Throughout the program, pre-service science teachers were engaged in assignments that required them to work in pairs. They also received assistance from their professors to research a particular science concept (in biology, chemistry or physics). They were able to suggest potential difficulties students. They were able to identify resources, activities and demonstrations for teaching the concept, and illustrated some of the teaching strategies to their peers.

### **3. Current Trends in Professional Development**

Professional learning experiences is critically important for developing teachers' knowledge and practices (Avalos, 1998). The NRC (1996), in a review of recent research on the cognitive science, teaching, and learning, argues that research studies are needed to determine the efficacy of various types of professional development activities, including pre-service and in-service seminars, workshops, and summer institutes. Studies should include professional development activities that are extended over time and across broad teacher learning communities in order to identify the processes and mechanisms that contribute to the development of teachers' learning communities.

Loucks-Horsley, *et al.* (1998, 2003) and Sparks (1999) described eighteen strategies used for science and mathematics teacher professional learning. The strategies are grouped into six clusters: (1) immersion experiences including immersion in inquiry into science and mathematics and immersion in the world of scientists and mathematicians; (2) aligning and implementation of the curriculum, consisting of curriculum implementation, replacement units, and development and adaptation; (3) examining teaching and learning, including action research, case discussion, examining students' work and lesson study; (4) collaborative work, comprising study groups, partnerships with scientists and mathematicians and

professional networks; (5) practicing teaching, comprising coaching, mentoring and demonstrating lesson plans; and (6) vehicles and mechanisms focusing on workshops, institutes, courses and seminars, technology for professional learning and developing professional developers.

According to Loucks-Horsley, *et al.* (1998, 2003) and Sparks (1999), every program, initiative, and professional development plan should use a variety of strategies in combination with one another form a unique design. These strategies are divided into five purposes: developing awareness, building knowledge, translating into practice, practicing teaching, and reflection. To develop awareness, strategies are usually used during the beginning phases of changes. The strategies are designed to elicit thoughtful questioning on the part of the teachers concerning new information. Examples of strategies that help raise awareness include professional networks, demonstration lessons, and study groups. Strategies to build knowledge provide opportunities for teachers to deepen their understandings of content and teaching practices. Case discussion, immersion experiences, workshops, technology for professional development, and partnerships with scientists and mathematicians are often used to build professional knowledge. In addition, strategies useful for translating understanding into practice include coaching, mentoring, curriculum implementation, and demonstration lessons. These help teachers to draw on their knowledge base to plan instruction and improve their teaching. Furthermore, strategies that focuses on teaching practices including examining student work, lesson study, coaching, mentoring, and demonstration lessons. These help teachers learn through the process of using a new approach, practice, or process with their students. Finally, strategies such as action research, study group, lesson study, case discussions, and examining student work encourage teachers to reflect on others' practice, and adapt ideas for their own use.

Particularly, the present study will focus only strategies for building science teacher's knowledge, and reflection. Loucks-Horsley and colleagues suggested several effective strategies in order to building science teacher's knowledge:

... Increasing science teachers' content knowledge is often best accomplished by immersing teachers in content as learners themselves. This can be accomplished through the immersion strategies, through partnerships, and in workshops/institutes. But learning content alone will not lead to changes in teaching, so designers must build in opportunities for teachers to put the content they learn into the context of teaching and provide opportunities to develop pedagogical content knowledge. This is accomplished through different strategies, such as, examining student works, case discussions, curriculum work, and lesson study. (2003: 114)

### **3.1 Workshop/Seminars**

A workshop is a traditional approach to professional development that occurs outside the teacher's own classroom (Garet *et al.*, 2001). It generally involves a leader or leaders with special expertise and participants who attend sessions at scheduled times, often after school, on the weekend, or during the summer (Garet *et al.*, 2001; Loucks-Horsley *et al.*, 1998). According to Loucks-Horsley *et al.* (2003), workshops provide opportunities for participants to focus intensely on topics of interest for weeks (e.g. institutes) or for an extended period of time (e.g. course). In addition, workshops and seminars tend to be offered for short periods of time and address more discrete learning goals, such as learning to use a particular set of lessons. Workshops also typically include more experimental or hands-on activities through which participants engage with new ideas and materials. Seminars tend to be more oriented toward sharing knowledge and experiences through discussions and reactions to others' practice or research results.

Features of effective workshop and seminar sessions were addressed based on Loucks-Horsley *et al.* (2003). Participants know clearly the goals, expectations, purposes, and benefits of the workshops and seminar sessions. The session also offers value to the participants by addressing their goals for learning and growth. In addition, a variety of learning activities are combined that engage participants and appeal to different learning styles. Furthermore, the sessions provide

time for participants to interact with each other and build relationships with new colleagues. Moreover, effective sessions make every minute count. For example, launch discussions can be tailored to helping participants process the content of the morning and to network. The facilitators also know their content well and are skilled in effective adult learning methods. They understand and respond to the goals of the participants. In addition, sessions are evaluated daily and given feedback for making adjustments and enhancing further sessions. The content is credible, sound, current, and interesting. Further, participants have access to print or electronic resources that extend their learning and provided them with reference materials to use in the future. Moreover, participants are guided to develop artifacts or products that reflect what they learn. Finally, the sessions clearly communicate its goals and purposes to target the right people for participation.

### **3.2 Collaboration**

Collaboration is important professional strategies that build teachers' science content knowledge and pedagogical content knowledge (Loucks-Horsley *et al.*, 2003). According to Loucks-Horsley *et al.* (2003), they suggested that teachers should share ideas and experiences equally in professional development. Working collaboratively with scientists, teachers can have opportunities to learn more about how the scientific process works, what scientists do, and how and why they do it. In their role as content experts, scientists strive to help teachers build confidence in teaching science by modeling inquiry and providing them with new insights and experiences. Also, through working with science educators, teachers are able to improve their teaching strategies.

### **3.3 Case discussions**

Lee Shulman (1992) defined cases as engaging narrative stories containing events that unfold over a period of time in a specified place. Cases are also thought of as "...narratives (whether in print form or on videotape) that offer a picture of a teaching or learning event and are specially designed to provoke discussion and

reflection” (Loucks-Horsley *et al.*, 2003: 169). Various formats of cases have emerged to illustrate problems or dilemmas in teaching and learning including narratives, critical incidents, protocols, vignettes, situations, video cases, computer-based presentations and more recently interactive video cases (Barnett, 1999; Tippins, Koballa and Payne, 2002). A good case is carefully designed for instruction and poses fundamental issues that reach beyond the particulars in the case and motivate ongoing reflection and inquiry (Barnett, 1999).

Cases are instructional tools used to explicate and clarify the professional knowledge of teachers while case study refers to a method of research (Koballa and Tippins, 2000). Miller and Kantrov defined that “...case refers to a narrative organized around a key event and portraying particular characters that is structured to invite engagement by participants in a discussion”, (1998: 2). However, case study is used to describe a qualitative research method that results in an intense and holistic description and analysis of an event or social unit (Veal, 1997).

According to Barnett, case-based professional development “...involved using carefully chosen, real-world examples of teaching to serve as springboards for discussions among small groups of teachers”, (1999: 26). Cases can help teachers discover ambiguity, conflict, and complexity with a deceptively simple-looking teaching situation. According to Tippins *et al.* (2002), cases serve as a vehicle for reflection and changing practice. Cases help prospective and practicing teachers to develop skills of critical analysis and problem solving, acquire board repertoires of pedagogical techniques, develop higher-order cognitive thinking, and engage in reflective practice. Cases can also provide situation-specific circumstances that can help teachers connect theory and practice.

According to Loucks-Horsley *et al.* (2003), case discussions are used to increase science teachers’ knowledge. Case discussions offer groups of teacher the opportunity to reflect on teaching and learning by examining narrative stories or videotapes that depict school, classroom, teaching, or learning situations. Teachers have opportunities to analyze students’ thinking and how their ideas are developing

and identify what students understand and where their confusion lies. As teachers reflect on students' thinking and approached to solving problems, and assess the reasoning of students' responses, they begin to think through science again for themselves, often seeing new aspects of familiar content and expanding their own understanding (Loucks-Horsley *et al.*, 2003).

Barnett (1999) described case discussion used for professional development. A group of teachers meets once a month for about two hours to discuss a case which they read before meeting. The case, selected from a book of field-tested cases written by teachers, describes a classroom experience that has an unexpected outcome or ran into difficulty. Before beginning the discussion, group member work on a problem related to the case for a few minutes. As they work, they are asked to think about what might be confusing or difficult from the students' view. Teachers note their insights. Then teachers identify issues from the case and frame them as questions. These issues are posted on chart paper and used to focus the discussion, which continues for about an hour.

### **3.4 Study Groups**

Study groups are a reform type of professional development. They often take place during the regular school day (Garet *et al.*, 2001). According to Loucks-Horsley *et al.* (2003: 115), study group are "...collegial, collaborative groups of problem solvers who convene to mutually examine issues of teaching and learning". Study groups are organized around a specific topics or issues of importance to the participants. In addition, teachers should join and form study groups voluntarily and determines their own focus for learning and the format of sessions.

According to Loucks-Horsley *et al.* (2003), study groups offer teachers the opportunity to come together to focus on issues of teaching and learning. Regardless of topics or issues being addressing, study group provide a forum in which teachers can be inquirers and asking questions. In addition, group of teachers have opportunities to discuss, reflect on and analyze teachers' implementation of strategies

learned in a workshop or other short term sessions. Teachers are also engaged to continue refining and improving new practices that they implemented in their classrooms. In working on research, study groups are useful for discussion of recent research and how it relates to classroom practices. Furthermore, study group encourages teachers to identify topics or practices which they would like to learn more about.

The Whole-Faculty Study Groups described by Murphy (1999) included seven steps of how the groups were organized and what the group did. First, staffs analyzed a wide range of data and indicators describing the status of student learning and the condition of the learning environment. Next, they used the data to generate a list of students' needs. Then they categorized students' needs and prioritized the categories or clusters. Next, they organized study group. Staffs created and implemented a study group action plan. Finally, staffs evaluated the impact of the study group effort on student performance.

## **Summary**

Professional growth is change over time in behavior, knowledge, images, beliefs, or perceptions of teachers (Kagen, 1992). Change is a personal process. Change develops through experiences, emotions, cognitions, and behaviors (Prochaska *et al.*, 1997). In order to address change process of teacher's knowledge and behavior, many aspects of principles of effective professional development experiences should be provided for teachers. According to Abdal-Haqq (1996); Darling-Hammond and McLaughlin, (1995); Garet *et al.* (2001); Jeanpierre *et al.* (2005); Liebman, (1995); Loucks-Horsley *et al.* (1998), (2003); Luft, (2001); ONEC (1999); and Tobin *et al.* (1994), professional development experiences emphasize building deep understandings of science concept knowledge and pedagogical content knowledge. In addition, professional development learning experiences provide teachers opportunities for investigations through inquiry, collaborative work, and sharing ideas. Teachers also reflect on their own knowledge and teaching, continuously assessing themselves and making improvements. Furthermore,

professional development experiences should be developed in line with teachers' interest, needs, and prior knowledge, and link with schools and district priorities. Finally, the professional development experiences should provide teachers with multiple opportunities for interaction.

From principles to designing professional development program to enhance teachers' knowledge of content knowledge and PCK, this program bases on professional strategies of workshop, seminars, case discussion, collaboration with scientist and science educator, study group and reflection. All of strategies are integrated for providing teacher professional experiences over teaching genetics in Thai lower secondary school.

### **Teacher knowledge**

Teacher knowledge is pivotal importance in the design and implementation of teaching situations that may help students to learn science (Jasti, 2005). When teachers have adequate knowledge of effective teaching in science, their students may learn and understand science effectively. Thus, this study describes what kinds of teacher knowledge are studied in education. In addition, this study reviews how teachers develop their knowledge in the context of teacher professional development experiences. In particular, pedagogical content knowledge (PCK) is mentioned as important teacher knowledge in this study. PCK will be described in terms of its meanings, components, and development it in the context of professional development experiences in science education, especially in middle grades. Furthermore, a small part of teacher knowledge in genetics is revealed in this study.

#### **1. Definition and Components of Teacher Knowledge**

The teacher education literature reflects a myriad of different conceptions of teacher knowledge (i.e., practical, craft, content, pedagogy, curriculum, pedagogical content knowledge, etc). All of this knowledge represents ways of viewing teaching and knowledge of teaching, and only differs in the context of use (Veal, 1997).

Elbaz (1983) included five categories of teacher knowledge in her vision of practical knowledge: knowledge of self; knowledge of the milieu of teaching; knowledge of subject matter, knowledge of curriculum development; and knowledge of instruction. Shulman (1987) categorized the knowledge base of teaching as consisting of: content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. In addition, Tamir (1988) listed six domains of teacher knowledge oriented specifically to science teacher education. He identified the domains of subject matter, pedagogy, subject matter specific pedagogy, general liberal education, personal performance, and foundations of the teaching profession as critical to successful science teaching. Furthermore, Gess-Newsome's (1999) description based on the knowledge bases for teaching and their interrelations was found in work of Grossman (1990). She defined four general areas of teacher knowledge "...as the cornerstones of emerging work on professional knowledge for teaching: general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge, and knowledge of context" (1990: 5).

### **1.1 Subject Matter Knowledge**

Subject matter knowledge includes knowledge of the content of a subject area as well as knowledge of the substantive and syntactic structures of the discipline (Schwab, 1964).

Shulman (1986) argued that the study of teachers' cognitive understanding of subject matter content and the relationships between such understanding and the instruction teachers provide for students are important. He called for the study of three types of content knowledge and their impact on classroom practice: subject matter knowledge, pedagogical knowledge and curriculum knowledge. Content knowledge or subject matter knowledge "...refers to the amount and organization of knowledge per se in the mind of the teacher" (Shulman, 1986: 9). Content knowledge also is "...the knowledge, understanding, skill, and disposition

that are to be learned by school children” (Shulman, 1987: 8-9). Grossman (1990) described that knowledge of content refers to knowledge of the major facts and concepts within a field and the relationships among them.

Schwab (1964) defined structure of content knowledge as consisting of two structures: substantive and syntactic structures of knowledge. The substantive structures are the variety of ways in which the basic concepts and principles of the disciplines are organized to incorporate its facts. The syntactic structure of a discipline is the set of ways in which truth or falsehood, validity or invalidity, are established.

## **1.2 Pedagogical Knowledge**

Shulman and Sykes (1986: 9) stated that pedagogical knowledge is “...lesson and unit planning, classroom organization and management, teaching techniques, student testing and grading, setting up a classroom for instruction, organizing groups, establishing routines”. In addition, it is knowledge of how to ask questions at an appropriate level, establish a proper pace for questions and answers, monitor the work of small groups or individuals at seat work, praise effectively and criticize sensitively (Shulman and Sykes, 1986). Similarly, Shulman (1987) placed general pedagogical knowledge in his model of teacher knowledge. It was described as knowledge referring to broad principles and strategies of classroom management and organization that pertains to teaching subject matter. Grossman (1990) focused on general pedagogical knowledge which includes a body of general knowledge, beliefs, and skills related to teaching: knowledge and beliefs concerning learning and learners; knowledge of general principles of instruction, such as academic learning time; knowledge and skills related to classroom management; and knowledge and beliefs about the aims and purposes of education.

Similarly Shulman described pedagogical content knowledge, pedagogical knowledge as knowledge of classroom organization and management, instructional models and strategies, and classroom communication and discourse (Morine-Desshimer and Kent, 1999). In addition, in a science teaching context,

knowledge of pedagogy includes methods that vary the instruction, such as including inquiry techniques, cooperative learning, monitoring and guiding students' projects, and implementing different questioning techniques (Hofstein, Carmeli and Shore, 2004).

### **1.3 Curriculum Knowledge**

Curriculum is a type of knowledge base of teaching (Shulman, 1987). It is "...the knowledge possessed by the teacher of how the almost infinite range of possible topics and skills that might be taught to students have been organized and arranged into systematic programs of instruction" (Shulman and Sykes, 1986: 10). Shulman and Sykes (1986) proposed three kinds of curriculum knowledge: particular curricular alternatives associated with the teaching of a given topic; the curriculum materials and topics in the same subject area typically employed before and after the materials...under consideration; and the curriculum materials and topics studied by one's students in other subject areas at the same time that a given subject is being taught.

In addition, curriculum knowledge is referred "...knowledge of alternative curriculum materials for a given subject or topics within a grade" (Shulman, 1986: 10). It is the teachers' ability to relate the content of a given course or lesson to topics or issues being discussed simultaneously in other classes (Shulman, 1986).

According to Grossman (1990), Magnusson *et al.* (1999), and Turner-Bisset (2001), curriculum knowledge is a part of pedagogical content knowledge. It is the knowledge of goals and objectives for students in a subject that teachers are teaching. It also is knowledge of special curriculum programs and materials that are relevant to teaching a particular domain of science and specific topics within that domain. For example, knowledge of what students have learned in previous years and what they are expected to learn in later years are elements of curriculum knowledge.

## 1.4 Knowledge of Student

Knowledge of students is a kind of teacher knowledge that the teachers should not ignore. This knowledge refers to "...knowing the prior understandings that student of given ages and backgrounds bring with them to the study of particular topics" (Shulman and Sykes, 1986: 11). In addition, there is a great deal to know about developmental differences among students and students' cultural and social characteristics (Shulman and Sykes, 1986).

In the context of science education, according to Magnusson *et al.* (1999), knowledge of students' understanding of science is the knowledge that teachers must have about students in order to help them develop specific scientific knowledge. It includes two categories of knowledge: requirements for learning specific science concepts, and areas of science that students find difficult. First, the category of knowledge of requirements for learning specific science concepts consists of teachers' knowledge and beliefs about prerequisite knowledge for learning specific scientific knowledge, as well as, their understanding of variations in students' approaches to learning as they related to the development of knowledge within specific topic areas. Teacher knowledge of prerequisite knowledge required for students to learn specific concepts includes knowledge of abilities and skills that students might need. Second, the knowledge of areas of student difficulty refers to the teachers' knowledge of which science concepts or topics students find difficult to learn, why they are difficult to learn, and knowledge of each type of difficulty.

## 1.5 Craft knowledge

Definitions of craft knowledge have focused on the practical aspects of teaching (Veal, 1997). Craft knowledge has been called knowledge of wisdom of practice (Shulman, 1987), occupational savy and know-how (Grimmett and MacKinnon, 1992), practical knowledge (Elbaz, 1983), and personal practical knowledge (Clandinin, 1986). Practical knowledge or craft knowledge, sought to understand what knowledge teachers brought to the classroom, how they used

knowledge in the classroom, and how their work influences their knowledge (Veal, 1997).

According to Grimmett and MacKinnon (1992: 396), craft knowledge of teaching is:

...not substantive, subject matter knowledge. It is a particular form of morally appropriate intelligent and sensible know-how that is constructed by teachers, holding progressive and radical educational beliefs, in the context of their lived experiences and work around issues of content-related and learner-focused pedagogy.

Teaching is a craft that includes the content, beliefs, feelings, and context. Grimmett and MacKinnon (1992: 393) also stated that:

...teaching as a craft, then, assumes certain skills, proficiencies, and dispositions among accomplished teachers-in brief, it suggests an emphasis on a specific kind of pedagogical content and learner know how, a teaching sensibility rather than to a knowledge of propositions.

In addition, craft knowledge tried to solve this dilemma by defining craft knowledge not as "...a knowledge base as such, but as a framework for helping prospective and experienced teachers develop their repertoire of responses, understandings, and magical tricks" (Grimmett and MacKinnon, 1992: 441).

van Driel, Verloop, and De Vos (1998) define craft knowledge as integrated knowledge which represents teachers' accumulated wisdom with respect to their teaching practice. As this knowledge guides the teachers' actions in practice, it encompasses teachers' knowledge and beliefs with respect to various aspects such as pedagogy, students, subject matter, and the curriculum. Although deeply rooted in teachers' practical work, craft knowledge is not in opposition to theoretical or scientific knowledge. Instead, craft knowledge encompasses knowledge derived from

prior education as well as from ongoing schooling activities (Beijaard and Verloop, 1996). Moreover, craft knowledge is supposedly influenced by factors related to teachers' personal backgrounds and by the context in which they work (Hoyle and John, 1995). It represents the construction of situated, learner-focused, procedural and content related pedagogical knowledge through deliberate action (Kennedy, 1987). In addition, according to Shimahara (1998), craft knowledge of teaching is embedded in reflection-in-action and represents an art in important respects. It derives from practitioners' understandings of teaching situation.

Thus, craft knowledge involves on practice, belief, pedagogy, context, content of teaching and reflection. van Driel *et al.* (1998) define craft knowledge as a types of knowledge which actually guide the teachers' behavior during classroom practice. Within their definition of craft knowledge, van Driel *et al.* (1998) considered PCK to be a specific form of this craft knowledge. This is explained as follows. PCK implies a transformation of subject matter knowledge, so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice. Thus, teachers may derive PCK from their own teaching practice (e.g., analyzing specific learning difficulties) as well as from schooling activities (e.g., an in-service course on student conceptions). More important, when dealing with subject matter, teachers' actions will be determined to a large extent by their PCK, making PCK an essential component of craft knowledge.

## **1.6 Practical knowledge**

Carter (1990) emphasized what teachers know and how that knowledge is acquired. His important notions of teacher's knowledge focus on two categories. First, teachers' practical knowledge includes personal knowledge and classroom knowledge. Second, pedagogical content knowledge is the way teachers understand and represent subject matter to their students.

Practical knowledge refers broadly to "...the knowledge teachers have of classroom situations and the practical dilemmas they face in carrying out purposeful

action in these settings” (Carter, 1990: 299). In practical knowledge, teachers were engaged in practical thinking that leads to an action appropriate to the particular situations (Carter, 1990). The knowledge required for practice under circumstances is experiential, that is, it evolved out of reflection-in-action (Schon, 1983). In addition, practical knowledge “...is shaped by professionals’ personal history, which includes intentions and purposes, as well as, cumulative effort of life experience” (Carter, 1990: 300).

Practical knowledge is action-oriented knowledge, acquired without direct help from others (Johnston, 1992). It is the accumulated wisdom of teachers on the basis of their experiences, which they can immediately use in their own teaching practice (Beijaard and Verloop, 1996; Carter, 1990). According to Johnston (1992), it allows teachers to achieve the goals they personally value. In addition, practical knowledge is affected by teachers’ concerns about their own teaching context. Thus, practical knowledge is situation specific, as it is adapted to a context which includes the students, the course books and other learning materials, the curriculum, the school culture, and so on. In addition, practical knowledge is implicit or tacit knowledge (Eraut, 1994). Teachers are not used to articulating their practical knowledge, but they are more in a doing environment, than in a knowing environment. Furthermore, it is integrated knowledge between scientific or formal knowledge and everyday knowledge, including norms and values (Handal and Lauvas, 1987). The process of knowledge integration is guided by experiences which play a key role in the development or change of teachers' practical knowledge. Through this process, practical knowledge, encompassed with elements of formal knowledge, is adapted to the teaching context. Such elements may be derived from the teacher's prior formal education, as well as from in-service schooling activities (Beijaard and Verloop, 1996). However, researchers still only minimally understand how teachers integrate knowledge from different sources into the conceptual frameworks that guide their actions in practice (Eraut, 1994).

Practical knowledge is relevant to aspects of PCK (van Driel, Beijaard, and Verloop, 2001). PCK refers to a transformation of the subject matter knowledge

used by teachers in the communication process with learners. As PCK refers to particular topics, practical knowledge is to be discerned from the knowledge of pedagogy, of educational purposes, and of learner characteristics in a general sense. Moreover, because PCK concerns the teaching of particular topics, it may turn out to differ considerably from subject matter knowledge per se. PCK may be perceived as a central element within teachers' practical knowledge (Cochran *et al.*, 1993).

## **2. Teacher Knowledge in the Context of Professional Development in Science Education**

Much research focused on the study of science education has been about the teacher knowledge. Some studies emphasized the development of teachers' practical knowledge through professional development experiences. For example, van Driel *et al.* (2001) addressed the question of what we can learn from research on teachers' practical knowledge in order to increase the success of reform in science education. In this study, practical knowledge consisted of teachers' knowledge and beliefs about their own teaching practice, and was mainly the result of their teaching experience. This result revealed that development of practical knowledge was conceptualized as action. As it is constructed by teachers in the context of their work, practical knowledge integrated experiential knowledge, formal knowledge, and personal beliefs. Furthermore, the study suggested that long-term professional development programs are needed to achieve lasting changes in teachers' practical knowledge. In particular, the following strategies are potentially powerful: (a) learning in networks, (b) peer coaching, (c) collaborative action research, and (d) the use of cases.

In addition, van Driel *et al.* (2001) suggested that professional development learning for promoting teachers' knowledge should focus on facilitating the growth of professional knowledge. Moreover, multiple strategies are used to promote changes in teachers' knowledge and beliefs. These strategies may include accessing to innovative classroom materials, giving opportunities to practice new ways of teaching, reflecting on practical experiences, possibilities to discuss elements of the reform with others (peers, coaches, supervisors), and supporting suitable environment for learning.

Other research focused on teachers' knowledge related to the content being taught. Carlsen (1993), for example, studied the effects of four new science teachers' subject matter knowledge on biology classroom discourse at the level of individual utterances in a year long study. The teachers had the opportunity to develop their subject matter knowledge in a teaching methods course. The new teachers did card-sort tasks in a curriculum workshop and then were asked about their personal subject matter knowledge in the topics of cell biology, ecology, evolution, and invertebrates. After that, the teachers taught half days in public secondary schools. Teachers' teaching was recorded. The teachers had a chance to reflect in their video teaching recordings. The results suggested that teacher subject matter knowledge affects language in the science classroom. When these teachers were not knowledgeable about the topics, they were more likely to ask low-level questions. In contrast, when they were knowledgeable of the topics, teachers often gave their students more opportunities to talk. In sum, the process of professional development should provide opportunities for teachers to develop their subject matter knowledge consistently with teaching practice.

Carter (1990) wrote about conducting case studies of middle grade science teachers. A science teacher of seventh and eight grades came to teaching science with a strongly held belief in the inquiry approach. He began to read criticisms of the inquiry approach for teaching. Later, he experimented by using his own blend of inquiry and content knowledge in science. Seeing that his students were constructing much-improved meaning about the subject of science, he altered his original view of teaching and continued to construct his own interpretation of teaching from his classroom experiences and from his reading of theory about how children learn. In their studies of professional knowledge in the aspect of personal practical knowledge, the investigators found that teacher became aware of the strategies with which they are comfortable. In addition, teachers become attentive to students' reactions, reflect on puzzling situations, and start to reframe their view of their practice. They began, in other words, reflection-in-action.

## **Pedagogical Content Knowledge**

Pedagogical content knowledge (PCK) is the specific kind of teacher's knowledge used as a framework of this research. Pedagogical content knowledge will be described in depth in the context of professional development in science education.

### **1. Definition of Pedagogical Content Knowledge**

The concept of pedagogical content knowledge has been variously defined. This concept was introduced by Shulman in a paper in which he argued that research on teaching and teacher education has ignored research questions dealing with the content of the lesson taught (Shulman, 1986). Consequently, he introduced pedagogical content knowledge as a kind of content knowledge:

...within the category of pedagogical content knowledge, I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstration—in a word, the ways of representing and formulating the subject that make it comprehensible to others (Shulman , 1986: 9).

In addition, according to Shulman (1986), the concept of PCK refers to teachers' interpretations and transformations of subject-matter knowledge in the context of facilitating student learning. Notably, PCK encompasses understanding of common learning difficulties and preconceptions of students.

In a paper (1987), PCK was listed by Shulman as one of seven knowledge bases for teaching, removing it as a subcategory and placing it on equal footing with content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of philosophical and historical aims of educations. PCK was:

...of special interest because it identifies the distinctive bodies of knowledge for teaching...It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction...pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue (Shulman, 1987: 8).

PCK consists of two key elements: knowledge of instructional strategies incorporating representations of subject matter, and understanding of specific learning difficulties and student conceptions with respect to that subject matter (van Driel, *et al.*, 1998). It is the way teachers understand and represent subject matter to their students (Carter, 1990). Tamir (1988: 105) suggested that PCK includes:

...a teacher's knowledge of students' interest and motivation to learn particularly topics within a discipline, a teacher's understanding of how to make outside-school settings (e.g., museums) quality learning environments for special content areas, and a teacher's discipline-based knowledge of special needs for testing and evaluating students' work (e.g., practical laboratory tests in science).

## **2. Component of PCK**

Other scholars have conceptualized PCK in various ways. (See table 2.1)

According to Grossman (1990), PCK consists of knowledge of strategies and representations for teaching particular topics and knowledge of students' understanding, conceptions, and misconceptions of these topics. In addition, PCK is composed of knowledge and beliefs about the purposes for teaching particular topics and knowledge of curriculum materials available for teaching. In Grossman's model of teacher knowledge, PCK is at the heart of teaching knowledge surrounded by three related categories: namely, knowledge of subject matter, general pedagogical

knowledge and contextual knowledge. Grossman identified the following sources from which PCK is generated and developed: a) observation of classes, both as a student and as a student teacher, often leading to tacit and conservative PCK; b) disciplinary education, which may lead to personal preferences for specific purposes or topics; c) specific courses during teacher education, of which the impact is normally unknown; and d) classroom teaching experience.

Based on an explicit constructivist view of teaching, Cochran, DeRuiter, and King (1993) renamed PCK as pedagogical content knowing (PCKg) to acknowledge the dynamic nature of knowledge development. In their model, PCKg is conceptualized much more broadly than in Shulman's view. PCKg is defined as "...a teacher's integrated understanding of four components of pedagogy, subject matter content, student characteristics, and the environmental context of learning" (Cochran *et al.*, 1993: 266). Ideally, PCKg is generated as a synthesis from the simultaneous development of these four components.

The idea of integration of knowledge components is also central in the conceptualization of PCK proposed by Fernandez-Balboa and Stiehl (1995). These authors identified five knowledge components of PCK: subject matter, the students, instructional strategies, the teaching context, and one's teaching purposes.

In the context of science education, many researchers identified components of PCK in similar ways to scholars in other fields. According to Smith and Neale (1989), their notion of PCK consists of knowledge of students' concepts, strategies for teaching content and shaping and elaborating the contents. The first aspect of this PCK is the teachers' knowledge of typical student errors and the usual developmental path along which student progress. PCK in the aspect of strategies for teaching content is knowledge of particular teaching strategies that enables students to make progress in conceptual understanding of the science content. In their article, based on other researchers, the strategies that work in facilitating students' conceptual change in science include: a) eliciting students' preconceptions and predictions about phenomena; b) asking for clarification and explanation; c) providing discrepant

events; d) encouraging debate and discussion about evidence, and clearly presenting alternative scientific explanations. The last aspect of PCK is the teacher's use of examples, good explanations, metaphors analogies, and representations.

Notion of Geddis (1993) based on Shulman (1986), PCK was defined in his work as teacher's knowledge of transform subject-matter content knowledge into a form accessible to students. Teachers need to know a multitude of particular things about the content that are relevant to it's teachable. It includes knowledge of (i) what makes the topics easy or difficult to understand-including the preconceptions about the topic that students bring to their studies; (ii) those strategies most likely to be effective in recognizing students' understanding to eliminate their misconceptions; and (iii) a variety of effective means of representing the ideas included in the topic-analogies, illustrations, examples, explanations, and demonstrations.

**Table 2.1** Knowledge components in different conceptualizations of pedagogical content knowledge (PCK)

Knowledge of:								
Scholars	Subject matter	Instructional strategies	Student learning and conceptions	General pedagogy	Curriculum and media	Assessment	Context	Purposes
Shulman (1987)		PCK	PCK					
Smith and Neal (1989)	PCK	PCK	PCK	PCK				
Grossman (1990)		PCK	PCK		PCK			PCK
Cochran <i>et al.</i> (1993)	PCKg		PCKg	PCKg			PCKg	
Geddis (1993)	PCK	PCK	PCK	PCK				
Fernandez-Balboa and Stiehl (1995)	PCK	PCK	PCK				PCK	PCK
Magnusson <i>et al.</i> (1999)	PCK	PCK	PCK	PCK	PCK	PCK		
Morine-Dershimer and Kent (1999)	PCK		PCK	PCK	PCK		PCK	PCK
Veal (2004)	PCK		PCK	PCK			PCK	

Based on work of Grossman (1990), Tamir (1988), and Magnusson, Krajcik and Borko (1999), PCK is conceptualized for science teaching as consisting of five components: a) orientations toward science teaching; b) knowledge and beliefs about science curriculum; c) knowledge and beliefs about students' understanding of specific science topics; d) knowledge and beliefs about assessment in science; and (e) knowledge and beliefs about instructional strategies for teaching science. First, PCK refers to teacher's knowledge of the goals and objectives for students in the subjects they are teaching. Second, in the knowledge and beliefs about science curriculum, PCK is knowledge of teachers about the vertical curriculum in their subjects, what students have learned in previous years, and what they are expected to learn in later years. It also refers to knowledge of the programs and materials that relevant to teaching a particular domain of science and specific topics within that domain. Third, in the category of knowledge of students' understanding of science, PCK refers to the teachers' knowledge and beliefs about prerequisite knowledge for learning specific scientific knowledge, their understanding of variations in students' approached to learning as they related to the development of knowledge within specific topic areas, and the knowledge of areas of student difficulty and each type of difficult. Fourth, in knowledge of assessment in science, based on Tamir (1988), PCK refers to the teachers' knowledge of the dimensions of science learning that are important to assess, knowledge of the methods by which that learning can be assessed, and the advantages and disadvantages associated with employing a particular assessment device or technique. Finally, in the component of knowledge of instructional strategies, PCK refers to knowledge of subject-specific strategies, and knowledge of topic-specific strategies. First subject-specific strategies are related to the orientations to teaching science component of PCK in that there are general approaches to science instruction that are consistent with the goals of particular orientation. Second, category knowledge of topic-specific strategies refers to teaches' knowledge of specific strategies related to representations and activities.

Morine-Dersheimer and Kent (1999) described categories contributing to PCK. These categories are specific content knowledge; specific curriculum knowledge; specific pedagogical knowledge; knowledge of specific learners and learning; and

specific knowledge of assessment procedures, evaluation of outcomes and educational ends, goals, purposes, and values.

According to Veal (2004), PCK is the knowledge base needed for teaching that includes subject matter knowledge, knowledge of students, knowledge of context, and pedagogical knowledge. These components are the ones that most researchers in science education have studied and concluded are necessary for a teacher to develop or have PCK.

All scholars agreed on Shulman's two key elements, that is, knowledge of representations of subject matter and understanding of specific learning difficulties and student conceptions. In addition, there appears to be agreement on the nature of PCK. First, as PCK refers to particular topics, it is to be discerned from knowledge of pedagogy, educational purposes, learner's characteristics, contents, curriculum, assessment, and the context. Second, because PCK concerns the teaching of particular topics, it differs from subject-matter knowledge.

### **3. Pedagogical Content Knowledge (PCK) in the Context of Science Educational Professional Development**

#### **3.1 PCK in the Context of Secondary Science Teachers**

In the context of science teachers professional development, Clermont *et al.* (1993), Hofstein *et al.* (2004), Jasti (2005), Lavonen (2004), van Driel *et al.* (1998), and Veal (2004) studied on both perspective and in-service science teachers' development of PCK.

Clermont *et al.* (1993) examined the influence of an intensive chemical demonstration workshop on fostering PCK growth among eight experienced science teachers as novice demonstrators. The two weeks summer workshop was designed around four training elements considered important to effective teacher in-serving:

theory, modeling, practice, and feedback. The workshop aims to increase both elementary and secondary science teachers' use of chemical demonstrations. The workshop had four major components: a) instruction on the purposes and characteristics of effective chemical demonstrations; b) demonstrations by workshop instructors to model appropriate techniques; c) demonstrations by participants with feedback by colleagues and workshop instructors; and d) demonstrations by participants to group of middle school students. The results found that the teachers increased number of chemical demonstrations and demonstration variations on each of the target chemical concepts that the teachers discussed after in-service workshop. In addition, the teachers increased awareness if the complexity of several chemical demonstrations, how these complexities could interfere with learning, and how simplified variations of the chemical demonstrations could promote science concept understanding. From this study, the researchers suggested that science teachers' PCK in chemistry can be enhanced through intensive, short-term in-service program.

A study of van Driel *et al.* (1998) focused on the development of PCK with respect to chemical equilibrium within the context of an in-service program. To achieve this purpose, they designed both; a) an experimental course on chemical equilibrium for students of upper-secondary education, and b) an in-service workshop for 12 chemistry teachers using the experimental course in their own classes. The first meeting focused on the PCK of chemical equilibrium participants held on entering the workshop. Therefore, participants performed and discussed chemical experiments and assignments from current chemistry textbooks. Moreover, they were asked to react to authentic student responses. In addition, the following two or three meetings coincided with the implementation of the experimental course. These meetings were used both to discuss recent practical experiences as well as to prepare participants for topics following shortly after the meeting, in the way described above. Final meeting was to reflect on experiences within the experimental course. In this meeting, teachers not only exchanged and discussed their personal experiences, but were also presented with specific results of research. This study revealed that the in-service science teachers had gained knowledge of specific types of students' reasoning and learning difficulties in the context of the introduction of chemical equilibrium during the

workshop sessions. In addition, some teachers reported to extend their repertoire of successful strategies and representations with respect to this topic.

Hofstein, Carmeli, and Shore (2004) described the development of an innovative model developed specifically for the professional development of high school chemistry coordinators in Israel. Long-term professional development of science teachers was designed so that the chemistry teachers who enrolled in the program were able to develop in three interrelated aspects: content knowledge; pedagogical content knowledge; and leadership ability. Twenty-one teachers from all over the country participated in a weekly, full day meeting. To develop content knowledge, this study used strategies of examining students' work and the partnership with scientists. During the program, the teachers were exposed to new research areas in chemistry by attending lectures and by visiting laboratories in which research in various areas of chemistry were conducted. To develop PCK, the teachers were also introduced to typical students' misconceptions that occurred in the chemistry matriculation examinations. They were asked to discuss and analyze in groups the reasons for and the sources of these misconceptions, based on the literature that was provided, and to suggest pedagogical remedies to overcome them. In the program, the participants were taught different instructional techniques through cooperative learning techniques, inquiry learning in the classroom and in the laboratory, simulations, field trips to research laboratories and various chemical industries, critical reading of scientific articles, questioning techniques, and students' mini-projects. The results revealed that the teachers' concerns were focused on their needs of particular classrooms and on their role as school chemistry coordinators. PCK appeared to be the predominant factor shaping these perceptions. In addition, they could adopt and frequently use a broad repertoire of new teaching strategies in their classrooms. This study suggested that the teachers have to improve their content knowledge, as well as their pedagogical content knowledge and their leadership skills.

One and a half year of in-service training program was conducted by Lavonen, (2004) to promote and enhance both physics teachers' subject knowledge and PCK. The project was designed to change teachers' classroom practice, especially

the role of laboratory experiments in physics education. Training was based on distance education through an e-mail list, and study group during lectures, exercises, and seminars about the role of experiments. To enhance PCK, the teachers are engaged in lecture to additional seminars. The study groups wrote study reports, seminars with questions and comments, in advance of each lecture. In the results, they believed that experiments helped their students enhance concepts of physics, motivated learning, allowed hands-on activities, learned nature of science, had science skills, and increased procedural understanding. In particular, they used the experiments consciously to help students constructing the meanings of new concepts, as well as to help them learning experiments' planning. Through e-mail list, teachers were aware of the role of experiments in learning concepts. It also indicated that the teachers were interested in how and what type of experiment best helped students in the physics classroom to learn or create meanings for concepts. To develop PCK, teachers should practice in real classroom setting, get recommendation, and reflect existing classroom situations.

The work of Jasti (2005) aimed at promoting and gaining an understanding of the development of beginning science teachers' content knowledge, curriculum knowledge, and pedagogical content knowledge. Five experienced science teachers (chemistry and physics), who were enrolled in a teacher's training program, participated in a models and modeling course, and conducted a research project in their classes. In the first phase, the teachers were provided a written questionnaire and followed by an interview. They were asked about good characterization of models and modeling. In the second phase, teachers took meeting over a period of 6 weeks. They were involved in learning activities concerned with the main aspects of models and modeling: the nature and purposes of models in everyday life and in science; the use of different modes of representation; the production and use of two-dimensional, three-dimensional, and pseudo-three dimensional (computerized) teaching models in science teaching; the advantages and limitations of each type of teaching model; the use of analogies as teaching models in science teaching; the characteristics of the modeling process; and the use of modeling activities in science teaching. Next, the teachers chose one of the aspects and conducted research project in their own classes.

This study suggested, to contribute teachers' development of curriculum knowledge, CK and PCK, the new elements or approaches presented to teachers should be clearly justified in terms of their possible contributions to enhancing students' learning. Moreover, teachers should have opportunities to use their new knowledge in their classes, and to investigate whether and how such knowledge contributes to their students' learning. Furthermore, teachers should be provided with opportunities to analyze their new experiences and to reflect on their own development. Finally, in a teacher development, process, researchers should mediate the teachers' reflection processes at distinct points of time. This mediation should focus on providing teachers with both new elements and different perspectives to support a deeper analysis of their practice.

Veal (2004)'s goal of his study was to describe how the knowledge of teaching, specifically pedagogical content knowledge (PCK), interacts with prospective secondary chemistry teachers' beliefs. The case study followed two pre-service chemistry teachers through their methods course, practicum experience, and student teaching internship. Pedagogical content knowledge vignettes, following a microgenetic model, and other data sources were used to monitor participants' conceptual change over time. Structured and semistructured interviews (initial, during, and exit), field notes (during methods class and field experiences), and reflective journal were collected. Participants were also asked to share and discuss classroom projects and assignments. The results revealed that participants had well-intentioned beliefs about teaching and chemistry. The beliefs about content were not changed whereas those for teaching did change. In addition, the prospective teachers' beliefs influenced how they constructed their views of the chemistry content knowledge found in the vignettes, how they instructed using representations (e.g. language use and real-world examples), how they integrated their knowledge of students (e.g. chemistry topics were abstract or non-visual), and how the context of teaching influenced their practice (e.g. discussions about a mole of substance and learning corollaries for covalent bonding).

### 3.2 PCK in the Context of Primary Science Teacher

The work of Smith and Neale (1989) was to develop the subject matter knowledge and beliefs of 10 primary science teachers in a four weeks summer program that focused upon conceptual change teaching in science. In the first week, teachers read and discussed research on children's misconceptions and teaching strategies. In addition, the teachers explored their own knowledge of light and shadows in activities aimed at revealing their misconceptions and facilitating their progress in understanding the content. For the second and the third weeks, teachers taught small groups of children in a morning. In afternoon, the teachers and their coaches met with researchers to discuss videotape of teaching in morning. Teachers were also explored new activities, discussed issues of children's understanding in lessons and constructed materials and activities for the next lessons. In the last week of teaching, teachers interviewed children again to assess their progress to assess their progress, and then met in teams to discuss activities and plan a two-week unit for their own classes. Data from interviews and videotapes of teaching showed that before the program, substantive and PCK about targeted science subject matter was limited. During the program, most teachers began to acquire targeted content knowledge and elements of a conceptual change orientation toward science teaching. The teachers learned the new contents as well as adequate content-specific instructional strategies. In addition, this study indicated that addressing both substantive and PCK, as well as beliefs about teaching has been need for teacher training program.

Geddis (1993) studied how the concept of PCK can play a critical role in clarifying the need for beginning pre-service science teachers to transform physics knowledge into forms that are accessible to children. To assist the teachers transform content knowledge, the researcher began to introduce the alternative children's conceptions and misconceptions. Then he posed multiple-choice questions, open-ended questions related to the concepts of electrical current, students' difficulties and how to teach. The teachers also had opportunities to discuss on them. The results revealed that a large number of teachers chose incorrect answers. Even though a number of science teachers knew correct answers, they displayed considerable

confusion as why it was happened. This study suggested that acquisition of PCK would appear to be central task in learning how to teach. The task should provide teachers with inquiry into their own content, their students' prior conceptions, and plausible reasons for students holding these conceptions. In addition, the teachers should be engaged in reflection on how this knowledge about children's ideas guides the transformation of subject matter content in the planning of instruction.

### **Summary**

PCK was first defined by Shulman (1986, 1987). He represented PCK as teachers' knowledge of strategies and representations for teaching particular topics and knowledge of students' learning difficulties and preconceptions. Many scholars (Carter, 1990; Grossman, 1990; Tamir, 1988; van Driel *et al.*, 1998) agreed with his ideas. However, PCK consisted of various components. Grossman (1990) added that PCK is composed of knowledge and beliefs about the purposes for teaching particular topics and knowledge of curriculum materials available for teaching while knowledge of context, students, subject matter content are additional knowledge by Cochran *et al.* (1993). Magnusson *et al.* (1999) also emphasize knowledge of assessment additional such components of PCK.

In addition, much research on science teachers' PCK has focused on the nature and the development of PCK, rather than investigating science teachers' PCK with respect to specific topics (Clermont *et al.*, 1993; Holstein *et al.*, 2004; Justi, 2005; Lavonen, 2004; van Driel *et al.*, 1998). These researchers emphasized providing in-service science teachers with opportunities to enhance the development of their knowledge, especially pedagogical content knowledge through professional development experiences. Most studies revealed that the professional development experiences influenced on development their knowledge of PCK.

## **Knowledge of Genetics**

### **1. Knowledge of Genetics Based on Standards**

Genetics is addressed in numerous science content standard documents (National Science Curriculum Standards (IPST, 2003), National Science Education Standards (NSES) (NRC, 1996), and is views as an important element of basic biological knowledge. All secondary students should develop a level of understanding that will allow them explain genetics phenomena that affect their daily lives (IPST, 2003; NRC, 1996).

The Thai National Science Curriculum Standard mentions that students should be able to understand the process of reproduction and inheritance that impact humans and the environment (IPST, 2003).

...At the end of the grade 7-grade 9the students should be able to search for information and discuss the genetic material in the nucleus, which controls characteristics and processes in the cell, the inheritability of genetic material and know the positive applications of genetic knowledge (IPST, 2003: 10).

The National Science Education Standards have aligned reproduction and heredity as an important content of life science standards on which middle school science teachers and students should understand for teaching and learning in educational reform (NRC, 1996). Especially concerning human heredity, the teachers and students have to understand that an egg and sperm begin the development of a new individual who receives genetic information from its mother (egg) and father (sperm). In addition, teachers and their students should understand heredity as the passage of set of instructions for specifying organism's traits from one generation to another. Furthermore, they understand structures, functions and relationship between genes, chromosomes, and genetic information. Finally, they should explain characteristics of organisms in terms of a combination of traits and describe interactions between traits and the environment.

## 2. Teacher's Knowledge of Genetics

There is little research on secondary science teachers' knowledge of genetic concepts. However, Stewart (1982), Oztap, Ozay and Oztap (2003) revealed their studies on teachers' perceptions in genetics.

Finley, Stewart, and Yarroch (1982) asked biology teacher to determine what content in biology was difficult and important for students to learn by a questionnaire. The results revealed that concepts of protein synthesis, cell divisions, multiple alleles, chromosome theory of heredity, probability, Mendelian genetics, dihybrid crosses, and population genetics are the most difficult concepts. Cell divisions, Mendelian genetics, chromosomes, and genes concepts were any the most important concepts for students' learning. In addition, cell divisions, Mendelian genetics, and chromosomes concepts were both important and difficult for students' learning.

Oztap *et al.* (2003) examined biology teachers' difficulties when teaching cell divisions by a questionnaire, multiple choice items, and written tests with open-ended questions. Teachers taught lessons for grasping students' understanding of the following: mitosis and meiosis phases, importance of meiosis, importance of crossing-over, DNA replication, homologous chromosomes and separation, relationships within DNA, and chromatids. The teachers perceived that cell division, especially meiosis, was the hardest part to teach at the secondary school levels. Some teachers also mentioned difficulties in teaching the relationship between DNA and chromosome. In addition, some teachers believed that students had confusion about the cell division terminology, meaning, and division processes.

Haddow (1982) attempted to assist secondary science teachers' understanding of human genetic through training by various experts. The teachers learned genetics through lecturing, demonstrations, and asking some questions about modes of inheritance, cytogenetics, screening for genetic disorders, treatment and prevention of genetic disorders in a two days workshop. In addition, they were given packets of material for using in their classrooms. The teachers were asked to respond to a

questionnaire after the workshop to evaluate the impact of workshop on their students. The teachers reported that after the workshop, they felt much more comfortable with and better informed about human genetic. They increase the amount of human genetics knowledge being taught and development of resources and materials presented in the workshops. They were able to address their teaching about relationships between human genetics concepts and everyday life.

### **3. Student's Knowledge of Genetics**

In Thai context, there are few studies about secondary students' conception in genetic. The findings reported that students had some difficulties in learning the concepts of heredity, multiple alleles, polygene, incomplete dominant gene, and chromosome (Ratanaroutai, 2006; Settapukdee, 2004; Sukpimontree, 1988).

Similarly, in studies outside of Thailand, genetics is considered its' difficulties by students. Wood-Robinson, Lewis, and Leach (2000) reported that secondary students' understanding on cellular genetics. Asked by discussion tasks, the students were probed about their understandings of chromosomes in different cells in human body and genes and genetic information. The results revealed that the most groups of students had some understanding of the role of chromosomes, genes, and DNA for determining the characteristics of an organism. However, there was considerable confusion over the relationship between them and their respective roles. One group referred that chromosomes carry genes that defines what people look like while another group described chromosomes as deciding what texture your skin is and what color your eyes are going to be. Most groups commented that chromosomes make DNA or are in the DNA or are in gene. In sum, the group of students was confused about the nature of genetic information in cells, and the mechanism by which genetic information was transferred from one cell to another and between generations.

Lewis, Leach and Wood-Robinson (2000a) studied secondary science students' understanding of genetics and between genes and genetics information. Asking by a series of written questions, students were examined their awareness of

genetic information between cells with one individual. The majority of students hold misconception that cells of different types (check cells, nerve cells, sperm cells) contained different genetic information because they had different functions and therefore required different information. Forty one percent of students responded “don’t know” and showed no reason or no clear idea of nature of genetic information within different cells in an individual. While, regardless of function, only 4 percent of the total student samples correctly recognized that all somatic cell carry the same genetic information; that sperm cells do not carry the same genetic information as somatic cells. Students understood that each sperm cell carries a different combination of genetic information.

Lewis, Leach and Wood-Robinson (2000b) also studied secondary students’ understandings of the nature of genes from written responses and interviews. The questions consist of three sets: size sequence; living things; and biological terms. The set of questions was designed to probe students’ understanding of the relationship between structures (cell, chromosome, gene, DNA, organism and nucleus), relationships among living things, chromosomes, and genetics, and terms of gene, DNA, nucleus, chromosomes, alleles, and genetic information (locations and functions). The data from coding schemes showed limited students’ understanding of the most basic ideas relating to function, structure, and location of genes. In a set question of size sequence, majority of students revealed an extensive lack of understanding of the relationship cell, chromosome, gene, DNA, organism and nucleus. For example, they showed that genes are bigger than chromosomes. Responses to the living things, many students were aware that genetic information is found in all living things. In addition, some students believed that some organisms contain chromosomes without containing genetic information. Finally, when students were asked directly about genes, 80 percent students responded that gene determines characteristics in organisms and 14 percent indicated that a gene transfers genetic information. No one referred directly to gene products. In addition, many students indicated that genes are found in all cells, while some students thought that genes are only found in specific organs or tissues, for example, the reproductive system. Furthermore, majority of students indicated that chromosomes are found in cell, while

few students explicitly indicated that chromosome locates in genes or in DNA or DNA locates in chromosomes or genes.

Lewis (2004) studied secondary students' understandings of the processes and mechanisms of inheritance. Three different techniques were used to probe students' understanding: written question, audio-taped small discussion tasks, and interview. Written questions were used to probe students' understanding in five parts: (a) understanding of relationship between living things and genetic information and between chromosomes and genetic information; (b) understanding of the terms gene, DNA, nucleus, chromosome, allele and genetic information related to location and function; (c) understanding of the transfer of genetic information within an individual; (e) understanding of the processes and purposes of cell division, and (f) understanding of the processes by which genetic information is transferred to a new individual. Small group discussion was used to validate findings from the written question. The interviews were used to probe students' understanding of the following concepts: heredity; gene; characteristics; inherited disease; genetic load; and eugenics. The findings revealed that students understood that genes are treated as small particles containing a trait or characteristic in miniature. However, students made no clear distinction between the genotype and phenotype. In addition, most of them stated that genes are important for the determining of characteristics, but they didn't understand its mechanisms. Furthermore, they had no clear understandings of the relationship among genes, chromosomes, DNA, and genetic information. Moreover, they showed strong belief that the genetic information in a cell can be deduced from the phenotype of the cell. The majority of students believed that all cells of the same type would contain the same genetic information and that cell of different types would contain different genetic information.

Lewis, Leach and Wood-Robinson (2000c) studied secondary students' understanding of the processes, purposes, and products of cell division and of the process and purpose of fertilization through written questions. The students were asked to compare chromosome number and genetic information in the original, the new cell, the egg, the sperm, and the fertilized egg and identify where, in the body,

this type of cell division takes place. A half of students recognized that chromosome number and genetic information would remain the same in mitosis division because the cells were of the same type. Majority gave correct responses that the genetic information in different type cells always are the same. Among those who said that the chromosome number would double. A number of other responses were ambiguous. They were able to distinguish between cell and chromosome. In set of question related to meiosis, some students recognized that chromosomes would have halve and genetics information would be different. In addition, 45 percent of students were able to give correctly chromosome number in the egg cell, but not always correct reason. Many students confused distinction between mitosis and meiosis. Students had no understanding of the role of sex chromosome in meiosis process. Furthermore, the most common view was that meiosis occurs in both types of tissue, somatic, and gonads, but almost one quarter of students recognized that meiosis only takes place in the gonads.

Brown (1990) examined college students' understanding about meiosis and relationships to Mendelian genetics through the students' notes. The students did not understand the processes of meiosis and its' relationship to Mendelian genetics. For example, some students said that each chromosome had not duplicate chromatids in meiosis process. In addition, in a task using pipe cleaners to represent duplication, students revealed misunderstanding about homologous pairs. They didn't understand that sister chromatids carry the same alleles. Furthermore, they showed misconception of heterozygote. They used one letter to label one or more chromatids. Finally they showed misconception of the locus that alleles were labeled at different positions on homologous chromosomes.

Stewart (1990) examined mental models of meiosis, chromosomes and genes. The students received approximately one month of instruction in meiosis, basic transmission genetics (simple dominance and co-dominance), advanced transmission genetics (multiple alleles and linkage) and molecular genetics. After completing the instruction, each of students took part in a 50 minute problem solving interview session. In the dihybrid problem, students used both correct and erroneous models of

chromosome/ gene behavior during meiosis to explain solutions to the problem. They realized that genes and chromosomes are related. In addition, most students indicated that genes are on chromosomes although some indicated chromosomes are on genes or traits are on chromosomes. Furthermore, many students had incidental knowledge about chromosome doubling, spitting and crossing over that used to get from the initial chromosome state to the chromosome state in the gametes.

Kindfield (1991) studied biology undergraduates' understandings of chromosome number and structure. Students were interviewed while they worked on a non-traditional genetics problem. The students showed the misconceptions about ploidy/structure. They said that two DNA molecule chromosomes are not formed by the process of replication, but rather formed by two single DNA molecule chromosomes, one from each parent. Each DNA molecule chromosome joins together at the centromeres region when two haploid gametes fuse to produce a diploid zygote. In addition, students held that if a chromosome contains a gene for which its resident cell/organism is heterozygous, each arm of the chromosome will contain a different allele for that gene.

Other studies explored secondary school and college student's knowledge of problem solving related to the concepts of monohybrid cross, dihybrid cross, co-dominance problem, and sex-linked inheritance (Moll, 1987; Stewart, 1982; Tolman, 1982). Stewart (1982) examined the knowledge and problem solving strategies used by 14 ninth grade biology students to solve three types of basic genetics problems. They were presented with nearly 100 problems. The problems were divided into three types: monohybrid-genotype presented; monohybrid-genotype embedded within a phenotype description; and dihybrid. All students used a Punnett square method when solving monohybrid cross and were asked, for example, why they placed one symbol for an allele over, or adjacent to, each internal square. The students had weak understanding of the relationships of meiosis division to monohybrid and dihybrid cross problems. They were not cognizant of chromosomal segregation during meiosis. They could offer an acceptable definition of segregation and independent assortment, but they cannot link to particular concept labels even though all evidence points to

understandings of the concepts. When students shifted from a Punnett square method to an algebraic method, many students could not identify gamete genotypes. In addition, misconceptions were employed by students when solving dihybrid cross problems. Students knew that each offspring must contain four symbols, but they didn't explain this process. They lacked knowledge that related the random segregation of chromosomes (or alleles) to dihybrid cross. Finally, when students were asked to describe how pair of concepts (e.g. gene to allele, allele to chromosome) is related; they had difficulty to explain them.

Tolman (1982) studied secondary students' understandings of genetic problems involving a monohybrid cross, a co-dominance problem, and a problem with sex-linked inheritance. Their understandings appeared on the transcripts and the worksheets. The major students understood difficultly on the concept that the pairs of alleles in an offspring are the result of transmission of one allele from each of the parents of the offspring. In addition, they understood hardly in associating the alleles with chromosomes and chromosome behavior and the segregation and random assortment during the first division of meiosis. While constructing Punnett squares, students manifested their error from assigning two alleles to each parent for an  $F_1$  trait. This resulted in offspring with four alleles for each trait. In the co-dominance problem (A, B, and O blood groups in human), the students did not realize the need for reduction division and the need for only one allele from each parent. For the sex linked problem (color-blindness), most students correctly identified the individual parents as probable sources of single alleles for the trait. All students used the symbol X for the X chromosome in which the alleles for normal and color-blind version are carried.

Moll (1987) investigated college biology students' knowledge of Mendelian, cellular and molecular genetics after course instruction. Students were shown videotape animations representing chromosome movements in meiosis, gamete formation, and recombination of chromosomes at fertilization. Instructors solved genetic problems in class by diagramming the pre-meiotic cells containing the duplicated chromosomes. Students were required to submit weekly homework

exercises, which they solved genetic problems using such approach. They were investigated their knowledge by testing and interview. Approximately equal numbers of students were able to solve two problems (monohybrid and dihybrid cross) correctly through meiotic or algorithmic approach. However, some students showed unsuccessful attempts to employ meiotic approach. For example, one student could not correctly combine gametes and the other indicated only one homologue in monohybrid cross problem. In problem of dihybrid cross, three students placed two different alleles on one homologue, two indicated only one homologue of each pair, two could not indicate correct genetic composition of gametes, and one could not correctly combine gametes. That is student had incorrectly placement of alleles on a chromosome.

As a result, the literature showed similarities among students' understandings of genetics concepts in Thai and international. Genetics is viewed as the most difficult topic by teachers (Barrass, 1984; Finley *et al.*, 1982). There is no research that explains teachers' understandings of genetic concepts, but two researches (Finley *et al.*, 1982; Oztap *et al.*, 2003) showed biology teachers' perception that protein synthesis, cell divisions, multiple alleles, genes, chromosomes, Mendelian genetic, dihybrid crosses, population genetics as the most difficult concepts as one of the most difficult concepts. However, many researchers reported that poor understanding of genetics was presented at all ages and levels of learners (Brown, 1990; Kindfield, 1991; Lewis, 2004; Lewis *et al.*, 2000a, 2000b, 2000c; Moll, 1987; Ratanaroutai, 2006; Settapukdee, 2004; Stewart, 1990, 1982; Sukpimontree, 1988; Tolman, 1982; Venville *et al.*, 2005; Wood-Robinson *et al.*, 2000). These researchers found that meiosis, gametes, alleles, genes, chromosomes, phenotype and genotype, molecular genetic and genetic information and their relationships were concepts that students had difficulty learning.

## **Summary**

Teacher knowledge consists of a variety of knowledge types such as content knowledge, pedagogical knowledge, curriculum knowledge, knowledge of learners,

PCK, practical knowledge or craft knowledge. Based on the literature, researchers consider PCK as an important knowledge of teachers' teaching in effective ways (Cochran *et al.*, 1993; Geddis, 1993; Grossman, 1990; Magusson, *et al.*, 1999; Morine-Dersheimer and Kent, 1999; Shulman, 1986, 1987; Smith and Neal, 1989; Tamir, 1988; van Driel *et al.*, 1998; Veal 2004). PCK supports development science teachers' theoretical and practical knowledge and assists their teaching and learning in comprehend ways (NRC, 1996, ONEC, 1999). Teachers' PCK helps them to make decisions about content and activities, interact with students, and select assessments for understanding students' abilities and attitudes (Geddis, 1993; Park, 2005; Halim and Meerah, 2002; van Driel *et al.*, 1998). In addition, knowledge of genetics is important and difficult for teachers and students (Barrass, 1984; Brown, 1990; Finley, Stewart, 1982; Kindfield, 1991; Lewis, 2004; Lewis *et al.*, 2000a, 2000b, 2000c; Moll, 1987; Ratanaroutai, 2006; Settapukdee, 2004; Stewart, 1990, 1982; Sukpimontree, 1988; Tolman, 1982; Venville *et al.*, 2005; Wood-Robinson *et al.*, 2000).

To development Thai lower secondary teachers' content knowledge and pedagogical content knowledge in genetics, this study focused on developing teachers' knowledge of topic-specific representations and activities in concepts of genetics based on notions of Shulman (1986); Grossman (1990); Tamir (1988), Magnusson *et al.* (1999). PCK is the teachers' knowledge of ways to represent genetics in order to facilitate student learning. It is the teachers' knowledge of strengths and weakness of representing particular genetic concepts. In addition it includes the teachers' ability to invent representations to aid their students developing understanding of genetic concepts. Finally, PCK is teachers' knowledge of what activities can be used to help their students understand particular genetic concepts.

## **Reflective Practices**

Reflection can be a beneficial process in teacher professional development (Ferraro, 2000). Osborne (1998) argued that the teacher becomes a learner through the act of teaching and reflection on teaching. When stimulated by problematic events, the teacher is able to encounter and criticize the understandings developed around the experiences of practices by a process of reflection (Schon, 1983, 1987). In addition, reflection is a vehicle for developing a critical consciousness of personal beliefs and values, and in defining teachers' knowledge and recognizing what they do and do not know (Osborne, 1998). Furthermore, reflection is the process of learning or arriving at new understandings from experience (Zemal-Saul, Blumenfeld and Krajcik, 2000). This section reviews different definitions of reflection in education, research on the role of reflective practices, and reflective tools in the context of professional development of science teachers.

### **1. Defining of Reflection**

The notion of reflection is one of the most pervasive concepts to influence science teacher education this past decade (Nichols, Tippins and Wieseman, 1997). Reflection is has many different meanings in education.

Historically, Dewey (1933) is acknowledged as a key originator of the concept of reflection. He considered it to be a special form of problem solving, thinking to resolve an issue which involved active chaining, and a careful ordering of ideas linking each with its predecessors. He referred to reflective thought as:

...Active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends...it includes a conscious and voluntary effort to establish belief upon a firm basis of evidence and rationality. (Dewey, 1933: 9)

That is, he indicated that reflection may be seen as an active and deliberative cognitive process, involving sequences of interconnected ideas which take account of underlying beliefs and knowledge. Reflective thinking generally addressed practical problems, allowing for doubt and perplexity before possible solutions are reached. Base on Dewey's idea, Edy, Herrell, and Hicks (2002) explained that the teachers who were engaged with reflective thinking voluntarily and willingly took their responsibilities for considering personal actions. The teachers were committed to reflect their thinking through difficult issues in depth, continued to consider matters even though it may be uncomfortable or tiring to do. Within reflective practices, the teachers wanted to improve their classroom performance and brought the greatest benefit to the lives of their students. The teachers recognized the value of informed practice, but maintained a healthy skepticism about various educational procedures and theories. Finally, the reflective thinkers were practiced by using evidences and criteria in making judgments.

A contemporary the work of Schon (1983, 1987), the notion of reflection is intimately bound up with action. Initially, Schon (1983: 54) argued "...knowing-in-action as the tacit knowing that we can execute smooth sequences of activity, recognition, decision, and adjustment without having, as we say, to think about it. Thus, Schon (1983) brought reflection into the centre of an understanding of what professionals did. He held that professionals should learn to frame and reframe the often complex and ambiguous problems they were facing, test out various interpretations, then modify their actions as a result. How one sees and listens to practice are what Schon (1987) referred to as frames. In his work on the nature and growth of professional knowledge, Schon emphasized the significance of frames in interpreting practice and underscored the importance of developing new frames (reframing) in learning from experience (Bryan and Abell, 1999).

Schon (1983, 1987) conceptualized notions of frame and reframe on professional practice in terms of two important notions: reflection-in-action and reflection-on-action. Reflection-in-action is a process of framing and reframing problematic contexts to reveal acting. It provides a compelling conceptualization of

the spontaneous intuitive performance of the skilled practitioner; it does not, however, provide a clear articulation of how that performance might be modified to meet new concerns and expectations.

Schon (1983: 54) described notions of reflection-in-action as "...thinking on our feet", "keeping your wits about you," and "learning by doing" suggest not only that we can think about doing but that we can think about doing something while doing it".

Reflection-in-action involves looking to our experiences, connecting with our feelings, and attending to our theories in use (Schon, 1983). It implies that the professional has reached a stage of competence where she or he is able to think consciously about what is taking place and modify actions virtually instantaneously (Hatton and Smith, 1995).

In addition, following Schon's notion of reflective-in-action, reflective practices involves reframing, hearing differently or seeing differently or seeing data in new ways. It also involves on-the-spot surfacing, critiquing, re-structuring, and testing or intuitive understandings of experienced phenomena; often, it takes the form of a reflective conversation with the situation (Sergiovanni, 1985).

In addition, Schon's notion of reflection-on-action means that "...reflect on action, thinking back on what we have done in order to discover how our knowing-in-action may have contributed to an unexpected outcome" ( 1983: 26).

According to Schon (1983, 1987), the act of reflecting-on-action enables exploring why teachers acted as they did, what was happening in a group and so on. In so doing teachers develop sets of questions and ideas about their activities and practice. In addition, reflecting-on-action involves careful consideration of familiar data while reflection-in-action presents the data quite differently.

According to Geddis (1996), while reflection-in-action and reflection-on-action are similar in form, both involve framing and reframing, that they occur over very different time frames. Reflection-in-action occurs in real time. The teacher's responses need to be virtually instantaneous. Reflection-on-action is subject to no such temporal imperative. Reflection-in-action relies on classroom frames that have become such an integral part of a teacher's performance that there is little awareness of either the frames employed or the process, such as both the frames employed and the process involved are tacit. In contrast, reflection-on-action involves a very deliberate choice and the use of a variety of frames.

Teacher educators have used the term "critical reflection" to emphasize the importance of revealing ideological aspects of teacher thinking and action (Nichols, Tippins, and Wieseman, 1997). According to Sweeney, Bula and Cornett, (2001), critical reflection is the connection between social research and social action. Critical reflection should take into account the notion that educational researchers can take concrete and explicit steps toward changing the theory, policy, and practical of educational research, as well as participating in the work of changing educational theory, educational policy, and educational practice.

Other notions of reflection are involved the action. Sergiovanni's (1985, 1986) notion of reflective practice rely heavily on informed intuition. He talked that informed intuition is informed by theoretical knowledge on one hand, and by interacting with the context of practice on the other. While Louden (1991) referred to reflection as a mental process which takes place out of the stream of action, looking forward or usually back to actions that have taken place. It becomes mirror to allow us understand ourselves or our circumstances in new ways. In addition, Louden (1991) developed two dimensions of reflection; interests and forms based on the work of Shchon (1983, 1987) and Sergiovanni (1985, 1986). Interests refer to the goal of end in view of an act of and cleaver personal understanding; or professional problem-solving; or critique of the conditions of professional action. Furthermore, Edy, Herrell, and Hicks (2002) mainly focus on withitness, an essential foundation for becoming a reflective teacher. Perceptive teachers constantly observe conditions and

gather information to make good judgments about what is happening in a classroom and what can or should be done to address it. Withitness continually raises the quality and level of reflective thinking because it helps the teacher observe more accurately and collect more complete information about classroom conditions.

In addition, reflection is viewed as reflective learning (Boyd and Fales, 1983; Grimmett, 1989). Boyd, and Faled (1983: 101) defined reflective learning as "...the process of creating and clarifying the meaning of experiences (present to past) in terms of self (self in relation to self in relation to the word)...the outcome of the process is changes conceptual perspective". They also described reflection as composed of six stages: 1) sense of inner discomfort; 2) identification or clarification of the concern; 3) openness to new information from internal and external sources, with the ability to observe and take in a variety or perspectives; 4) resolution, expressed as integration, coming together, acceptance of self reality, and creative synthesis; 5) establishing continuity of self with past, present and future; and 6) deciding whether to act on the outcome of the reflective process. Similarly, Grimmett (1989) defined reflection as an approach that leads to new understanding of: (i) action situations; (ii) self as teacher in terms of the cultural milieu of teaching; and (iii) taken-for-granted assumptions about teaching (derived from a critical-theoretical stance).

In this study, reflective-on-action, based on Schon (1983, 1987), is the important process for developing lower secondary science teachers' science content knowledge and pedagogical content knowledge. Reflection-on-action engages the teachers looking back at what knowledge they possess, why they acted as they did, and what happened in their classroom, and how to solve classroom problems of themselves and student learning. This process fostered teachers' developing understanding about themselves and the science teaching practice.

## **2. Researches on the Role of Reflective Practices in the Context of Professional Development of Science Teachers**

To develop science teachers' professional growth, this section concludes roles of reflective practices in context of professional development. Professional development programs encourage participants to reflect on their knowledge in science teaching (Eick and Dias, 2005; Geddis, 1996; Osborne, 1998; Zembal-Saul, Blumenfeld, and Krajcik, 2000), reflect interrelation about their knowledge and practices (Freese, 2006; Hatton and Smith, 1995; Luft, 2001; Sweeney, Bula, and Cornett, 2001; van Zee and Roberts, 2001; Wise, Spiegel, and Bruning, 1999) and reflect their belief about teaching and learning in science (Bryan and Abell, 1999).

### **2.1 In the Context of In-Service Science Teacher Professional Development**

In developing in-service elementary science teachers' knowledge and practice, Osborn (1998) stated that a teacher's practice reflects changing experiences, knowledge, values, and identities, and as such can be productively thought of as a site for learning as much as a site for expounding upon what is known. The teacher used reflection-in-action to reflect what she was teaching and how she was teaching. For example, she let her students tell stories from a series of dinosaur pictures individually. Then, students went into group to discuss stories about dinosaur. She reflected her teaching immediately from different ideas of students. She reshaped her teaching by illustrating a student's story. After that, her students asked questions that they want to answer. From such process of reflection, she was able to add new knowledge in line with students' prior knowledge and interests. She also had a chance to reflect her content knowledge, pedagogy knowledge, knowledge of students, and pedagogical content knowledge through reflection-in-action.

Geddis (1996) described a seminar based on Schon's ideas about reflection-in-action. The in-service elementary science teachers enrolled in this seminar improved their own classroom instruction by the process of reflection-in-

action. Geddis' work emphasizes the process of framing and reframing in action and addressing the teachers' use reflection-on-action. In the seminar, study of three case teachers explored the nature of science and both constructivist views of learning and perspectives on what it means to teach. The teachers were engaged in reflective critiques of their views of the nature of science, and science teaching, and learning. Data of each critique consists of a transcription of one teaching episodes extracted from an audiotape recording of a complete science lesson. The study's findings revealed teachers' reflection-in- action that the two teachers experienced difficulties in modifying both conceptual and action components of their classroom frames. However, one teacher attempted to developed new ways of seeing her classroom teaching. For example, Ms Vinaldi has not yet developed the scripts necessary for the enactment of her modified conceptions of science and teaching. In contrast, Mr Albani exhibited classroom moves that appeared to incorporate the seminar's perspectives on science and teaching.

According to Wise, Spiegel, and Bruning (1999), reflective practice has been as a process evaluating effectiveness of in-service science professional development. Their Promoting Educational Excellence Regionally and Statewide (PEERS) project engaged the K-12 in-service science teachers in reflecting on their implementation of knowledge from workshop belonged. The teachers reflected on how their strategies or lessons fit with the Science and Mathematics standards, how well the strategies or lessons worked for the students, and how they assessed their student understanding of the concepts presented. At the conclusion of the program, the teachers acknowledged that they had learned how to apply the mathematics and science standards and create learning environments.

## **2.2 In the Context of Pre-service Science Teacher Professional Development**

Freese (2006) studied complexities of pre-service teachers' learning how to teach, as well as the complexities of assisting pre-service teachers on their journey to becoming teachers through 2 years in the Master of Education in Teaching (MET)

program. The student teachers were engaged to reflect their knowledge and action during university-based professional studies, seminars, field experiences, and site-based seminars. The program emphasized inquiry, reflection, and collaboration, and involves extensive field experiences in the context of a professional development school setting. They used observation notes, journal reflections, dialogue journals, and the student's action research/self-study paper. The results from reflective practices provide insight into how pre-service teachers think, the conflicts they experience, the fears they encounter, and the benefits they derive from systematically examining their teaching and their students' learning.

Bryan and Abell (1999) focused on understanding of how one pre-service elementary teacher experienced within the context of reflective science teacher education influencing on their development of professional knowledge. Within reflection context during science method course and student teaching experience, the student teacher was investigated her beliefs about science teaching and learning. In addition, the reflective practices were engaged to identify the tensions with which she grappled in learning to teach elementary science, understand the frames from which she identified problems of practice, and discern how her experiences played a role in framing and reframing problems of practice. The student teacher was encouraged to reflect on their ideas about teaching and learning. In phase of science method courses, the student teachers reflected: (a) others' teaching via classroom episodes from video cases; (b) their own teaching in the field experiences at a local elementary school; (c) theories presented in current educational research; and (d) their own science learning. In one case study, the student reflected on such four aspects through responding freely to open-ended questions, written reflections, and audiotape and transcribed five large- and small-group discussions. In phase of teaching experiences, the student teachers reflected her own teaching by observer's field notes contained descriptions of the class environment, class activities, and her activities, as well as feelings and interpretations about observations. The teacher was able to acknowledge her tensions in thinking about science teaching and learning as a result of inconsistencies between her vision of science teaching and her practice. In addition, she thought again the connections between her classroom actions and students' learning and created new

perspectives for viewing her practice. Through reframing, she was able to consider and begin implementing alternative practices more resonant with her beliefs.

van Zee and Roberts (2001) studied some of the positive long-term effects of eliciting reflections about successful science learning experiences in developing expertise in teaching, researching, and mentoring across teaching method course. Within process of reflection, at the first day of class, the prospective elementary science teachers drew pictures of experiences in which they had enjoyed learning science and wrote captions describing their pictures. Through the semester, the instructors wrote journals describing science learning they observed and analyzed factors that fostered learning in those instances. The instructors used reflective practices to shape the way they teach. In addition, the instructors understood the student teachers' prior knowledge about science learning and teaching. They can enhance the student teachers' confidence and competence of the prospective teachers to enact as they enter the teaching.

Zemal-Saul, Blumenfeld, and Krajcik (2000) examined changing teachers' content knowledge, pedagogical content knowledge and understanding of learners through two prospective elementary teachers during teacher preparation program. The teacher preparation program designed to enhance the teaching of science at the elementary level. The student teachers in this study engaged in two complete cycles of instruction during their first year in the program. Cycles of instruction refer to planning, teaching, and reflection associated with teaching a series of three lessons around a narrow set of science concepts. These cycles prompted prospective teachers to address issues of representing content accurately and in a variety of ways, linking representations within and across lessons, assessing and being responsive to learners' prior knowledge, and engaging learners actively and conceptually with the content. Multiple forms of data that reflect such changes, including audiotape interviews, written documents, and videotaped teaching episodes were collected. As part of reflections, the prospective teachers were generally capable of using the considerations for content representation to identify the key strengths and weaknesses associated with their teaching experiences. They also learned more about

children's ideas and thinking from interactions with them and they addressed learner-related issues much more readily in their subsequent planning and reflections.

### **2.3 In the Context of Professional Development in Secondary Grades**

According to Hatton and Smith (1995), the Sydney program engaged their student as reflective teachers. Students are engaged in reading key articles from the literature on reflection, together with studies into its facilitation, clarifying concepts which arise, and applying them in class and pair exercises. They undertook mind mapping related to reflection, and be introduced to elements of a reflective writing genre. The groups also undertook more specific and regular reflection after this school-based activity, and also post-practicum, through group and written tasks based upon their attempts to teach, along with feedback provided by staff and peers. They were encouraged to using data gathered about co-operating teachers' approaches to aspects of classroom management, as well as drawing upon their own practicum experiences and relevant literature.

Luft (2001) explored how an inquiry-based demonstration classroom in-service program impacted the belief and practices of beginning and experienced secondary science teachers. In the professional development program, when teachers implemented their knowledge of inquiry instruction from workshop, pertaining to problem solving, developing a view of the student in the context of problem solving, redefined their understanding of problem solving, the teachers were encouraged to reflect their own teaching (reflection-on-action) through electronic discussion. They had opportunities to interact and observe one another, exploring and reframing their beliefs and practices of extended inquiry instruction with one another. Throughout discussion, participants modified their views about their role in the classroom and about inquiry instruction. Most of the teachers reframed their science teaching views toward a more personal orientation, while other teachers entailed their views of science teaching towards a more utilitarian perspective. In addition, the teachers gained ideas about different lesson plans and pragmatic issues related to the implementing inquiry cycle.

Sweeney, Bula, and Cornett (2001) used notion of critical reflection to examine the relationships between a beginning science teacher's articulated personal practice theories and his actions as demonstrated by his curriculum decisions and instructional practices. In professional development, science teacher opened their views to learn about new teaching/ learning/ assessment activities for classroom use. Then the teacher practiced and evaluated new teaching activities over a period of time. In addition, he worked with other science teachers to reconstruct what it means to be a teacher of science (social development). He had opportunity awareness and acceptance the ongoing need for professional growth by reflection (personal development). Teacher's journals were regarded as teacher's documentations of classroom life in which he record observations, analyze their experiences, and reflect on and interpret his practices over time of professional development. Essays by teacher were collected to reflect on his experiences to construct a reasoned argument or present a considered, rationalized perspective about some aspect of classroom life. From this study, reflective process associated with the analysis would be especially useful for secondary science teachers entering the teaching profession as a second career. The teacher was willing to engage on an analysis of their own classroom teaching be expected from curriculum.

Eick and Dias (2005) studied secondary science teachers' development of conscious elements of practical teacher knowledge supporting the use of structured inquiry on co-teaching professional model. Reflective practices was engaged the science teachers to understand change of their own thinking about practice over the time through authentic practice in this model and to develop their practical teacher knowledge of using structured inquiry. Practical knowledge is examined through ongoing reflective dialogue on practice posted to an electronic bulletin board is tool for understanding and developing their practical knowledge of inquiry. From reflection, the result revealed that during early co-teaching, participants develop knowledge of learning how to teach in this model. They attempted to apply their program course knowledge and experiences in solving their difficulties in practice. After they observed, practice following co-teacher and reflect teaching each week, they can create new instructions and have more confidence on their teaching.

In sum, many professional development programs used reflective practices as a vehicle for developing both in-service and pre-service science teachers' knowledge, for examples, content knowledge, pedagogical knowledge, PCK, and teachers' teaching for students' learning.

### **3. Reflective Tools**

Reflective tools are used to understand how teachers think and act within the context of their perceived experiences (Nichols, Tippins, and Wieseman, 1997). Variety of tools has been used to prompt reflection among science teachers.

Nichols, Tippins, and Wieseman (1997) described an array of tools such as portfolios, journals, classroom cases, learning maps, stories, metaphors, and proverbs for developing critically reflective teachers. In addition, Taggart and Wilson (1998) suggested that strategies used to promote reflective thinking included observational learning; reflective journal; practicum activities, such as reflective teaching and microteaching; mental model strategies, such as metaphors and repertory grids; narrative strategies, such as story, autobiographical sketches, and case study; and action research. Other researchers used a variety of reflective tools for developing their knowledge and practice of science teaching (Eick and Dias, 2005; Freese, 2006; Geddis, 1996; Hatton and Smith, 1995; Luft, 2001; Osborne, 1998; Sweeney, Bula, and Cornett, 2001; van Zee and Roberts, 2001; Zembal-Saul, Blumenfeld, and Krajcik, 2000) and for reflecting their beliefs about teaching and learning in science (Bryan and Abell, 1999). For example, writing journals, stories, audiotapes and videotapes of teaching episodes, reflective electronic and essays are reflective tools encouraging science teachers' development their knowledge, practices, and beliefs. Among these reflective tools, most effective and functional with practitioners are portfolio, observational learning, journals, narrative reflection (and cases) and metaphors (Taggart and Wilson, 1998).

Portfolios are used by science teachers and science educators in a variety of ways which allow for re-presentation of individual learning (Tippins, Duna and

Kemen, 1994). According to Nichols, Tippins, and Wieseman (1997), primarily, their potential has been explored in three aspects of science education: (a) student assessment; (b) university science teacher preparation programs; and (c) practicing teacher of science assessment. Portfolios are an example of performance-based assessment that is evaluation of knowledge based on personal learning experiences. They are especially good at capturing content, change, and personal style. Essentially, portfolios are tools which enable learners to show how and what they have experienced as a context for critical reflection (Tobin, Tippins, and Gallard, 1994).

Journals are record of teacher's experiences within and outside the classroom that bear directly on classroom life. According to Nichols, Tippins, and Wieseman (1997), journals are dynamic text recordings of the evolution of how science teachers are seeing themselves in their own practices. From study of Nichols, Tippins, and Wieseman (1997), journals are to provide prospective teacher's opportunity to critique, for example, events experienced issues of empowerment, change processes, or perhaps negotiate alternative views of science teaching and learning. In addition, based on Boreen, Johnson, Niday and Potts (2000), journals may be used to capture and then critique what is working well and what is working poorly. It is also one way to develop teacher knowledge and skills and reflect on classroom occurrences, events, conflicts, successes, and disappointments. Based on Francis (1995), journal writing is involved into four clear sections: (i) teaching plans; (ii) reflective writing about workshop content, strategies, and issues; (iii) a professional diary documenting events which make an impact on personal view of teaching; and (iv) a critical summary of professional reading. The journal allows pre-service teachers to determine their own focus and what they want to understand. In addition, outcome from journals inform teachers' thinking about difficulty of teaching and what they learn from their professional program (Freese, 2006). Furthermore, journals are used by instructors for describing their learning as they observed and analyzed factors that fostered learning of students' teachers (van Zee and Roberts, 2001).

Nichole *et al.* (1997) explained various journal forms including: (a) personal; (b) dialogue; and (c) roving journal. While program of 4-year secondary bachelor of

education degree at the University of Sydney identify three types of writing: descriptive reflection, dialogic reflection and critical reflection (Hatton and Smith, 1995). A personal journal is used to record an individual's in-class and out of the class science learning experience (Nichole *et al.*, 1997). Dialogue journal used to enhance reflective thinking record events and personal vignettes and may describe the episode, analyze cause and effect, and attempt to determine roles and beliefs stemming from the events (Taggart and Wilson, 1998). In addition, dialogic reflection is a form of weighing competing claims and viewpoints, and then exploring alternative ways to solve problems in a professional situation (Hatton and Smith, 1995). Dialogue and roving journals involve the exchange of journals between two or more persons. Whereas the dialogue journal is maintained among two or three writers engaged in conversation of writing entities over time, a roving journal is randomly exchanged to capture the reflections of a larger group of learners (Nichole *et al.*, 1997). According to Hatton and Smith (1995), descriptive reflection is to seeking what is seen as possible best practice. It is used to analysis one's performance in professional role, giving reasons for action taken. The last form, critical reflection, involves reason giving for decisions or events which takes account of the broader historical, social, and/or political contexts (Hatton and Smith, 1995).

Case-based pedagogy is a reflective tool for helping prospective teachers' construction of teaching knowledge (Dana and Dana, 1995). Cases describe a real or realistic classroom situation that incorporates all the facts needed to clarify and solve target problems (Kowalski, Weaver and Henson, 1990). Based on Nichole *et al.* (1997), cases provide a tool through which instructional practices can be viewed as inextricably connected with meaning and context. It can serve as an interpretive framework, enabling learners to actively construct knowledge as they draw on their own background experiences to make personal sense of their planning and teaching.

Based on Nichole *et al.* (1997), cases can be found in various educational literatures: (a) cases in instructional materials; (b) cases as raw data in research on teacher cognition; and (c) cases as vehicles for in-service education. When cases are used as instructional materials, they take many form including critical incidents,

protocols, vignettes and simulations. When cases are regarded as example of narrative, they provide the raw data for research on teacher cognition. Narrative involves the selection of descriptive details that are organized into a coherent story that illustrates a theoretical point or brings meaning to events. Finally, collaborative case writing can serve as a tool to help teachers understand their own practice.

Metaphor is a reflective tool that has a coherence and internal consistency which provide insights into ideas that are not explicit or consciously held (Francis, 1995). Metaphor is the transfer of meaning from one object to another on the basis of a perceived similarity (Taggart and Wilson, 1998). It can also serve as holistic ways of re-presenting knowledge about science teaching and learning (Nichole *et al.*, 1997). When perspectives and practicing teachers construct metaphorical understanding of experience they ground them in individual semantic systems and beliefs embedded in the culture in which they live (Nichole *et al.*, 1997). It can be evocative, stimulating both self and other to tease out connections which might not be made by use of direct questions (Francis, 1995). For example, study of Francis (1995) allow science teacher use metaphor to reflect professional growth in aspect of teaching by writing a paragraph beginning "teaching is like . . .". Then, groups in the professional program analyzed the metaphors looking for relationships between metaphor and beliefs about teaching.

Observational learning is one's ability to acquire new responses by observing the behavior of a model (Taggart and Wilson, 1998). Based on Boreen, Johnson, Niday, and Potts (2000), observing and scripting is one way to document what you observe is to script a lesson. Scripting involves describing and recording the student and teachers interactions, materials and activities observer observe in the classroom context. Observer can script by taking note or by recording observation with the formats. In addition, observation notes from several class sessions will determine how teaching and learning is (Carlson, Humphrey and Reinhardt, 2003).

Other reflective tools used in context of science teacher education, for example, Geddis (1996), Bryan and Abell (1999) and Zembal-Saul, Blumenfeld, and

Krajcik (2000) used videotape or audiotape for discussing effectiveness of teaching and engaging science teachers to improve their own knowledge and teaching.

Videotape or audiotape will inform particularly issue on which college share his or her impressions or comment (Carlson, Humphrey and Reinhardt, 2003). In addition, Eick and Dias (2005) used reflective dialogue on practice on electronic forum to develop teachers' practical knowledge. This reflection aims at understand elements formal learning, biography (past and present) that informed thinking on practice. Luft (2001) also engage science teachers to reflect on action through electronic.

Furthermore, Osborne (1998) described that science teacher used students' stories as reflective tools to face what the teacher were teaching and to reflected how she was teaching. Similarly, essays were used to reflect on teacher's experiences for constructing some perspectives about classroom life (Sweeney, Bula and Cornett, 2001).

## **Summary**

For teacher professional development to be effective, reflective practices are important. Through process of reflection, growth of professional knowledge can proceed through framing and reframing in learning experiences (Schon, 1983). The teachers can be employed in identifying problems of practices, approaching these problems and implementing solutions, and making sense of the outcomes of their action (Bryan and Abell, 1999). Teachers gain their understandings of what is happened and shaping successive practice steps using multiple viewpoints as appropriate (Hatton and Smith, 1995). The teachers have a chance to think back on what they have done in action and identify new frame for developing new ways of thinking and teaching (Schon, 1983, 1987). In addition, the role of reflective practice in the context of professional development is to develop science teachers' knowledge, practices and belief about teaching and learning in science (Bryan and Abell, 1999; Eick and Dias, 2005; Freese, 2006; Geddis, 1996; Hatton and Smith, 1995; Luft, 2001; Osborne, 1998; Sweeney *et al.*, 2001; van Zee and Roberts, 2001; Zembal-Saul, Blumenfeld, and Krajcik, 2000). Reflective tools are varied used for engaging reflective teacher in different purposes.

In this study, writing journal, cases, observation, videotape are important reflective tools for developing science teachers' content knowledge and pedagogical content knowledge in genetics over a period of professional development. Based on Schon's (1983, 1987) notion of reflection-on-action, journals may engage science teachers seeing themselves the evolution of their knowledge and practice and critiquing what problems or issues of teaching science occur (Nichols *et al.*, 1997). Cases and videotape of teaching episodes were used for constructing science teachers' content knowledge and pedagogical content knowledge in genetics. They informed a real of classroom situations. In addition, observation was used to reflect on what teachers' knowledge was and how teachers' learning and teaching in science were. These reflective tools encouraged science teaches' developing understanding about themselves and practices in teaching genetics.

### **Summary**

This study aims to develop Thai lower secondary science teachers' knowledge of CK and PCK in genetics. Based on the literature, professional development experiences incorporating workshop, seminars, case discussion, study group and collaboration with scientists and science educators can engage science teachers' development of CK and PCK in particular topics (Loucks-Horsley *et al.*, 1998, 2003). In addition, professional development experiences, emphasizing learning approaches that focus on deep teachers' understanding of concepts, providing teachers for investigations, collaborative work, and reflection, are effective opportunities for teachers' growth knowledge of CK and PCK (Abdal-Haqq, 1996; Darling-Hammond and McLaughlin, 1995; Fiszer, 2004; Garet, 2001; Jeanpierre *et al.*, 2005; Liebman, 1995; Loucks-Horsley *et al.*, 1998, 2003; Luft, 2001; Tobin *et al.*, 1994). Especially, reflective practice is important process that prompts teachers to develop their knowledge and action (Schon, 1983, 1987). In addition, the role of reflective practice in the context of professional development is to develop science teachers' knowledge, practices and beliefs about teaching and learning (Bryan and Abell, 1999; Eick and Dias, 2005; Freese, 2006; Geddis, 1996; Hatton and Smith, 1995; Luft, 2001; Osborne, 1998; Sweeney *et al.*, 2001; van Zee and Roberts, 2001; Zembal-Saul *et al.*,

2000). Thus, this study developed science teachers' CK and PCK through such aspects of professional development experiences.

## **CHAPTER III**

### **RESEARCH METHODOLOGY**

#### **Introduction**

The main purpose is to study the development of Thai lower secondary science teachers' content knowledge (CK) and pedagogical content knowledge (PCK) in genetics. The plan for the study was generated from results of a pilot study which aimed to investigate the opinions of Thai lower secondary science teachers about problems and needs associated with teaching and learning in biology. As a result, lower secondary science teachers' needs for development their CK and PCK in genetics were studied. This research for developing science teachers' CK and PCK was conducted in three phases: development, implementation, and following-up. This chapter presents the research methodology of the study through discussion of the following: research methodology as grounded theory, case study as a research method, context of the study, participants of the study, the procedures of the study, data collection, and data analysis.

#### **Grounded Theory: A Research Methodology**

Grounded theory is the "...discovery of theory from data systematically obtained and analyzed in social research" (Glaser and Strauss, 1967: 1). It explicitly involves generating theory and doing social research with the same process (Glaser, 1978). In other words, theory evolves during actual research, and it occurs through continuous interplay between the analysts and data analysis (Denzin and Lincoln, 1994; Strauss and Corbin, 1998, 1999).

Grounded theory is a general methodology used in qualitative research for developing theory that is grounded in data systematically gathered and analyzed (Charmaz, 1994, 1995; Glaser and Strauss, 1967; Strauss and Corbin, 1990, 1997,

1998, 1999). Grounded theory is a process of pure induction (Henwood and Pidgeon, 2003). The goal of grounded theory is "...to generate a theory that accounts for a pattern of behavior which is relevant and problematical for those involved" (Strauss, 1987: 34). The researcher is involved in the creative and interpretive process of generating new understandings and theory (Henwood and Pidgeon, 2003).

According to Charmaz (1994), grounded theorists intend to construct theory from the data themselves. They need to work with solid, rich data that can be used to elicit thorough development of analytic issues. Grounded theorists shape their data collection from their analytic interpretations and discoveries, and therefore, sharpen their observations. Additionally, they check and fill out emerging ideas by collecting further data. Similarly, grounded theory is the iterative process of data collection and analysis involving constant comparative, which leads to the gradual development and refinement of theory grounded in the data (Tuettemann, 2003). That means the researcher starts with individual cases, incidents or experiences and develops progressively more abstract conceptual categories to synthesize, to explain, to understand his or her data and to identify patterned relationships within them (Charmaz (1995).

According to Charmaz (1994) and Strauss and Corbin (1999), grounded theory differs from other qualitative approaches. Most qualitative approaches collect amounts of data before delving into the analysis. In contrast, grounded theorists use their emerging theoretical categories to shape the data collection while in the field as well as to structure the analytic processes of coding, memo-making, integrating and writing the developing theory. Generally, much qualitative research depends on implicit methods and thus, relies on the researcher's intuition and talent. In contrast, grounded theory specifies an explicit set of analytic guidelines and procedures that can help any qualitative researcher develop conceptualizations of his or her data.

Based on works of Charmaz, (1994), (1995), Henwood and Pidgeon (2003), Strauss and Corbin (1990), (1997), (1998), (1999), Tuettemann (2003), processes of grounded theory include: 1) open coding, including coding, constant comparison and

writing memos of emerging categories; 2) axial coding, including process of theoretical sampling for relating categories to their subcategories; 3) selective coding, including identifying a core category and theoretical saturation for category development of generating a theory and; 4) writing a theory

First, the open coding is the analytic process through which concepts are identified and their properties and dimensions are discovered in data (Strauss and Corbin, 1998). Coding is initial process of defining what the data were all about. The aim is to produce concepts that seem to fit the data. In addition, this process involves constant comparison. The coded categories are made comparisons of similarities, differences and degrees of consistency of meaning. Second, the axial coding is the process of relating categories to their sub-categories, termed axial because coding occurs around the axis of a category, linking categories at the level of properties and dimensions (Glaser and Strauss, 1967; Strauss and Corbin, 1990, 1998). To develop main categories and their sub categories, theoretical sampling is conducted. Theoretical sampling is to extend the emergent theory by checking out emerging ideas, extending richness and scope, and in particular to add qualitative variety to the core data included within the analysis (Henwood and Pidgeon, 2003). Theoretical sampling allows the researcher to develop concepts when collecting data and to compare new data with data already collected (Glaser and Strauss, 1967; Strauss and Corbin, 1998). Third, selective coding is the process of integrating and refining the theory. It is the process of choosing one category to be the core category, and relating all other categories to that category (Strauss and Corbin. 1998). In addition, this process involves theoretical saturation. The researcher can look back at the prior categories and then collect rich and deep data for refining a theory. Finally, writing a theory is the final process and product.

This study used grounded theory as a research methodology. It was an inductive process that involves systematically and intensively analyzing qualitative data for generating a theory of how science teachers construct CK and PCK in genetics.

### **Case Study: A Research Method**

Case study is different from cases. Miller and Kantrov (1998: 2) provide a useful definition in which "...case refers to narrative organized around the key of event and portraying particular characters that is structured to invite engagement by participants in a discussion". Lee Shulman (1992) believed that most power cases are more than simply narratives of events, they are cases of something that represent some larger set of ideas and therefore are worthy of reflection and deliberation. In addition, classroom cases usually include descriptions of the participants, thoughts, feelings, and behaviors (Kagan, 1993). The classroom case is a tool for professional preparation and development, cases serve as a discipline-based teaching method, cases facilitate critical thinking and exploring dilemmas, and cases may be used as assessment tools (Koballa and Tippins, 2000). Harrington, Quinn-Leering, and Hodson (1996: 26) stated that "...dilemma-based cases are intended to provide students of teaching with opportunities to recognize specific events as problematic; gain an understanding of them; reflect on them and on the consequences of their action; and devise sensible, moral, and educative ways of acting".

Case study has been used to describe a qualitative research method that results in an intense and holistic description and analysis of an event or social unit (Veal, 1997). Case study is a form of qualitative research (Lee, 2003). Merriam (1988: 16) stated that "...case study is defined as an intensive, holistic description and analysis of a single entity, phenomenon, or social unit without controlling the situation of events". The case study is a way of organizing social data for the purpose of viewing social reality (Best and Kahn, 2006; Cohen and Menion, 1989; Cohen, Menion and Morrison, 2000).

The case study is interested in an in-depth understanding of the "...nature of the setting- what it means for participants to be in that setting, what their lives are like, what is going on for them, what their meanings are, what the world looks like in that particular setting" (Patton, 1985: 1). It does not attempt to predict the future or generalize an outcome from the study; rather, it seeks to understand a person's

contextualized situations and their uniqueness (Lee, 2003). It aims to understand the meaning people have constructed, that is, how they make sense of their world and the experiences they have in the world (Merriam, 1998). The case study method provides a context for exploring particular principles or problems (Sykes and Bird, 1992). It becomes a means for effective learning that draws the attention of the student audience by portraying real-life scenarios (Sykes and Bird, 1992). In addition, it provides a chronological narrative of events relevant to the case (Cohen, Menion and Morrison, 2000). In addition, the case study is an inductive approach that leads to findings in the forms of themes, categories, or concepts by observing and intuitively understanding data from the field (Lee, 2003). The researcher concentrates on understanding the phenomenon from the perspective that is the insider viewpoint of research participants. The case study involves researchers spending substantial time personally in contact with the activities and operations of the case, reflecting, revising meanings of what is going on (Stake, 1994).

In this study, three case studies of lower secondary science teachers were conducted that required rich, intensive, and thick description of the development science teachers' CK and PCK in genetics. The three case studies were of interest and interpreted in order to develop an in-depth understanding of the teachers' CK and PCK, and how they develop CK and PCK in genetics. The case studies were based on data collected independently from multiple data sources: interviews, and written cases, researcher's field notes, teachers' writing journal entities, and documents.

### **Research Context of the Study**

The professional development program to be developed and studied was based on lower secondary science teachers' needs and prior knowledge. The teachers taught genetics in schools located in the Educational Area 1 of Suphanburi province, Thailand. There are thirty-five schools in this area. Only twenty-four schools provided data about teaching and learning genetics. They are extended schools, including both elementary (grade 1-6) and lower secondary (grade 7-9) classes. These schools teach subject courses for elementary and lower secondary students. Most of these schools

are located in close proximity to area temples, so they tend to be small or intermediate in size. In small school, there are 1-499 students in range. In intermediate school, there are 500-1,499 students in range. Other schools are secondary schools (grade 7-12). Three of them are large schools, attended by 1,500-2,499 students in range. The remaining schools are intermediate schools located in agricultural areas. Most of students attending schools in Suphanburi province come from middle income and poor families.

Based on twenty-four school above, eight secondary schools (grade 7-12) were volunteered to participate in the professional development program. Two schools are large in size, one school is intermediate in size and other five schools are small in size. Most students in the large schools come from rich and middle income families, while most students from the intermediate and small schools come from agricultural families.

### **Participants of the Study**

Participants in this study included the research team, and ten in-service Thai lower secondary science teachers as participants in the professional development experiences.

#### **1. Research Team**

The research team was comprised of two science educators, a scientist, and an educational researcher. Their backgrounds were viewed in the Table 3.1. In this study, all members of the team worked cooperatively to design the research procedures for studying the teachers' development of CK and PCK in genetics during the 2006 school year. The procedures consisted of three phases: 1) designing the professional development experiences; 2) implementing the workshop and seminars; and 3) following-up three teachers' teaching genetics in their classroom that were conducted during seminars.

**Table 3.1** Background information of research team

<b>Information</b>	<b>Educator 1</b>	<b>Educator 2</b>	<b>Scientist</b>	<b>Researcher</b>
Highest Education	Ph.D. (Science Education)	Ph.D. (Science Education)	Ph.D. (Biology)	B.C. Biology/ Certificate in Teaching Science
Position	Assistant Prof.	Associate Prof.	Associate Prof.	Ph. D. Student
Workplace	Faculty of Education, Kasetsart University	Faculty of Education, Kasetsart University	Faculty of Science, Department of Zoology, Kasetsart University	Faculty of Education, Kasetsart University

First, the research team worked together to design an effective teacher professional development experience that addressed the needs of Thai lower secondary science teachers in the Educational Area 1 in Suphanburi province. The science educators gave suggestions and helped the researcher check the accuracy and suitability of the educational contents and activities related to teaching genetics in the workshop and seminars. The scientist gave suggestions and helped the researcher check the accuracy and suitability of the genetics contents, and whether activities were well suited for Thai lower secondary science teachers, the Science Curriculum Standard, and their school curriculum. The researcher took notes about how the research team designed the professional development experiences for developing teachers' CK and PCK in genetics.

Second, during the period of implementing the professional development, the researcher also prepared activities in the professional development experiences for the participants. Specifically, the scientist helped the researcher to develop a variety of activities that addressed genetics contents, while the science educators helped the researcher to develop a variety of activities that addressed teaching genetics in the

professional development program. The researcher carried out the procedures in the workshop and seminars. In addition, in the workshop and seminars, the scientist explained the genetics concepts to participants. The scientist answered some teachers' questions related genetics knowledge and gave suggestions to the participants about knowledge of genetics. In addition, the scientist helped the teachers to do the activities in their small groups. The science educators gave suggestions to the teachers about how to teach genetics and how to develop their lesson plans. They also helped the researcher to answer some questions about teaching genetics from the teachers. They helped the teachers to do some activities as the teachers did them in their groups.

Third, during the time of the three teachers' teaching genetics in their classroom, the researcher collected and analyzed the data for generating the categories of how the teachers developed their CK and PCK in genetics. The scientist and science educators help cooperatively the researcher to analyze the data. The scientist focused on how the teachers developed their CK in genetics. The science educators focused on how the teachers developed their PCK in genetics.

## **2. Participants in the Teacher Professional Development Program**

The participants in this section were ten in-service lower secondary science teachers who participated in a teacher professional development experience (a five-day workshop) that aimed to development teachers' CK and PCK in genetics. All of them were from eight schools and taught genetics in the lower secondary level in the Educational Area 1 in Suphanburi province during the 2006 school year.

The teachers included nine females and one male. The teachers had science teaching experience ranging from four to twenty-eight years at the secondary levels (grade 7-12). They had only taught genetics as required course from one to two years. All of them had never participated in the professional development in area of teaching genetics. All teachers' backgrounds were showed in the Table 3.2

**Table 3.2** Background information of the participants in the professional development program

Information	Science Teachers									
	1	2	3	4	5	6	7	8	9	10
<b>Sex</b>	Female	Female	Female	Female	Female	Female	Female	Female	Female	Male
<b>Age</b>	Forty-Eight	Twenty-Seven	Thirty-Nine	Fifty-Two	Forty-One	Forty-Seven	Forty-One	Forty-One	Forty-Two	Forty-Two
<b>Education</b>	Certificate Higher Education	B.S./Certificate Education/ Studying M.S.	B.S.	B.S.	B.S.	M.S.	B.S.	B.S.	M.S.	B.S.
<b>Science Background</b>	General Science	Science Teaching/ Science Education in Chemistry	General Science	General Science	Chemistry	Chemistry & Biology	Zoology	General Science	Science Teaching (Biology)	General Science
<b>Science Teaching Experiences</b>	Biology & General Science	General Science & Chemistry	Chemistry & General Science	Biology	Chemistry & General Science	Chemistry & General Science	Biology & General Science	General Science	Biology & General Science	Physics & General Science
<b>Science Teaching Years</b>	Twenty-Eight	Five	Eleven	Thirty	Twenty-Three	Five	Eleven	Five	Seventeen	Nine
<b>Genetic Teaching Years</b>	One	Two	One	Two	Two	Two	One	One	Two	One
<b>School Size</b>	Intermediate	Small	Small	Large	Large	Large	Small	Small	Small	Small

All teachers had two reasons to participate in the teacher professional development program. First, they were teaching genetic topics in schools located in the same community. This allowed all the teachers can exchange their ideas about teaching for developing their CK and PCK in genetics. Second, they were willing to participate in this professional development experiences for expanding their knowledge and teaching experiences about genetics topics.

In the professional development program, all teachers participated in a five-day workshop in October 2006. They were engaged in a variety of tasks in the professional development experiences designed to enhance their CK and PCK about genetics together in the mornings. They engaged in inquiry and case-based experiences that intended to help them improve their understandings of the following genetics concepts: genetics traits, chromosomes, genes, alleles, DNA, monohybrid cross, Mendelian genetics, phenotype, genotype, cell divisions, and applying genetics. Additionally, they shared their ideas and their experiences for teaching genetics during the workshop. In the afternoon of each day of the workshop, they cooperatively created or modified their lesson plans. They were expected to enhance their understandings of how to sequence of teaching the genetics concepts; and of what the strengths and weaknesses of the activities and representations used in the genetic lessons. Furthermore, they reflected on their learning from the activities in the workshop.

### **3. Participants as Case Studies**

The participants as case studies were three Thai lower secondary science teachers in the Educational Area 1 at Suphanburi province. Backgrounds of each person were described on number 1-3 in the Table 3.2. The criteria used for selecting the three teachers was as follows: a) they were enrolled in the same professional development experiences that address teachers' CK and PCK in genetics; b) they were teaching genetics in the different schools located in same area, that is Sriprachan area so that they had a chance to exchange their knowledge of teaching within the same context; and c) the teachers were willing to participated in the research procedures

such as interviews, reflective journals, cases responses, and observation, that might involve some extra time and effort on their part. At the time of this study, the three teachers were teaching genetics topics to lower secondary students (grade 9<sup>th</sup>).

In this study, the three female teachers were studied in-depth before, during and at the end of their teaching genetics for understanding teachers' development of CK and PCK in genetics. This study lasted two semesters of the 2006 school year. Each teacher was questioned about her own knowledge of genetics concepts by the concept interview, and the teacher was inquired her PCK by responding to the same case before the workshop and after the teaching in classroom. In addition, they participated in the five-day workshop in October 2006 and participated in two seminars in November and December 2006 in a school at Suphanburi province. Their developing CK and PCK related to genetics during the workshops and two seminars were investigated by the researcher. Then, they taught genetic concepts in their classrooms from November 2006 to January 2007. They used their lesson plans that were created or modified during the workshop, seminars and their teaching. They reflected their learning from the workshop experiences through teaching and writing journals. They were asked to respond the interview of teaching in each lesson. They were also observed as they were teaching genetics by the researcher. In addition, they were asked to write the self-assessment questionnaire at the end of professional development program.

### **Procedures of the Study**

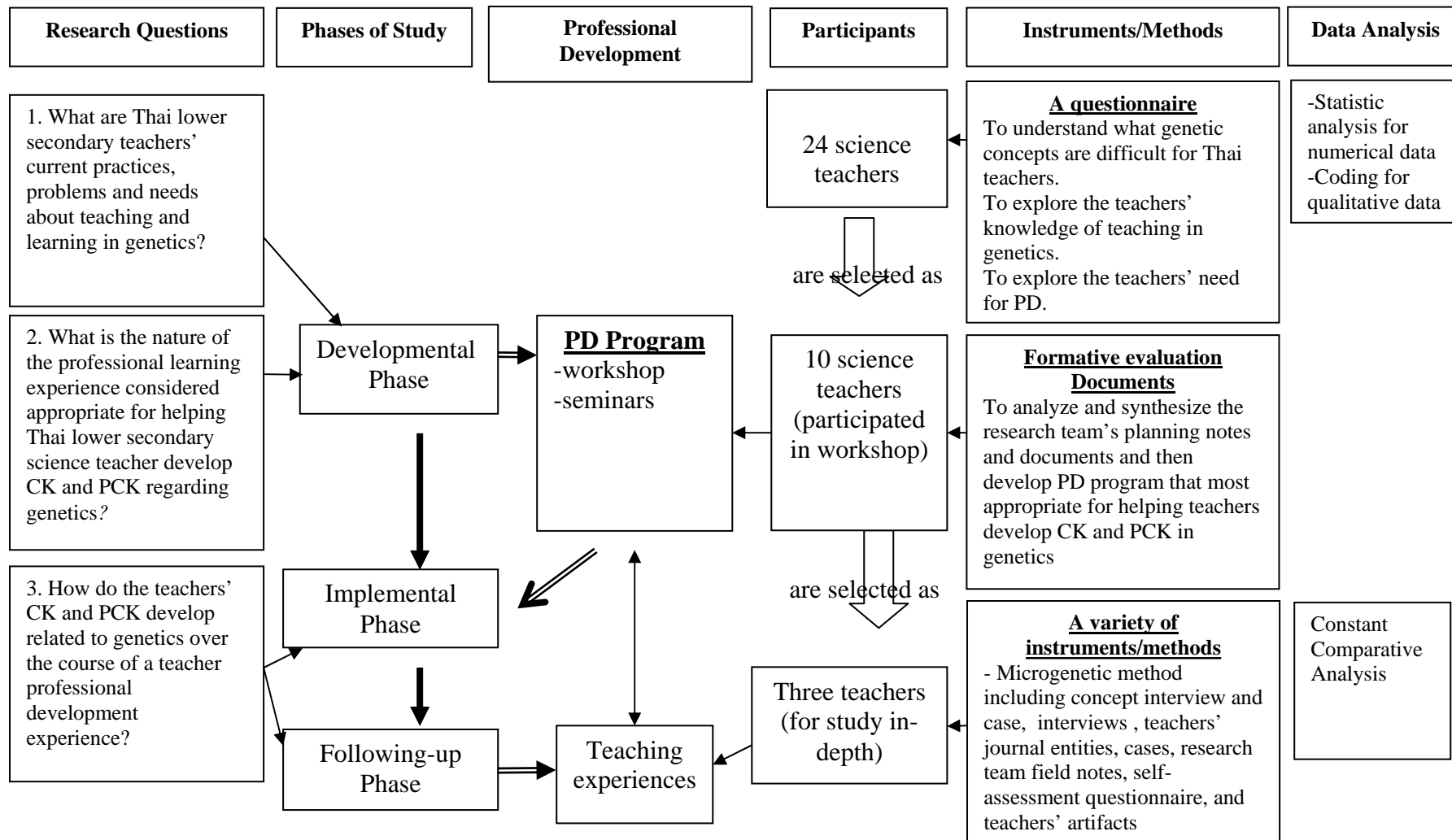
This study consisted of three phases: developmental, implemental and following-up phase. In the first phase, the researcher investigated of Thai science teachers' perceptions of difficulties topics in teaching biology in lower secondary level from thirty -five schools in the educational area 1, Suphanburi in the 2005 academic year. The results revealed that twenty-four lower secondary science teachers perceived that genetics topics were the most difficult to teach and for students to learn at this level. They needed a professional development program for developing their knowledge of teaching genetics. As a result, the researcher

developed a survey to question the same lower secondary science teachers about three purposes: a) their knowledge of genetics; b) difficulties associated with teaching genetics, c) their needs for teacher professional development program; and d) knowledge of scientific inquiry related to the teaching genetics. In addition, the researcher studied the effectiveness of teacher professional development from documents and analyzed the research team's planning notes to support the design of the teacher professional development program. Furthermore, the context of teacher participants and their schools contexts were explored. As a result, a teacher professional development program that focused on the teachers' CK and PCK in genetics was designed within teachers' contexts.

After that, implementation and follow-up phases were conducted. Before and after implementation of the professional development program was begun, the three teachers as case studies were asked to respond in the microgenetic method in September 2006. Microgenetic method, including case and concept interview, was a data collection for gathering the teachers' development of CK and PCK in genetics.

The teacher professional development program was implemented for the same group of teachers who responded on the questionnaire. The teachers were engaged on a variety of contents and activities in a five-day workshop on October 2006. In the workshop, the teachers participated in activities that were intended to lead them building up the knowledge of genetics concepts, and teaching in the topics every day's morning. The genetics concepts selected were considered to be the most difficulties to teach by the science teachers. The teachers were engaged to develop new understandings of genetics traits, dominant and recessive genes, chromosomes, DNA, alleles, genotype, phenotype, monohybrid cross, Mendel's laws, Punnett square, cell division, and applied genetics and how to teach them every day in the morning. In addition, they had a chance to learn how to construct concept map, writing case, and 5E inquiry teaching. Furthermore, the teachers had opportunities to exchange their ideas and modify their genetic lesson plans every day in the afternoon. Moreover, they reflected their own learning in each day. They wrote down what they learned at the end of each day.

After that, the three teachers taught genetics concepts in their schools. When the teachers were teaching genetics in their school, the two seminars were conducted on the weekends of the third week of November and the second week of December 2006 respectively. Each seminar lasted six hours. Different genetics concepts from researcher or teacher generated cases were addressed during each day of seminars. The first seminar focused on the concepts that the teachers would teach in the first three weeks. The second seminar focused on the concepts that the teachers would teach in the last three weeks. In each seminar, the teachers were engaged in writing, reading, reacting, and discussing on cases and video of teaching in a small group in the morning. Then, the teachers modified their lesson plans in the afternoon. After that, the teachers brought knowledge and suggestion to their classrooms. In addition, during the three teachers' teaching, data were collected to document their development of CK and PCK in genetics, using reflective journals, teachers' interviews, researcher's field notes, and teachers' artifacts. Furthermore, at the end of professional development program, the teachers' self-assessment questionnaire was collected for informing their development of CK and PCK in genetics. The procedures of the research are shown in Figure 3.1.



**Figure 3.1** Research Procedures

### **Data Collection**

In order to develop a durable, useful grounded theory, the researcher needs rich detailed data (Charmaz, 1994). Multiple data sources were used during the three phases of the research procedure: developmental phase, implementation and following-up phase. Two research questions were addressed during the developmental phase: What are Thai lower secondary teachers' current practices, problems and needs about teaching and learning in genetics?, and what is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teacher develop CK and PCK regarding genetics?. Research data sources used in this portion of the study are showed in the Table 3.3.

To answer the first research question, a questionnaire was conducted with Thai lower secondary science teachers in 24 schools in Suphanburi province. In addition, to answer the second research question, research planning notes were taken.

Importantly, in the implementation and following-up phase, to answer the third research question as the main research question: How do the teachers' CK and PCK develop related to genetics over the course of a teacher professional development experience?, multiple data sources were collected from three teachers as case studies. The primary data sources including the concept interview, the researcher and teacher generated cases, semi-structured interviews, and researcher's field notes. These teachers' responses of the microgenetic method including the concept interview, and the researcher generated case were collected before the teachers participated in the workshop, and after they taught genetics topics. In addition, during teachers' teaching genetic in their classroom, the teachers' interviews, and researcher's field notes in each genetic lessons were collected. Furthermore, during seminars, discussing on the teacher generated cases was collected. Moreover, the three teachers' reflective journals, artifacts and self-assessment questionnaire were served as secondary data sources. These data were collected during their teaching in real classroom. Multiple data sources can increase dependability, conformability as well as credibility (Patton, 2002).

**Table 3.3** Data sources in research methodology

Research Questions	Purposes	Data sources								
		Questionnaire	Research team's Planning Notes, Documents	Concept Interview, Researcher's Case (Microgenetic Method)	Teachers' Cases	Teachers' Interviews	Researcher's Field notes	Teachers' Journals	Teachers' Artifacts	Teachers' Self-Assessment Questionnaire
1. What are Thai lower secondary teachers' current practices, problems and needs about teaching and learning in genetics?	To explore teacher's current practices, problems, and needs about teaching and learning in genetics	X								
2. What is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teacher develop content knowledge and pedagogical content knowledge regarding genetics?	To design PD program appropriate for helping the teacher develop CK and PCK regarding genetics		X							
3. How do the teachers' CK and PCK develop related to genetics over the course of a teacher professional development experience?	To study the development of CK and PCK related to genetics over the course of a PD experiences			X	X	X	X	X	X	X

In this study, all tools for collecting qualitative data such as cases, and interview protocols were sent to the research team to check for accuracy and plausibility. In addition, all data were analyzed and synthesized for informing the researcher understandings of the teachers' development of CK and PCK in genetics.

## **1. Questionnaire**

A questionnaire is a data gathering instruments through which respondents answer questions or respond to statements in writing (Best and Kahn, 2006). According to Best and Kahn (2006), Cohen, Manion and Morrision (2000), the questionnaire has two forms: closed and opened form. The closed-form is marking yes or no or dichotomous questions, writing short answers, checking on items, rating scales, or multiple choices questions. It is easy to fill out, take little time, keeps the respondent on the subject. In addition, it is relatively objective and is fairly easy to tabulate and analysis. In contrast, the opened-form involves calling for a free response in the respondent's own words. Many questionnaires include both opened and closed-type items. The builder must decide which type is more likely to supply the information wanted.

The questionnaire was used to answer research question 1: What are Thai lower secondary teachers' current practices, problems and needs about teaching and learning in genetics?. The questionnaire was sent for Thai lower secondary science teachers who participated in the teacher professional development by mail during the 2005 school year.

The questionnaire was developed through a process of validity and reliability checked by two the science educators, a scientist and teachers who tried out. There are four purposes served by the questionnaire: (a) to explore teachers' knowledge of teaching genetics topics; (b) to determine what genetic topics are difficult for lower secondary science teachers to represent and provide activities to help students learning; (c) to explore the teachers' needs for teacher professional development related to teaching genetics; and (d) to explore the

teachers' knowledge of scientific inquiry as it related to the teaching of genetic (Appendix A). All teachers who were teaching genetics topics in 24 lower secondary schools were asked to answer a variety type of questions during the 2005 school years. The survey consists of four parts: (1) personal; (2) teaching and learning genetics; (3) teachers' difficulty in teaching genetics and needs of teacher professional development; and (4) inquiry based science lessons. Closed and open-ended questions were used. For the closed questions, the teachers responded yes or no, wrote a short respond or checked items from a list of suggested responses or gave order from the most to less, or checked on multiple choices in all four parts. In addition, open-ended questions were used for teachers' responses independently in three parts, excepting personal part.

In addition, self-assessment questionnaire was used for answering how the teachers developed their CK and PCK in genetics in the research question 3. Three teachers as case studies gave their levels of satisfaction and wrote down what they learned in each activity in the professional development program.

## **2. Research Team's Planning Notes**

The research team's planning notes were used to answer research question 2: what is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teacher develop CK and PCK regarding genetics? During the time the professional development was being designed, the research team took notes regarding how to develop a PD program that is most appropriate for helping teachers develop CK and PCK in genetics.

## **3. Microgenetic Method**

The present study examined development of three science teachers as case studies of CK and PCK in genetics. "...The study of development is the study of change" (Appelbaum and McCall, 1983: 415). Microgenetic method is necessary to look at the development of teachers' CK and PCK (Veal, 1997, 2004). According to

Fletcher, Huffman, Bray and Grupe (1998), microgenetic method can provide new information about cognitive change. Microgenetic method has therefore provided evidence of competencies rather than beliefs. Individuals of different ages seem to differ in the frequency of complex thinking skills and strategies. The use of the microgenetic method can predict change of thinking skills and strategies. The method is used for understanding before and after of the thinking skills and strategies. Microgenetic method also helps the researcher understand problem types and factors that influence individual changes.

The microgenetic method is a procedure whereby the participants have frequent encounters with the same task over a period of time (Siegler and Crowley, 1991). According to Opfer and Siegler (2004), Siegler and Chen (1998), Siegler and Crowley (1991), the microgenetic method has three key characteristics: 1) knowledge is assessed before, during and after the period of change; 2) the density of observations within this period is high relative to the rate of change of the phenomenon; and 3) observations behavior is intensively analyzed, with the goal of interfering the changing representations and process.

In this study, the microgenetic method was used to monitor the development of Thai lower secondary science teachers' CK and PCK in genetics. Three teachers were asked to respond orally two times (before a five day workshop, and the end of teaching genetics in the schools) to a concept interview and one genetic science teaching case developed by the researcher. First, concepts interview (Appendix A) was used for capturing the teachers' change of their CK in genetics. The concept interview consisted of ten questions that concerns real situations. The interview lasted one hour for each teacher. Second, for monitoring the teachers' development of PCK, a researcher generated case (case A) (Appendix B) was used that described a likely dilemma in a secondary classroom which could be solved. It contained potentially problematic incidents that could easily happen in a genetics teachers' classroom. The case was given to the three teachers to read, and then respond to a set of semi-structured interview questions. Both the concept interview and case were conducted in a quiet classroom in teachers' schools.

#### 4. Cases

Cases were constructed as a tool to reveal Thai lower secondary science teachers' CK and PCK development in genetics. Classroom cases can serve science teachers have opportunities to practice analysis, or to stimulate personal reflection (Koballa and Tippins, 2000, 2001). Cases are stories with a message to educate not for entertainment (Herreid, 1997). Cases are typically written as dilemmas that reveal the personal history of an individual, institution or business faced with a problem that must be solved (Herreid, 1994). Cases refer to a narrative organized around a key event and portraying particular characters and that is structured to invite engagement by participants when discussing a case (Miller and Kantrov, 1998). According to Miller and Kantrov, (1998), a case is a relatively short text that prompts conversations and reflection on a set of issues that are frames through the narrative. Various formats of cases have emerged to illustrate problems or dilemmas in teaching and learning including narratives, critical incidents, protocols, vignettes, situations, video cases, computer-based presentations and more recently interactive video cases (Barnett, 1999; Tippins, Koballa and Payne, 2002).

According Herreid (1994), cases are classified into three basic types. First, cases are decision or dilemma cases that present problems or decisions that need to be made by a central character in the drama. The kind of case usually consists of a short introductory paragraph setting up the problem to be considered; a background section that fills in the necessary historical information to understand the situation; a narrative section that presents the recent developments; and exhibits that include tables, graphs, letters, or documents that help lay the foundation for a possible solution to the problem. Second, appraisal cases or issue cases are used to teach students the skills of analysis. It focuses on the question "what is going on here?". Third, case histories are largely finished stories and are generally less exciting than decision or appraisal cases. For example, these cases serve the illustrative programs of science in action.

This study used four narrative cases as reflective tools for teachers' development of CK and PCK in genetics during microgenetic method, and the

professional development experiences. All cases also were primary data sources for analyzing how they develop their CK and PCK. All cases were developed by the researcher and teachers as case studies and used by the teacher for exploring how to teach genetics concepts. Based on Kagan and Tippins (1991), Koballa and Tippins (2000, 2001), four cases were developed guidelines in follows. Cases reflected a realistic view of the complexity of teaching. In addition, cases emphasized the human dimensions of teaching and learning that invoked intentions and feeling that were often at the heart of classroom dilemmas. Cases were of reasonable length to facilitate opportunities for group discussion. Each case included a clear description of the dilemma or challenge. Each case included any or all of following components: descriptions of the teacher; teacher's backgrounds and/or experiences; descriptions of teacher's classroom, school, or community; descriptions of the students; teachers' and/or students' feelings and intentions; actual or imaginary dialogue; and descriptions of relevant parties (e.g. other teachers).

Case A was used in the microgenetic method. Case B, C and D were used in case discussion. The three teachers were provided the opportunity to engage in discussion on them for facilitating critical reflection, analysis, evaluation of possible solution. The cases were read and discussed in the workshop and seminars of the teacher professional development experiences. Based on Koballa and Tippins (2000, 2001), Miller and Kantrov's (1998), case discussions encouraged a dialogue rather than debate. In addition, group of discussion on cases should be small enough to encourage participation of all members. The teachers should be provided with ample time to read.

The first case (A) (Appendix B) is narrative that describes a typical situation in a lower secondary classroom which illustrates teaching concepts of genes, chromosomes, DNA and their relationships. This case was used as a tool within the microgenetic method for development three teachers' developing PCK in a specific topic. The case focused on how to represent and teach these concepts, and on the strengths and weaknesses of teaching these concepts. The teachers were engaged

independently with the case before a five day workshop and after teaching genetics in their schools.

The second case (B) (Appendix C) was a narrative situation about teaching genetic problem solving in a real classroom. It was used during a five-day workshop for all participants. This case was to develop all teacher participants' understanding of what case is, teachers' thinking about how to teach in this case (development of PCK) and teachers' knowledge of genetics concepts of phenotype, genotype, dominant and recessive genes and monohybrid cross.

In addition, two cases (C and D) were used for developing three teachers' CK and PCK in genetics during two seminars. Each teachers developed their own case within a topic. The topics that the teachers selected were: (i) what were your understandings in genetic concepts?, and how did your understanding effect students' understanding?; (ii) what were relationship between lesson plan and actions?; and (iii) what activities or instructional media did you use?, why did you use?, and how did your teaching effect students' learning and understanding in genetics?. Each teacher generated one case and discuss in each seminar.

## **5. Interview**

An interview is a purposeful conversation, usually between two people but sometimes involving more, that is directed by one in order to get information from the other (Bogdan and Biklen, 2003). The goal of understanding how the person who is been interviewing thinks it at the point of the interview (Bogdan and Biklen, 2003). On the other hand, the purpose of interview is to find out what is in or on someone else's mind (Best and Kahn, 2006). The interview is an effective way to understand what the teachers know and why they do what they do from their perspectives (Park, 2005). In the other words, because researchers cannot observer everything they might want to know, interviews can provide access to the context of teachers' action (Seidman, 1998). The interview is used to gather descriptive data in the subjects' own words so that the researcher can develop insights on how subjects interpret some

piece of the word (Bogdan and Biklen, 2003). Thus, to understand what teachers knew, what they felt, how they understood and why they did, interview was essential to understand the teachers' CK and PCK in genetics in this study.

Many aspects of interviews are considered. According to Bogdan and Biklen (2003), good interviews are ones in which the subjects can talk freely about their point of view. Good interviews produce rich data filled with words that reveal the respondents' perspectives. Transcriptions are filled with detail and example. The interviewer may ask for clarification when the respondent mentions something that seems unfamiliar. In qualitative interview, the interviewer should avoid as much as possible questions that can be answered by "yes" or "no". Importantly, the interviewer need to listen carefully to what the respondent says. In addition, the interviewer has said something that is more like a conversation than a formal, highly structured interchange between an interviewee and interviewer. According to Liamputtong and Ezzy (2002), good interview is two-way affair. One person talks while the other listens, responds and encourages.

In addition, processes of interview are presented. Early in the interview, the researcher tries to briefly inform the teachers of the purpose of interviews (Bogdan and Biklen, 2003). In interviewing, the researcher encourages the subjects to talk in the areas of interest and then probes more deeply; picking up on the topics and issues the respondent imitates (Bogdan and Biklen, 2003). Specifically in this study, the researcher asked the three teachers as case studies with semi-structured questions and then probes interesting responses in depth. For example, probing questions consists of What do you mean?, Would you explain that?, Give me an example., and Tell me about it. After the investigatory work has been done, if the researcher wanted to interview more in order to get more information, the researcher interviewed additionally the teachers. Audiotapes were used during interviews. It could be very effective in gathering information of subject's statements when a study involves extensive interviewing (Bogdan and Biklen, 2003; Osterman and Kottkamp, 2004). The tapes could be replay several times for continued study and analysis (Fraenkel

and Wallen, 2000). The researcher could hear what the interviewee said and critiqued what data were not enough to analysis for the future interview by tape recording.

In this study, two interviews were developed as primary data sources. The two interview protocols were semi-structured interviews. According to Berg (2004), these semi-structured questions were typically asked of each teacher in a systemic and consistent order. However, the interviewer was permitted to probe far beyond the answers to their prepared standardized questions. The semi-structured interviews fitted for grounded theory methodology. As researcher was interviewing the teachers follow structured questions, the researcher elicited additional information for constructing categories that led to constructing a theory of developing CK and PCK in genetics.

First, the interview protocol#1 was used to ask the three teachers who were case studies about their backgrounds, educational backgrounds, teaching experiences, and teacher professional development experiences (Appendix D). It was conducted before teachers' teaching in real classroom setting in the 2006 school year. This information was supported analysis data of how the teachers developed their CK and PCK in genetics. Second, the interview of teaching (Appendix E) was used after the teachers taught the genetic lessons based on lesson plans that they developed during the workshop and during time of teaching. The three teachers were asked about e.g. Do you have problems about your own understanding of genetic concepts that you taught?, What do the activities, instructional media, and teaching strategies you use in lesson of...? Why?, and How do these activities, instructional media, and teaching strategies influence on your students' learning?. The teachers' responses on these questions were analyzed to determine how the teachers develop their CK and PCK in genetics. During interviewing, the researcher also recorded data by tapes.

## 6. Field Notes

The teachers' CK and PCK concern their teaching of particular topics and guide their action when dealing with subject matter in the classroom (Park, 2005). Accordingly, the translation of teachers' knowledge into classroom practice is clearly a critical aspect of PCK. Moreover, teachers' actions are a more accurate representation of what they know than the usual array of self-report measures (Van Driel *et al.*, 2001). In addition, what the teachers say does not always reflect what they do (Park, 2005). Furthermore, according to Cohen and Menion (1989), the observation is used for studying the characteristics of an individual. The purpose of such observation is to probe deeply and to analyze intensively the multifarious phenomena that individual encounter. Therefore, classroom observation is necessary to examine teachers' CK and PCK in genetics.

Researcher's field notes are a primary data source in this study. The field notes are the written account of what the researcher heard, saw, experienced, and thought in the course of collecting and reflecting on the data (Bogdan and Biklen, 2003; Fraenkel and Wallen, 2000). According to Best and Kahn (2006), the observation usually consisted of detailed notation of behaviors, events, and the contexts surrounding the events and behaviors.

In this study, the researcher observed the three teachers and wrote field notes. The purpose of the field notes is to explore the development of teachers' CK and PCK as the teachers teach genetics concepts. According to Bogdan and Biklen (2003), the researcher's field notes consisted of two kinds of materials: descriptive and reflective material. Descriptive parts provided words, and pictures of the setting people, actions, and conversations as observed. This part recorded the details of what occurred in the teachers' classrooms of genetic lessons. The reflective parts captured more of the researcher's frame of mind, ideas, and concerns. The emphasis on this part was on speculation, feelings, problems, ideas, hunches, impressions, and prejudices. Also it included the researcher's plans for the future research as well as clarifies and corrects mistakes or misunderstandings in the researcher's field notes.

The researcher's field notes (Appendix F) were focused on eight elements: (a) context of classroom (arrangement of tables, learning resources, environment of classroom) and students' learning (learning styles, relationship with teachers); (b) relationships between teacher and students, between students and students; (c) How do teachers teach this lesson? Does the teachers' teaching relevant to their lesson plans? What do the teachers change during their teaching this lesson?; (d) What teaching strategies do teacher use?; (e) What activities and instructional media do teachers use? Do their students learn genetic concepts from these activities and instructional media?; (f) What are teachers' problems of teaching genetic concepts? How?, and How do the teachers solve that problems?; (g) What are teachers' understandings of genetic concepts of...?; and (h) What are students' understandings of genetic concepts of...?

## **7. Teachers' Journals**

According to Osterman and Kottkamp (2004), Taggart and Wilson (1998), journal is one form of narrative writing often associated with reflective practice. The journal is an important means of gathering information about events (actions, feelings, and interpretations). The two types of journals are described. One, a log, is a running account of important events and interactions occurring in the work setting. The second is reflective assessment of those events, where the writer raises questions about these experiences and often shares thoughts with others.

According to Taggart and Wilson (1998), journaling provides the teachers with opportunities to: (1) analyze and reasoning through a dilemma; (2) enhance development and reflection; (3) promote growth in critical analysis of teaching; (4) promote awareness of relationships between education and practical experiences; (5) systematically reflect on self-development and on actions within classroom and work contexts; (6) build understanding by writing about what is learned; and (7) link understanding with classroom practice.

Teachers' journals were collected as primary data source in this study. The journals were collected after teachers finished their teaching in each lessons. The journals were used as a reflective tool for assisting and examining the teachers' development of CK and PCK in genetics during the 2006 school year. There were six journal entities that the three teachers were asked to write one journal/ a lesson. Three teachers were asked to write about: (i) their understanding in genetic concepts and teachers' feeling when teachers taught the concepts; (ii) students' learning and learning styles; (iii) teaching experiences that they thought were successful in genetic classroom; and (iv) teaching experiences in which they encountered problem in genetic classroom.

### **8. Teachers' Artifacts**

Teachers' artifacts means all the teachers' lesson plans developed during the workshop and teaching in their classroom, all teachers' papers on tasks in the workshop and seminars, three teachers' handouts, papers, assignment sheets, lab sheets, lecture notes, instructional media relevant to the teachers' teaching in genetics. All artifacts were collected and used as secondary data sources. These artifacts were to be reviewed in the context of their use and examined for the presence of change in CK and PCK in genetics topics.

In summary, in the developmental phase, a questionnaire was used to explore what concepts of genetic concepts were difficult for Thai lower secondary science teachers to teach and how they taught the concepts as well as their need for professional development experiences in the Educational Area 1, Suphanburi provinces. In addition, data from the research team's planning notes and documents about professional development program were analyzed and synthesized to design the professional development program.

In the implementation and follow-up phases, the three case studies of lower secondary science teachers were conducted. These involved collected and analyzed data relative to the teachers' development of CK and PCK in genetics.

To study how the three teachers develop their CK and PCK the teacher professional development program, multiple data sources are used during the research processes. The primary data sources was gathered from teachers' responses of a dilemma of case, the concept interview; interviews about teachers' teaching; three dilemmas of cases; the researcher's field notes; teachers' journal entities and teachers' self-assessment questionnaire. Additional data sources will include teachers' lesson plans and other teachers' documents related to the topics of genetics. All sources of data were useful for constructing a theory related to the development of the teachers' CK and PCK in genetics.

### **Data Analysis**

In the developmental phase, two methods of analysis: statistical analysis and coding analysis were used for answering the research question 1: What are Thai lower secondary teachers' current practices, problems and needs about teaching and learning in genetics?. These were used for analyzing teachers' responses on the questionnaire. The questionnaire included both closed- and open-ended questions. Thus, statistical analysis was used for analyzing teachers' responses from numerical data. The coding was used for analyzing teachers' responses from qualitative data. In addition, to answer the research question 2: what is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teacher develop CK and PCK regarding genetics?, coding analysis was used for interpreting data from research team's planning notes.

In the statistical analysis, the researcher counted numbers of teachers' responses on items of using activities and difficult levels of teaching genetics in the questionnaire. Then the researcher reported results by comparing each other.

The coding analysis occurred after data collection. The researcher read through the data concluding words, or phrases of each teacher's responses in the questionnaire and the researcher's planning notes. The researcher developed code from repeat data in follow steps according to Bogdan and Biklen (2003). First, the

researcher searched through all data for regularities and patterns as well as for topics that data cover, and then wrote down words and phrases to represent topics or patterns. These words and phrases were coding categories. Then the research defined what each category was meant. After that, the science educators and scientist helped the researcher check trustworthiness of results before reporting the results.

In addition, in the implementation and follow-up phase, constant comparative analysis as a procedure of grounded theory was used to answer the research question 3: How do the teachers' CK and PCK develop related to genetics over the course of a teacher professional development experience?. It was used for interpreting all qualitative data (e.g. teachers' interviews, teachers' generated cases, researcher's field notes, teachers' journals and artifacts).

Constant comparative analysis is a staple feature of social science research (Strauss and Corbin, 1998). It included four steps of analysis. First, each incident was compared and grouped similarities and differences with other incidents into a category (Strauss and Corbin, 1998). The researcher compared data from the same individuals at different points in time (Charmaz, 1995). In this study, data from primary data sources, such as, the teacher's responses from the first interview of teaching was compared with the researcher's field notes, teacher's cases, and teachers' journals for creating categories of teachers' development of CK and PCK in genetics. The researcher looked at the data line by line and then asked these questions "what were the teachers doing, saying, and thinking?, and how did teachers do?". Then, the researcher coded the categories. Second, categories and their sub-categories were related (Glaser and Strauss, 1967; Strauss and Corbin, 1990, 1998). The researcher defined the categories and maked relationship between categories and sub-categories. The researcher was allowed to check out emerged categories, fill out information, and modify the categories if it was necessary (Henwood and Pidgeon, 2003). Third, core categories were developed (Strauss and Corbin, 1998). The researcher selected the main categories for constructing conclusion in line with the research questions. Finally, conclusion was written. In this study, teachers' development of CK and PCK was written from emerged categories. These brought the

researcher to understand how the teachers developed their CK and PCK in genetics, that is, a theory generated in this study.

The interpreted data were checked by the teacher participants for accuracy and plausibility. When the researcher transcribed and interpreted data, the teachers from whom the data were collected and checked the accurate of their meaning. In addition, it was checked trustworthiness by the science educators and scientist. When the researcher coded the categories and sub-categories, the science educators and scientist checked the accuracy and suitability of these categories in line with answering the research questions. The conformability of the data was enhanced by teachers' artifacts. In addition, terms of transferability, the researcher described research context as rich and thick as the researcher can, so that readers determined whether the findings are transferable.

In summary, in the developmental phase, statistic and coding analysis were used to interpret quantitative and qualitative data for designing the professional development program. In the implemental and following-up phases, constant comparative analysis was mainly used to analyze multiple data sources for understanding the lower secondary science teachers' development of CK and PCK in genetics

## Summary

This chapter describes the research methodology that is conducted in three phases: developmental, implementation and follow-up phase. During three phases, the researcher used grounded theory as theoretical perspective in organizing explanation of Thai lower secondary science teachers' development of CK and PCK. Grounded theory was described as a research methodology that researcher discovered systematically of a theory from data obtained. In addition, the researcher described research methods, including case studies and microgenetic method, used to monitor the teachers' development of CK and PCK in genetics. Three case studies of development CK and PCK in genetics were conducted, with data being collected before, during, and at the end of research procedures including the teacher professional development experiences. Data for the three case studies were collected and analyzed through a variety of primary and secondary data sources including interviews, field notes, cases responses, teachers' artifacts, teachers' journals, and teachers' self-assessment questionnaire. All data was analyzed by constant comparative analysis for generating science teachers' development of CK and PCK in genetics.

## **CHAPTER IV**

### **RESEARCH INTERVENTION**

#### **Overview of the Chapter**

This chapter presents a description of a science teacher professional development program namely, PCK-Based Science Teacher Professional Development Program (PCK-Based PD Program) as research intervention which is formed in the developmental phase of the study. The PCK-Based PD Program was implemented with lower secondary science teachers in the Educational Area 1 in Suphanburi province. The chapter is divided into two main sections. In the first section, discusses the processes of developing the program are presented in Figure 4.1. In the final section, the activities of the PCK-Based PD Program are presented.

#### **Processes of Developing the Research Intervention**

##### **1. Current Practices, Problems and Needs of Science Teachers about Teaching and Learning in Genetics are Preliminary Data for Developing the PCK-Based PD Program**

To understand the real situation of Thai lower secondary science teachers, their current practices, problems and needs about teaching and learning were explored.

First, the current genetics teaching practices of 24 lower secondary science teachers in the Educational Area 1 in Suphanburi province were examined during the 2005 academic year. A variety of teaching strategies were used for teaching genetic concepts. All genetic concepts taught, included of genetic traits, gene, chromosome, cell division, phenotype, genotype, Mendel's laws, Punnett squares, genetic disorders, and applied genetics, were taught most often by lecture. Most concepts were also

taught by asking questions, showing pictures and giving examples. Demonstration, solving problem, investigation, presentation, comparison, constructing model, experiment, doing report, using real material, and using technology were not often used for transforming genetic concepts to students' learning experiences. For example, a teacher often used lecture and asked questions when teaching Mendel's laws. The teacher also used problems, pictures, and technology on her teaching. The teacher gave her reason why she selected these strategies that i) her students had never learn genetics, and ii) this concepts were difficult for her students to learn by themselves. The teacher had to explain firstly the concepts by lecture, and then let students do activities.

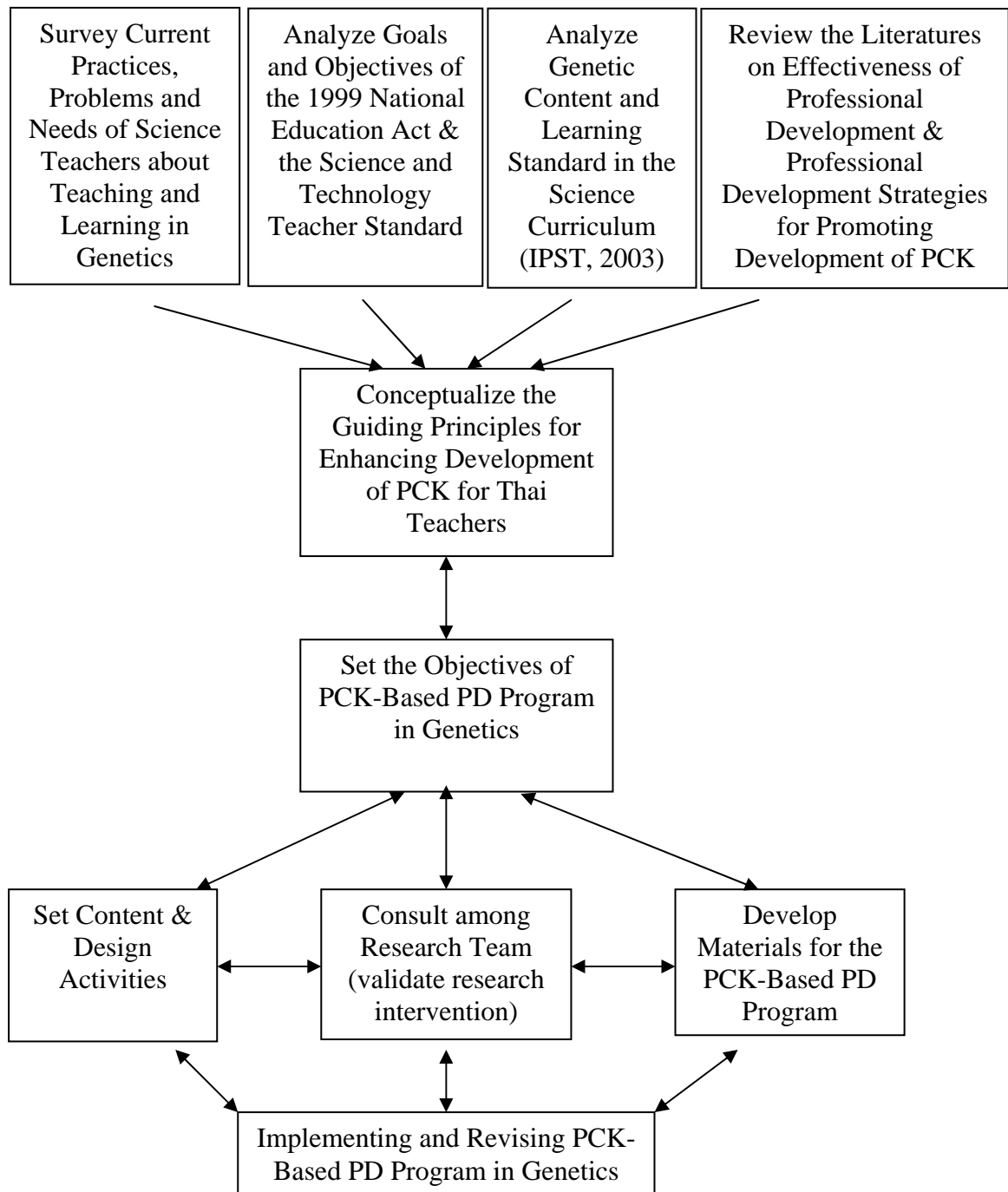
Furthermore, inquiry emphasized on student-centered and teacher-centered approach when teaching genetics concepts was explored in this questionnaire. Most teachers emphasized on teacher-centered approach. Eighteen of teachers posted questions to students' investigation. Nineteen of teachers determined data and let their students to find out results by themselves. A half of teachers also guided their students to explain their results. However, thirteen of teachers gave a chance to students to explain and examine their knowledge from learning resources themselves. All teachers knew that inquiry was an important learning process because it encourages students' curiosity, and helps students learn and gain knowledge by themselves. In addition, the results indicate that the teachers believe that inquiry helps students to enhance their scientific skills and improve attitudes toward science. It also provided students to practice and think systematically. However, the teachers were not successful for inquiry teaching. Their students didn't like to investigate and think by themselves. The teachers used long time for a lesson. The teachers thought that inquiry was not suitable for students who had low achievements. The school also lacked of the learning resources for supporting inquiry-based instruction.

Second, teachers' difficulties of teaching and learning in genetics were explored. Half of the teachers indicated having the most problems with understanding of Mendel's principle. In addition, ten of teachers reported that genotype, and Punnett squares were challenging topics to teach. Furthermore, fourteen of teachers gave their

opinions that genetic disorders, applied genetics, chromosomes, genes, genetic traits were moderately difficult to teach. Various causes of difficulty were given by the teachers. First, they didn't understand these concepts in depth. Second, they were not able to teach these abstract concepts in concrete way. The teachers often used lecture, so their students were not interested in the lesson. Third, the teachers had not enough instructional media and learning resources for representing the concepts. Fourth, the genetic contents were difficult for lower secondary grade and their students had never learned genetics.

Third, needs of the teacher professional development was explored. The teachers have never participated in the professional development about teaching genetics. However, some teachers had variously teacher professional development opportunities in science, such as, professional development for astronomy teachers, local science learning activities, writing lesson plans of integrated science, action researches, teaching science in lower secondary level, teaching and learning science through a satellite. All teachers needed to gain their professional knowledge in area of teaching genetics. They expressed a need for more simple and correct contents, new and interested strategies, VCD and electronic media and documents about teaching genetics.

As a result, from survey indicated that teachers had difficulties of teaching and learning in genetics. They didn't have various teaching strategies and taught genetics by using inquiry emphasized on teacher-centered teaching. Teachers needed a teacher professional development program for helping them decrease in the challenges that they associate with teaching and learning genetics.



**Figure 4.1** Processes of developing the research intervention

## **2. Analyze Goals and Objectives of the 1999 National Education Act and the Science and Technology Teacher Standard**

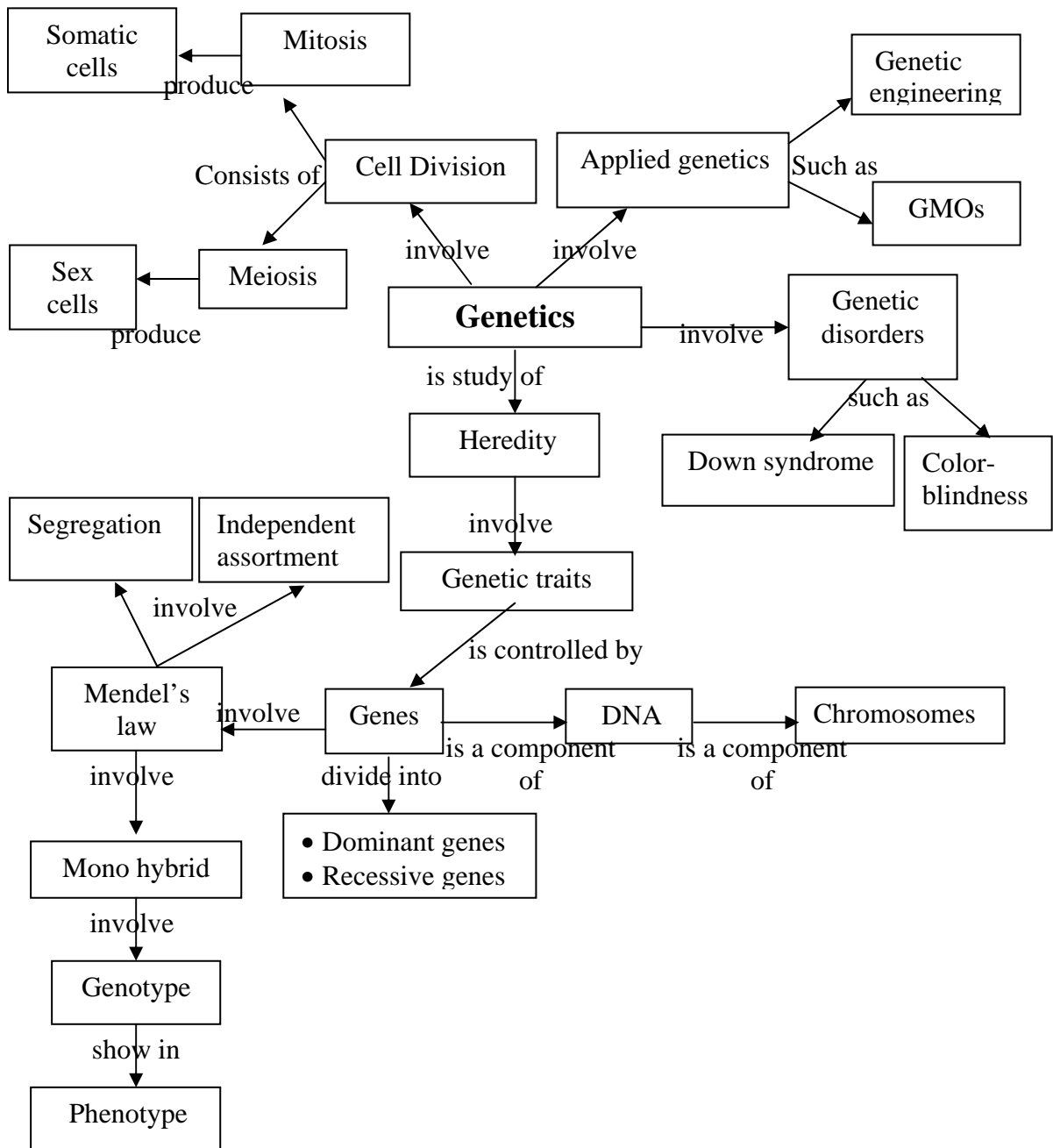
The National Education Act (1999 revised 2002) offers suggestions about objectives of learning processes and of professional development to guide the development of the PCK-Based PD Program. To meet the goals and objectives of the Act, the program should aim at the full development of the teachers and students in all aspects: physical and mental health; intellect; knowledge; morality; integrity; and desirable way of life so as to be able to live in harmony with other people. In addition, the program should develop the teachers who shall be developed on the continuous basis. Furthermore, the program should provide professional experiences for all learners who are capable of learning and self-development. The program also enables the teachers to develop teaching and learning process for learners to develop themselves at their own pace and to the best of their potentiality. Especially, in the science area, to meet the Science and Technology Teacher Standard (IPST, 2002), the program should help science teachers not only to develop science contents, but also to understand the nature of science and technology. In addition, the program should encourage science teachers to understand and use a variety of teaching pedagogy enabling learners to develop their critical thinking and practice. Furthermore, the program should support the teachers to develop their own curriculum and lesson plans based on the learning standard in the Science Curriculum Standard (IPST, 2003) and community's needs.

## **3. Analyze Genetic Content and Learning Standard in the Science Curriculum Standard (IPST, 2003)**

Following the National Education Act and the Teacher Standard, the Science Curriculum Standard (IPST, 2003) offers suggestions regarding science learning in schools. Teachers in the PCK-Based PD Program are science learners, so they should develop their learning in ways that will enable them to develop their students later. They must understand the principles and theories basic to genetic. They also must understand the nature of science. They are provided skills for discovery and creation

in genetic and develop the thinking process, imagination, ability to solve problems, data management, communication skills and ability to make decision. In addition, they must develop awareness of relationships between genetic, humans and the environment in terms of influence and impact on one another.

PCK-Based PD Program must be based on teachers' expectation about learning and teaching genetics. Genetics in lower secondary grades (grade 7-9) is in the sub-strand 1: Living Things and Living Processes. At the end of highest grade of this level, students should be able to search for information and discuss the genetic material in the nucleus, which controls characteristics and processes in the cell, the inheritability of genetic material and know the positive applications of genetic knowledge. Based on this strand, the IPST imply genetic contents in the IPST book that science teachers should provide these basic contents to their students consisting of genetic traits, dominant and recessive genetic trait, Mendel's laws, gene, chromosome, mono-hybrid cross, genetic disorders, and applied genetics. As a result, the PCK-Based PD Program should address all these science content areas and support science teachers' development of lesson plans in line with the learning standards. Not only should the teachers understand the meaning of concepts, but they should also understand the relationships among concepts. The scope and relationships of genetic concepts for lower secondary levels was mapped in the Figure 4.2.



**Figure 4.2** Concept map of genetic concepts and their relations for lower secondary levels in line with the IPST text book

#### **4. Review the Literature on Effectiveness of Professional Development and Science Teacher Professional Development Strategies for Promoting Development of PCK**

The PCK-Based PD Program was designed based on what is known about effectiveness of professional development and science teacher professional development strategies. These topics were all reviewed in chapter 2. Professional development for in-service teachers must include experiences that put the science contents they learn into the context of teaching (Garet *et al.*, 2001; Loucks-Horsley *et al.*, 2003). In addition, the program should develop the science teachers' content knowledge in depth and the teachers' PCK (Lee, Hart, Cuevas, and Enders (2004). Furthermore, the program should provide science teacher to collaborate among the people involved in programs, including science teachers, educators, teacher unions, scientists, administrators, policy makers, members of professional and scientific organizations, parents, and business (ONEC, 1999). Moreover, the professional development program should give a chance to science teacher to reflect their knowledge and action. Finally, the program should provide science teachers to employ professional development learning for a long time (Loucks-Horsley *et al.*, 2003).

#### **5. Conceptualize the Guiding Principles for Development of PCK for Thai Teachers**

The PCK-based on PD program in teaching genetics was designed based on guiding principles of the program that were conceptualized below.

##### **5.1 Science Teacher is a Learner Who Actively and Continuously Develops Their Profession**

Professional growth is aspired to science teachers in the research intervention, because it provide science teachers learned and change their own knowledge, behavior, and/or beliefs over time. In this study, the program should

provide professional experiences for the science teachers to help them learned how to teach genetics for their students' understanding and learned how to develop continually their knowledge and practices by themselves. It also provides an opportunity for the teachers to change or improve their thinking and practices over the course and the future.

### **5.2 Understanding Genetic Contents and Knowledge of Representations and Activities Based on Their Context as Important Aspects of Developing PCK**

In this study, the PCK-Based PD Program was designed for developing of PCK for teaching genetics. PCK is regarded as teachers' knowledge that enables lower secondary science teachers to transform particular genetic content knowledge into forms that are understandable for the students. Hence, the program should encourage the teachers to understand genetic content and knowledge of representations and activities for their students' understanding. The program should provide the teachers a chance to learn correct concepts and learn examples of representations and activities in line with teachers' contexts for promoting learning at the same time. In addition, the teachers should have an opportunity to discuss the contents and how to teach them among the other teachers who are in the same community. Furthermore, they should have direct understanding in which genetic content knowledge and knowledge of pedagogy integrated into lesson plans and teaching practices.

### **5.3 Inquiry and Reflection as a Vehicle for Enhancing PCK in the Context of the Professional Development Program.**

To assist science teachers in developing their science content knowledge and PCK by themselves, contents and activities in the professional development programs were designed based on inquiry-approaches. Inquiry learning experiences tend to improve understanding of content knowledge as well as teachers' ability to represent the content for students' understandings—in other words, their PCK. Inquiry is a process that encourages learners to use scientific processes and skills to construct

meaningful knowledge and perceptions. In this study, 5E inquiry model consists of Engagement, Exploration, Explanation, Elaboration, and Evaluation used to stimulate science teacher to develop their own knowledge and teaching practices. They were instructed how to do activities of teaching based on 5E inquiry model. They also are supported to think and practice using the 5E inquiry model into genetic lessons.

In addition, reflection is as a process of creating and clarifying the meaning of experiences in terms of self. In this study, the teachers should have chance to reflect on their own knowledge and practices over the professional development program. The teachers will reflect on their knowledge and practices with other teachers, and improve them together from the professional activities. They also reflect on their feeling and understanding of knowledge and actions through reflective tools, such as weekly journals entities, cases.

#### **5.4 Workshop, Seminars, Case Discussion, Collaboration and Study Group are Professional Strategies for Promoting Development of PCK**

The workshop provides opportunities for the participants to focus intensely on topics of interest for weeks. In this study, a five-day workshop (7 hours per day) was offered as a primary means of in-service science teacher professional development. The workshop took place in a school during a holiday, and addressed educational knowledge such as, constructing concept map, describing scientific knowledge and doing hands-on activities which the teachers were engaged with genetic content knowledge, new materials and inquiry approach for teaching genetics. The workshop was a place where teachers, two science educators, a scientist, and an educational researcher collaborated to develop teachers' knowledge and practices for teaching genetics. Working collaboratively with the scientist, the science teachers had opportunities to learn more about how the scientific process works, what scientists do, and how and why they do it. In their role as content experts, scientists helped the teachers build confidence in teaching science. Also, through working with science educators, the educators modeled inquiry and provided it with new insights and experiences of teaching. In addition, the workshop offered the science teachers who

came from the same context thought and developed their genetic lesson plans and shared their ideas and problems from their teaching experiences in small groups. Furthermore, the teachers practiced as reflective persons on their understanding in this workshop.

Seminars tend to be more oriented toward sharing knowledge and experiences through discussions. Two seminars were offered during weekend, each lasting 7 hours a seminar. One seminar was implemented in the second week of the teachers' teaching genetics. The other seminar was provided in the fourth week of their teaching. Cases of problematic teaching in genetic were used to generate issues for discussion among three teachers, two science educators, and a scientist during seminars. Teacher-generated cases serve as a vehicle for reflection and changing practice. Cases helped the teachers to develop skills of critical analysis and problem solving, acquire broad repertoires of pedagogical techniques, developed higher-order thinking, and engage in reflective practice. Case discussions offered groups of teacher the opportunity to reflect and analyze what the teachers understood and where their confusion about genetic content and practices occurred. In addition, revising lesson plans was done in the seminars. The teachers had a chance to work collaboratively to improve their own lessons before they taught them.

## **6. Set the Objectives of PCK-Based PD Program in Genetics**

The objectives of the PCK-Based PD Program were designed according to information from preliminary research study, goals and objectives of the 1999 National Education Act, the Science and Technology Teacher Standard, and the learning standards in the Science Curriculum Standard, reviewing the literature of teacher professional development for promoting PCK and conceptualizing the guiding principles of the program. The main objective of program is that lower secondary science teachers will be able to develop their CK and PCK in teaching genetics. The sub-objectives are that the teachers will be able to:

1. Explain genetic concepts in lower secondary levels based on acceptable view in scientists' community.
2. Plan, write, and revise the genetic lesson plans in lower secondary levels by selecting appropriate representation, activities, and instructional media for students' understanding in genetics.
3. Discuss strengths and weakness of representation, activities, and instructional media.
4. Teach the genetic lessons in ways of understandable for students.
5. Reflect on and develop their CK and PCK and genetic teaching practices.

## **7. Design Content, Learning Activities, Instructional Materials**

From the objectives of the program, content, learning activities and instructional materials are shown below. During designing, and developing the instructional materials, the researcher as developer consulted them among the research team for improving and checking accuracy and validity of contents in the program consistent with the objectives. The science educators helped to check accuracy and validity of the contents of activities, worksheets, and documents and check organizing sequences of learning activities. The scientist helped to check accuracy of genetic content and documents concerning science. The science educators and scientist also helped the researcher to check accuracy and suitability of instructional materials and learning resources used in the teacher professional development.

## **7.1 Contents**

1. Genetic concepts
2. Science curriculum
3. Constructing concept map
4. Teaching strategies relied on 5E of inquiry
5. Writing Cases
6. Developing Lesson plan

## **7.2 Activities**

1. Introduction
2. Constructing genetic concept map and checking understanding of genetic concepts within small group
3. Description genetic contents accompany with hands-on activities of inquiry teaching in five genetic lessons in small group
4. Planning, writing, trying-out, presenting and revising genetic lesson plans based on the standards and teachers' contexts
5. Writing and discussing on cases
6. Reflection of self- learning, knowledge and practices

## **8. Implementing and Revising PCK-Based PD Program in Genetics**

After the validity of contents and activities were checked by the science educators and scientist, the PCK-Based PD Program was implemented on the first week of October 2006. While a five-day workshop was offered for lower secondary science teachers, the researcher reflected and revised the contents and activities during and after the learning activities day-by day consistent with situation. For example, when the teachers were asked to construct a genetic concept maps, most teachers didn't understand the concepts. The researcher extended time for discussing on the meaning of the concepts, because if the teachers didn't understand the correct concepts, the teachers were not able to develop their PCK. The researcher also provided additionally opportunities for the teachers to ask and share their understandings with their other science teachers and the research team. In addition, the researcher adjusted time for doing next activities. All activities of the program were described below.

### **Activities of the PCK-Based PD Program in Genetics**

The PCK-Based PD Program in genetics consisted of three main activities, a five-day workshop, teaching genetics and seminars. All activities aimed at developing the lower secondary science teachers' PCK for teaching genetics.

First, the science teachers participated in a five-day workshop at the first week of October, 2006. The activities were shown in Table 4.1.

**Table 4.1** Activities in a five-day workshop

Day	Topics	Objectives	Activities	Time
1	1.1 Introduction	<ul style="list-style-type: none"> <li>• Know and construct relationships with each other.</li> <li>• Know how to do in the workshop.</li> </ul>	<ul style="list-style-type: none"> <li>• Find individually name and name of school of teachers who are able to answer genetic questions</li> <li>• Present the finding</li> </ul>	30 mins.
	1.2 What your students should know?	<ul style="list-style-type: none"> <li>• Explain meaning and construct concept map of genetic concepts and explain benefits of concept map in science classrooms.</li> <li>• Apply the concept map for teaching genetics.</li> <li>• Justify what genetic concepts should be taught in classroom.</li> <li>• Give sequence of genetic concepts in the classroom for lower secondary level.</li> </ul>	<ul style="list-style-type: none"> <li>• Construct and present a concept map in small group.</li> <li>• Describe how to construct a concept map and give example of a science concept.</li> <li>• Construct, present, and discuss a genetic concept map for lower secondary levels in small group.</li> <li>• Discuss the importance of a concept map.</li> <li>• Discuss, share and justify what genetic concepts should be taught and give sequences of genetic concepts taught in the lower secondary classrooms.</li> <li>• Science educator and Scientist answer teachers' questions about concept map.</li> </ul>	1 hour 30 mins

**Table 4.1** (Continued)

<b>Day</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
1	1.3 What does your genetic traits look like?	<ul style="list-style-type: none"> <li>• Explain concepts of genetic traits, dominant and recessive genetic traits, genotype and phenotype.</li> <li>• Identify genetic traits and phenotype in their families.</li> <li>• Identify the advantages and disadvantages of activities and media for teaching these concepts.</li> </ul>	<ul style="list-style-type: none"> <li>• Do a activity of genetic traits based on 5E inquiry in small group.</li> <li>• Discuss and present the results of doing the activity.</li> <li>• Describe additionally concepts of genetic traits, dominant and recessive genetic traits, phenotype and genotype.</li> <li>• Discuss and present the advantages and disadvantages of the activities and media.</li> </ul>	1 hour 15 mins.
	1.4 What does your lesson looks like?	<ul style="list-style-type: none"> <li>• Analyze relationships between curriculum and contents in a lesson plan.</li> <li>• Modify the genetic lesson plan in line with the requirement of curriculum.</li> </ul>	<ul style="list-style-type: none"> <li>• Analyze, discuss, and present consistency of contents in a lesson plan with requirement of the IPST science curriculum in small group.</li> <li>• Science educator and Scientist answer teachers' questions about writing lesson plans.</li> <li>• Modify a lesson of genetic traits that will be taught in real classroom in small group.</li> </ul>	1 hours 45 mins.
	1.5 What have you learned?	<ul style="list-style-type: none"> <li>• Reflect their own learning from all activities today</li> </ul>	<ul style="list-style-type: none"> <li>• Give individually level of satisfy of learning through each activity and reasons.</li> </ul>	15 mins
2	2.1 What does offspring look like?	<ul style="list-style-type: none"> <li>• Be aware of Mendel's work (nature of science).</li> <li>• Explain concepts of Mendel's work, monohybrid cross, and Punnett squares and</li> </ul>	<ul style="list-style-type: none"> <li>• Engage the teachers with a situation.</li> <li>• Read, and present the Mendel's work.</li> <li>• Do the activities based on 5E inquiry and present the</li> </ul>	2 hours 45 mins.

**Table 4.1** (Continued)

<b>Day</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
2	2.1 (continued)	Relationships of these concepts and genetic traits of offspring. • Predict genotype and phenotype of offspring.	Findings in small group. • Answer the teachers' questions.	
	2.2 Inquiry	• Explain inquiry. • Analyze activities based on inquiry.	• Doing an inquiry activity individual. • Analyze and present the inquiry activity. • Discuss what inquiry is. • Describe additionally inquiry.	45 mins.
	2.3 What does your lesson look like?	• Modify own lesson plan of Mendel's work, genotype, phenotype and monohybrid cross.	• Analyze lesson plan based on inquiry. • Create and/or modify and write a lesson plan of Mendel's work, genotype, phenotype and monohybrid cross in small group. • Ask questions from teachers.	1 hour 30 mins.
	2.4 What have you learned?	• Reflect their own learning from all activities today	• Give individually level of satisfy of learning through each activity and reasons.	15 mins
3	3.1 Relationships among gene, chromosome, and DNA	• Draw relationships among chromosome, gene and DNA. • Explain relationships among chromosome, gene and DNA.	• Draw and present relationships among chromosome, gene and DNA in small group.	30 mins.

**Table 4.1** (Continued)

<b>Day</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
3	3.2 How do the cells increase?	<ul style="list-style-type: none"> <li>• Explain the important events of mitosis division and cytokinesis.</li> <li>• Construct model of mitosis division.</li> <li>• Analyze advantages and disadvantages of a variety of activities and media in this lesson.</li> <li>• Create assessment and evaluation in lesson of mitosis division.</li> </ul>	<ul style="list-style-type: none"> <li>• Do a variety of activities based on 5E inquiry in small group.</li> <li>• Construct and present model of mitosis division.</li> <li>• Discuss advantages and disadvantages of a variety of activities and media in this lesson.</li> <li>• Discuss and create assessment and evaluation in lesson of mitosis division.</li> </ul>	2 hours 30 mins.
	3.3 How is genetic information transferred from parent to offspring?	<ul style="list-style-type: none"> <li>• Explain the important events of meiosis division and relationships between meiosis division and genetic inheritance.</li> <li>• Identify advantages and disadvantages of a variety of activities and media in this lesson.</li> </ul>	<ul style="list-style-type: none"> <li>• Role-play meiosis division</li> <li>• Describe and ask questions of meiosis division.</li> <li>• Discuss advantages and disadvantages of a variety of activities and media in this lesson.</li> </ul>	1 hour 15 mins.
	3.4 What does your lesson look like?	<ul style="list-style-type: none"> <li>• Modify own lesson plan of mitosis and meiosis division.</li> </ul>	<ul style="list-style-type: none"> <li>• Create and/or modify and write a lesson plan of cell division in small group.</li> <li>• Ask questions from teachers.</li> </ul>	1 hour
	3.5 What have you learned?	<ul style="list-style-type: none"> <li>• Reflect their own learning from all activities today</li> </ul>	<ul style="list-style-type: none"> <li>• Give individually level of satisfy of learning through each activity and reasons.</li> </ul>	15 mins

**Table 4.1** (Continued)

<b>Day</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
4	4.1 What does an actual DNA strand really look like?	<ul style="list-style-type: none"> <li>• Explain structure and function of DNA and DNA replication.</li> <li>• Construct model of DNA.</li> <li>• Identify advantages and disadvantages of a variety of DNA model.</li> </ul>	<ul style="list-style-type: none"> <li>• Engage the importance of DNA and structure and function of DNA from a situation.</li> <li>• Learn DNA model and construct the model in small group.</li> <li>• Describe additionally about DNA.</li> <li>• Compare advantages and disadvantages of DNA models.</li> </ul>	3 hours 15 mins.
	4.2 Applied genetics	<ul style="list-style-type: none"> <li>• Explain DNA fingerprint.</li> <li>• Apply the genetic knowledge in real life.</li> </ul>	<ul style="list-style-type: none"> <li>• Doing an activity of DNA fingerprint through internet.</li> <li>• Discuss the importance of DNA fingerprint and genetic knowledge in real life.</li> </ul>	1 hour 30 mins.
	4.3 What does your lesson look like?	<ul style="list-style-type: none"> <li>• Explain DNA discovery and relationships between its structure and function.</li> <li>• Modify a lesson plan of DNA.</li> </ul>	<ul style="list-style-type: none"> <li>• Describe DNA discovery and relationships between its structure and function.</li> <li>• Create and/or modify and write a lesson plan of DNA.</li> </ul>	1 hour
	4.4 What have you learned?	<ul style="list-style-type: none"> <li>• Reflect their own learning from all activities today</li> </ul>	<ul style="list-style-type: none"> <li>• Give individually level of satisfy of learning through each activity and reasons.</li> </ul>	15 mins.

**Table 4.1** (Continued)

<b>Day</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
5	5.1 How do you teach genetic concepts?	<ul style="list-style-type: none"> <li>• Explain meaning of concepts of genotype, phenotype, dominant and recessive gene and solving problems and discuss teaching these concepts through a researcher-generated narrative case.</li> </ul>	<ul style="list-style-type: none"> <li>• Discuss on a researcher-generated narrative case about teaching concepts of genotype, phenotype, dominant and recessive gene and solving problems.</li> <li>• Present discussion.</li> </ul>	1 hour 30 mins.
	5.2 What does your lesson look like?	<ul style="list-style-type: none"> <li>• Select and present the modified lesson plans.</li> <li>• Analyze the advantages and disadvantages of a variety of activities and media.</li> <li>• Reflect and share teaching experiences in genetic lessons.</li> </ul>	<ul style="list-style-type: none"> <li>• Select and present as a modified lesson plan through microteaching in small group</li> <li>• Discuss, analyze, and suggest the advantages and disadvantages of a variety of activities and media in the lesson plan of each group.</li> <li>• Ask questions from teachers.</li> </ul>	4 hours
	5.3 What have you learned?	<ul style="list-style-type: none"> <li>• Reflect own learning.</li> <li>• Evaluate all activities in a five-day workshop.</li> </ul>	<ul style="list-style-type: none"> <li>• Give individually level of satisfy of learning through each activity and reasons.</li> <li>• Evaluate all activities in the workshop through a evaluation form.</li> </ul>	15 mins

Second, after the teachers had professional experiences through a five-day workshop, the teachers returned to their own schools to teach genetic lessons. Their genetics instruction ranged from six to seven weeks or forty to seventeen hours. Detail

of the lesson contents, concepts, sequence and time of teaching were determined by teachers independently. The scope of teacher's genetic lessons was shown in Table 4.2. The researcher followed-up to explore and help their practices in the classroom. Third, while the teachers were teaching genetics, the teachers were provided opportunities to reflect and improve their knowledge and practices through two seminars at the second and fourth of weekend. Each seminar lasted approximately six hours. A variety of activity was shown in Table 4.3.

**Table 4.2** Scope of teacher's genetic lesson plans

<b>Period</b>	<b>Lesson of</b>	<b>Time</b>	<b>Note</b>
1	Genetic traits	2-3 hours	
2	Chromosome, gene and DNA	3 hours	The first seminar on Saturday
3	Cell division	1-2 hours	
4	Mendel's laws and genetic inheritance	2-5 hours	The second seminar on Saturday
5	Genetic disorders and mutation	2 hours	
6	Applied genetics	2-3 hours	

**Table 4.3** Activities in two seminars

<b>Seminar</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
1	1.1 Discussion on cases	<ul style="list-style-type: none"> <li>• Write and discuss on the cases for solving problem of teaching genetic lesson.</li> </ul>	<ul style="list-style-type: none"> <li>• Write and discuss a narrative case of teaching genetics. (one case per one teacher).</li> <li>• Discuss about problems of using activities and media of teaching genetics and solve the problems.</li> </ul>	3 hours
	1.2 Discussion on teaching and learning	<ul style="list-style-type: none"> <li>• Discuss on the genetic concepts, advantages and disadvantages of activities and media, and students' learning.</li> <li>• Reflect knowledge of content knowledge.</li> </ul>	<ul style="list-style-type: none"> <li>• Open a video of teaching genetic and then discuss on meaning of concepts, advantages and disadvantages of activities and media, and students' learning.</li> <li>• Write own needs about knowledge of genetic concepts.</li> </ul>	1 hour
	1.3 Developing of lesson plan	<ul style="list-style-type: none"> <li>• Analyze the components of lesson plan.</li> <li>• Modify a lesson plan that will be implemented after the seminar.</li> <li>• Reflect own learning.</li> </ul>	<ul style="list-style-type: none"> <li>• Analyze and modify collaboratively a lesson plan that will be implemented after the seminar by teachers, educators, scientist, and researcher.</li> <li>• Prepare to write other case that is discussed on the next seminar.</li> <li>• Reflect own learning and give suggestions for development activities in the second seminar.</li> </ul>	2 hour

**Table 4.3** (Continued)

<b>Seminar</b>	<b>Topics</b>	<b>Objectives</b>	<b>Activities</b>	<b>Time</b>
2	2.1 Discussion on cases	<ul style="list-style-type: none"> <li>• Write and discuss on the cases for solving problem of teaching the genetic lesson.</li> </ul>	<ul style="list-style-type: none"> <li>• Write and discuss a narrative case of teaching genetics. (one case per one teacher).</li> <li>• Discuss about problems of using activities and media of teaching genetics and solve the problems.</li> </ul>	2 hours 15 mins.
	2.2 Reflection teaching and learning	<ul style="list-style-type: none"> <li>• Reflect own teaching and learning in genetics</li> </ul>	<ul style="list-style-type: none"> <li>• Open three video of teaching genetic (one example per one teacher and different lessons) and then discuss on meaning of concepts, and advantages and disadvantages of activities and media.</li> <li>• Ask some questions by teachers</li> </ul>	2 hour 15mins
	2.3 Development of lesson plan	<ul style="list-style-type: none"> <li>• Analyze the components of lesson plan.</li> <li>• Modify a lesson plan that will be implemented after the seminar.</li> <li>• Reflect own learning.</li> </ul>	<ul style="list-style-type: none"> <li>• Analyze and modify collaboratively a lesson plan that will be implemented after the seminar by teachers, educators, scientist, and researcher.</li> <li>• Reflect own learning and give suggestions for development activities in the second seminar.</li> </ul>	2 hour

## Summary

The research intervention, namely, PCK-Based PD Program in genetics was developed based on the preliminary research study, goals and objectives of the 1999 National Education Act, the Science and Technology Teacher Standard, the learning standard of the Science Curriculum Standard, and a review the literature of teacher professional development promoting PCK. The program was aimed at developing Thai lower secondary science teachers' PCK for teaching genetics. Contents and activities in the program were set based on the following conceptualized guiding principles: (a) science teacher is a learner who actively and continuously develops their profession; (b) understanding genetic content and knowledge of representation and activities based on their context as important aspects of development PCK; (c) inquiry and reflection are vehicles for enhancing PCK in the context of the professional development program; and (d) workshop, seminars, case discussion, collaboration and study group are professional strategies for promoting development of PCK. As a result, the research intervention or the program consists of activities in a five-day workshop, following up in teachers' classroom, and two seminars. The contents and activities were validated by the research team over the time of the program. Chapters 5, the findings of the implementation of the professional development program are reported.

## **CHAPTER V**

### **RESULTS OF THE STUDY**

#### **Overview of This Chapter**

This chapter presents the results of analysis of a variety of data to answer the research question, namely: “How do in-service lower secondary science teachers’ content knowledge (CK) and pedagogical content knowledge (PCK) develop related to genetics over the course of a teacher professional development experiences?. This chapter provides development of three cases of in-service lower secondary science teachers’ CK and PCK over the course of the teacher professional development experiences in genetics. Up to this, the pseudonyms were used to represent the in-service science teachers’ names, that is, Tunya, Yarinda and Tarinee. Within each case, their background and backgrounds, development of CK and PCK in teaching genetics are presented. In addition, this chapter involves the cross-case comparisons emerged from the analysis development of three in-service science teachers in the teacher professional development experiences.

#### **The Case of Tunya**

##### **1. Tunya’s Backgrounds, Students, Classroom and School**

###### **1.1 Tunya’s Backgrounds**

At the time of this study, Tunya was a 49-years old, female, in-service science teacher. She graduated with a four-year certificate of higher education in general science. After that she graduated with a four-year bachelor’s degree in secondary science teaching from the University in Bangkok. She expected further to study for a master degree in educational research and assessment if she was able to ask permission from administrators.

Tunya already had 28 years of science teaching experiences in a secondary school in Suphanburi province, Thailand. She always taught biology and sometimes geology and physics. During her years of science teaching, before educational reform in 1999 (revised 2002), she taught genetics for one hour a week over 10 years since it was a selective topic for lower secondary grades. After the educational reform, genetics was aligned as a required topic in her school curriculum in 2005. Hence, she must change her practices to teach genetics for 2 hours a week to lower secondary students. She expressed her feeling in teaching change that:

...I had difficulty to prepare my lessons from an hour to two hours for teaching genetics. Usually, concepts in genetic were taught in a selected topic less than required course. (Interview#1)

In this study, Tunya taught various science topics totally 19 periods a week including four science topics. She taught genetics for 14 hours of genetics as the required topic to seven classrooms of grade nine students. Based on her school curriculum, she selected students' text books in line with the IPST Science Curriculum by herself. She tried to use a various text books from multiple companies for guiding and organizing genetic concepts suitable with her students' learning. For example, the Life and Environment, published by the IPST, the Science level 3 (Vol.3), published by Modern academic centers (Mac). In addition, Tunya taught geology as a selected topic for one-period a week to three classrooms of grade 12 students. She also taught topic of substances in real life as a selected topic for grade eight students. Furthermore, she taught biodiversity for one-period a week to one classroom of grade nine students. She was not only teaching science, but also she was responsible for other tasks in her school, such as a head of school health, and a head of educational quality guarantee.

For her professional development experiences, she was a participant of many professional development programs provided by Thai educational institutes at the end of semester 2005 and 2006. First, she attended a three-day local curriculum program in which she employed how to do science project related to local curriculum.

Second, she enrolled a three-day science teacher leader professional development program. In this program, facilitators presented and gave various examples of teaching strategies for science discipline. She said that she got much knowledge and applied it in her classroom. Third, she attended an astronomic teacher professional development program. Facilitators encouraged her and other science teachers as learners who were learning astronomic concepts. She expressed her feelings about this experience in her interview that:

...I liked this kind of learning experiences in the professional development activities because I applied these activities in my classroom. While I was doing activities in the program, I was also thinking how I taught astronomy in ways of understandable and happy teaching for my students. I felt good as I was a learner because if we were students, we will know how our students' feelings are as they learn astronomy through these activities. (Interview#1)

When researcher asked Tunya's needs of professional development in genetic, she expressed her thoughts in following:

...I'd like to attend a science teacher professional development program in genetic because I had never participated. In addition, I wanted to gain knowledge of teaching genetics for grade nine students in this semester. Usually, I wanted to gain my learning experiences from all teacher professional development experiences. I didn't care how long the professional development was taken. I was willing to participate. I was glad that you [researcher] invited me to participate in your professional development program. (Interview#1)

## **1.2 Tunya's Students**

In this study, Tunya's teaching in genetic was studied one classroom of twenty-six students. Most of student came from agricultural and employed families. Twenty students had good attitude toward science. They liked science because they

gained science knowledge, had a chance to do some experiments and used computer. Furthermore, they were able to apply science knowledge for real life. The rest of students didn't like to learn science because they were confused and did not understand especially abstract concepts. Specifically, ninety students had never learned genetics, but the rest of them learned it in a science classroom.

### **1.3 Tunya's Classroom**

Tunya taught her genetic lessons in a biological laboratory. It is big and convenient. Teachers and students did activities in front-haft of the room and science learning resources was kept in the rest of room. There were biological charts such as mitosis and meiosis division, models, magazines, equipments, chemical substances, and reports of students' science projects. She also had a computer, a visualize aid, a transparency, a television, a VCD player and microphone in the room. Students and teachers saw rice fields from windows around the room. There were four electrical fans hanged on the ceiling. Tables are arranged in six groups. Students sat separate gender on a table. Four to six students worked in a same group through all semester.

### **1.4 Tunya's School**

Tunya's school is a moderate secondary public school in size. In 2006 academic year, there were totally 866 students in grade seven to twelve. The school is located in the center of a distinct of Suphanburi province near a river. People living in the same community of school were generally farmers and agricultural business. They built their houses very close to their relatives. Most of them are Buddhists and they were always pleased to attend Thai cultural activities in the community. In addition, there are many local learning resources within the community where Tunya's school is located including experts that had local wisdom and knowledge, agricultural factories, fresh-water fish farms, a crocodile farm, fog farms, pork farms, mango groves, rice fields, water chestnut fields, sugar-can fields, temples, hospitals, a river, markets, and rice mills.

In summary, Tunya was an in-service science teacher who was working over 10 years in a moderate, secondary public school in Suphanburi province. Although she graduated in general science, not biology directly, she attempted to teach genetic for students' understanding even though she less experiences in teaching genetics. She was a science teacher who had much important duty, however, as possible as, she wanted to develop her profession continually. Specially, she wanted to be a participant in a professional development of teaching genetic in this study. In addition, she taught genetics for twenty-six of grade nine lower secondary students who had moderate learning outcomes in science. Most students came from agricultural and Buddhist families. They had never learned genetics, however, they had good attitude toward science. Her classroom was a biological laboratory where was big and convenient and had many learning equipments and resources. In addition, her school is located in area of rich learning resources and within warm and cultural community.

## **2. Tunya's Content Knowledge (CK) Development in Genetics**

In this section, the results from multiple sources are analyzed in terms of (a) Tunya's CK development and (b) factors influencing Tunya's CK development in genetics.

### **2.1 Tunya's CK Development in Genetics**

Tunya gained a stronger understanding in some concepts. For example, initially, Tunya did not teach concepts of DNA fingerprinting in 2005. She had little knowledge about it. When she was asked how DNA fingerprinting was used to identify relationships between father and son, she was unsure about her answer. She said that:

...I did not know it [DNA fingerprinting] because it was new knowledge. I had to find out more about it. I thought that DNA that was extracted from blood, the roots of hair, or all body [I was not sure] was used for identifying

persons. DNA has many stripes. In identifying between father and son, I forgot how many points on the DNA stripes from father and son are similar, (1<sup>st</sup> Concept Interview).

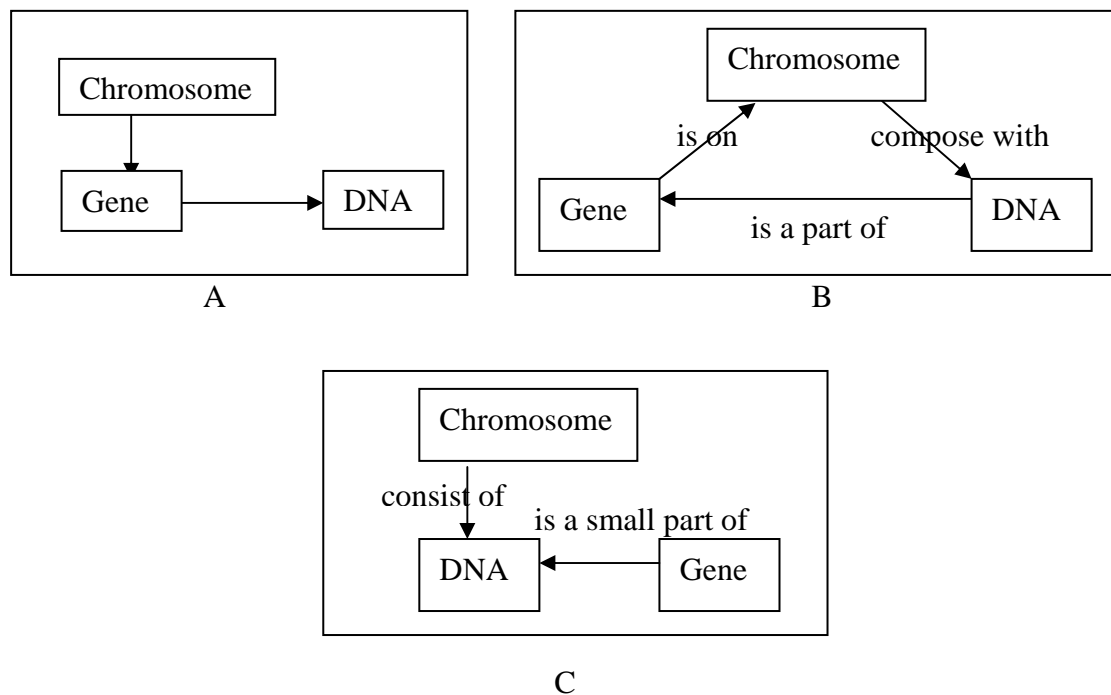
After she did the activity “Applied genetics” (Table 4.1: Activity 4.2), where she did an activity on DNA finger printing with other science teachers using the 5E inquiry, and discussed the importance of DNA finger printing in real life, in a five day workshop, her understanding increased. She explained this about DNA finger printing:

...I was sure that DNA was extracted from every cell that has a nucleus. This extracted DNA was fragmented by restriction enzymes, and DNA fragments were poured on the tray of agarose gel. After that, DNA fragments on the agarose gel were separated in a gel electrophoresis; then, each DNA fragment was matched with a probe on a nylon sheet. Next, the matched DNA was placed on the x-ray film, and DNA stripes were observed. If two rows of DNA strips were similar, the two people were identified as relations, (6<sup>th</sup> Interview of Teaching).

Another example, initially, before Tunya participated in the PCK-Based PD Program, she knew about concepts of dominant and recessive genetic traits, “dominant traits are expressed more than recessive traits; in contrast, recessive genetic traits are expressed less than dominant traits,” (Lesson plan in 2005). After she had a chance to discuss those concepts during a hands-on activity called “What do your genetic traits look like?” (Table 4.1: Activity 1.3) in the workshop and discussed her written case in the seminars, she understood that “dominant genetic traits can be expressed both homozygous and heterozygous” (1<sup>st</sup> Interview of Teaching).

Furthermore, she gained a better understanding of relationship between the concepts. For example, initially when she expressed her knowledge of relationships among genes, chromosomes, and DNA, she knew the functions of the three concepts, that they play important roles in transferring genetic information to

offspring, however, she did not know their relationships as shown in the Figure 5.1: A. From the activity of constructing a concept map of genetics (Table 4.1: Activity 1.2) and the activity, “Relationships among genes, chromosomes, and DNA” (Table 4.1: Activity 3.1), it is evident that she still had misunderstandings on the relationships, however, she have accurately constructed the concept map, (Figure 5.1: B). During teaching genetics in her real classroom in 2006, she had a chance to reflect on the functions and structures of the three concepts from her instructional media by playing a VCD of “DNA and Life”, and showing pictures. Finally, she correctly understood the concepts as shown in Figure 5.1: C.



**Figure 5.1** Tunya's conceptions of relationship among chromosome gene and DNA  
 Source: (A) from the 1<sup>st</sup> concept interview; (B) during a five-day workshop and; (C) from the 2<sup>nd</sup> concept interview

However, she still possessed misconceptions on some topics. For example, in teaching the second lesson in 2006, she understood that sex chromosomes (XX or XY) were found only in a sex cell, while autosomes were found only in somatic cells (3<sup>rd</sup> Researcher's Field Note).

Also, initially, she did not understand some relationships between genetic concepts because she did not have sufficient in depth knowledge on certain topics, such as genetic disorders. She understood only that "genetic disorders appear on autosome and sex chromosomes." She did not know the relationship between genetic disorders and mutations. After teaching in 2006, she reflected on her learning in the journal, saying that, "I had problems with some genetic disorders, such as Down's syndrome. This disorder came from an error in the number of autosomes, not sex-chromosomes. I wondered whether or not the Down's syndrome was transferred to the next generation through a sex cell and how the syndrome related to mutations," (5<sup>th</sup> Teacher's journal). This shows that she did not understand that mutations were a cause of genetic disorders that were transferred to offspring in a sex cell.

Additionally, she did not understand the relationship between Mendel's laws and cell division. From the fourth teaching interview it was evident that, she knew Mendel's laws well, but she did not understand cell division, especially meiosis, in depth. She knew only that an offspring's traits were inherited by genetic information from the father and mother in halves, but she did not know by what processes and why these processes occurred.

## **2.2 Factors Influencing Tunya's CK Development in Genetics**

There were many factors that supported and hindered Tunya's development of CK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the professional development program; (b) personal characteristics and beliefs; and (c) teaching experiences in genetics.

First, the activities in the PCK-Based PD Program in teaching genetics strongly impacted Tunya's CK development. In the workshop, when the developer described genetic concepts and Tunya did hands-on- activities using the 5E inquiry with the other teachers in the workshop, she had a chance to discuss the concepts in the lesson plans. She said:

...When I did the activity "Applied genetics" (Table 4.1: Activity 4.2) in the workshop, I got better knowledge on DNA fingerprinting than I initially had. In addition, I brought this knowledge to the class to help students construct an understanding of the concepts, (Self-Assessment Questionnaire).

Furthermore, in the workshop, she had a chance to ask a scientist about some concepts that she did not understand so she could gain more knowledge. For example, she asked a scientist if, "a dominant genetic trait is always controlled by dominant genes, and if a recessive genetic trait is always controlled by recessive genes," (Researcher's Field Note in the Workshop).

In addition, in the seminars, when she had a chance to reflect on her understanding of genetics concepts from case discussions in small groups, she enhanced her understanding of genetic concepts. For example, she said:

...I learned accurate concepts; like that dominant genetic traits are not expressed more than recessive traits, (Researcher's Field Note of Discussing on Case in the First Seminar).

I learned accuracy of concepts [Mendel's laws, Punnett squares, cell divisions, genetic disorders] from discussions on cases and videos on teaching those concepts, (Self-Assessment Questionnaire).

Finally, when she was teaching, she had more understanding of genetic concepts from her instructional media that she provided to her students. For example, she learned correct concepts of chromosome, gene, and DNA from the VCD of "DNA

and Life”, and pictures. She said that “when I played the VCD and pictures in my PowerPoint, I learned what gene, chromosome, and DNA are and I knew their relationship, too.” (2<sup>nd</sup> Interview of Teaching)

Second, Tunya’s personal characteristics and beliefs impacted her development of her content knowledge in genetics. For example, she is a curious person, when she knew that she had misunderstandings or did not have sufficient content knowledge, she would search for more knowledge from learning resources, such as the internet and text books. For example, when she knew that she misunderstood about chromosomes, she said, “I must search the internet and look up more information to make sure what is the right number of chromosomes in sex cells and somatic cells”. (2<sup>nd</sup> Interview of Teaching)

On the other hand, initially, she trusted in an accuracy of text book, so she didn’t realize that she possessed misconception of genetic concepts. In the text book wrote that “gene consists of DNA”, so she held her misconception in Figure 5.1: A. However, finally she was able to develop her understanding in these concepts.

Third, teaching experiences impacted her development of CK. She was a biology teacher, so she knew some genetic concepts. She also taught genetics for one hour a week over 10 years as a selective course. Hence, she easily gained her understandings of genetics. From the researcher’s field notes in the workshop, she usually explained her correct understandings to other teachers in her group.

### **2.3 Summary of Tunya’ CK Development thought the PCK-Based PD Program**

Tunya gradually developed many genetic concepts. She got better genetic concepts that were provided in the workshop, such as DNA fingerprinting, the relationship among chromosomes, genes, DNA, cell division, Mendel’s laws, and genetic traits. However, some concepts, such as mutation, she still had misconceptions on because it was not discussed in the workshop. As a result, she has

correct information and misconceptions because of three factors. First, the activities in the PCK-Based PD Program in teaching genetics consisted of describing and discussing genetic concepts during hands-on activities, asking questions from a scientist in the five day workshop, discussing and reflecting on the teachers' and researcher's written cases in the seminars, and reflecting on her instructional media that she used in her classroom. This helped her understand more about genetic concepts. Second, personal characteristics and beliefs were a factor that impacted her development of CK. She trusted in the text book, so she possessed some misconceptions. However, she wanted to develop her knowledge that she knew was incorrect or unclear. Finally, her teaching experiences in biology and genetics impacted her development of CK.

### **3. Tunya's PCK Development**

In this section, the results are analyzed in terms of Tunya's development of PCK based on the definition of PCK in this study. That is, PCK is lower secondary science teachers' abilities to transform genetics content knowledge and knowledge of representations and activities he or she possess into forms that are useful for helping lower secondary science students comprehends genetics concepts. Hence, Tunya's PCK development presented below are; (a) content knowledge into teaching genetics, (b) knowledge of representations and activities in teaching genetics; and (c) other teacher's knowledge emerged from the activities in the PCK-Based PD Program in teaching; and (d) factors influencing development of PCK in teaching genetics.

#### **3.1 Tunya's Content Knowledge into Teaching Genetics**

Consistent with the development of the CK presented above, Tunya's understanding of genetic concepts affected her confidence in teaching. For example, Tunya said that while teaching DNA fingerprinting in 2005, it was new knowledge for her, so she was not able to think of an activity for her students, except to have students search for knowledge, (5<sup>th</sup> Interview of teaching). After she did the hands-on-activity "Applied genetics" (Table 4.1: Activity 4.2) through 5E inquiry with the other

teachers in the workshop, she had a chance to discuss the concepts in those lessons and she learned that the activity was probably suitable for her students. When she was confident in teaching, she was able to think about activities for her students. Finally, in her lesson in 2006, she gave her students a situation where they had to identify a father and son, and a murderer.

Furthermore, when she understood the relationships among concepts, she became more aware of the importance of teaching them with activities like constructing concept maps (Table 4.1: Activity 1.2) and the lesson “Relationships among genes, chromosomes, and DNA” (Table 5: activity 3.1) from the workshop. For example, in teaching chromosomes, genes, and DNA, she tried to help her students understand their relationships. She knew that if her students understood their relationships, they would be able to explain their structures and functions. Therefore, she had her students draw a chromosome and explain it. In addition, she used an analogy of a train to explain a strand of DNA; each carriage of the train represented a part of a gene. Furthermore, she gave chances for her students to construct concept maps of the three concepts.

However, her misconceptions affected her students’ understandings. She did not know where two types of chromosomes (autosomes, and sex chromosomes) were in the cell. When she taught these concepts in 2006, she made the mistake that sex chromosomes (XX or XY) are found only in a sex cell, while autosomes are found only in somatic cells (3<sup>rd</sup> Researcher’s Field Note). She said:

...Actually, I thought that I knew about them well [autosomes and sex chromosomes]. However, when I was teaching, I felt that I was confused and I provided incorrect information to my students. I must tell them the correct concepts next time that the autosomes and sex chromosomes are found in every cell. (3<sup>rd</sup> Interview of Teaching)

### **3.2 Tunya's Knowledge of Representations and Activities into Teaching Genetics**

Initially, in the previous lesson, she always used the same activities for all six lessons. She encouraged her students to search for knowledge from a library and the internet and present their knowledge (Appendix G). However, at the first period of the PCK-Based PD Program, Tunya reflected on her understandings of the strengths and weaknesses of representations and activities with other teachers through the 1<sup>st</sup> case A (Appendix B). For example, in the case, a teacher had her students learn mitosis division by pictures and explanations and then learn meiosis division by lecture. However, Tunya thought that concepts of cell division should not be represented through pictures, but with animation. She also gave for her students to construct a model of mitosis with plasticine and explain their understandings. Her reason was that students were more interested and imagined what happened in a cell.

During the program, she was got stronger in her understandings of the strengths and weaknesses of representations and activities through the hands-on activities in the five day workshop, discussion on her written cases, and videos of her teaching in two seminars with other teachers, and talks with the research team. First, she selected the advantages of the representations and activities and revised them. Then, she was more confident in using them during her teaching in 2006. For example, in the workshop, she discussed role-playing for representing each stage of mitosis and meiosis and using animation to the research team. In the 3<sup>rd</sup> Researcher's field notes, it was stated that Tunya used animation to explain each stage of mitosis and meiosis. In addition, she provided her students with role-playing activities where they were chromosomes in each stage of mitosis and meiosis. She was confident in using a role-playing activity to teach chromosomes (Appendix G). She wrote in her case D that:

...My students were interested in and acted curiously about chromosomes in each of the mitosis and meiosis divisions. My students enhanced their learning from the previous year.

For another example, when she planned to teach the lesson on genetic disorders, she engaged her students' interests through pictures of a person with Down's syndrome and gave her students an activity to do. After she discussed her lesson plans for genetic disorders with the other teachers and the research team at the seminar, Tunya thought that the pictures were not interesting to the students, and she revised her lesson. In the 5<sup>th</sup> researcher's field notes, it is stated that in her actual class, she played a comedy movie in which a Down's syndrome child was an actor. Then, she gave her students a question to answer. Her students were very interested in the activity and were able to think of some questions.

Also, when she planned the lesson on chromosomes, genes, DNA, and their relationships, she began her lesson by showing a picture of a person and asking the question, "Why do you look like your parents?" Then, she used a VCD on DNA and life to explain the answer. After discussing this lesson with other teacher's cases in the seminar, she saw the strengths of calling students to the front of classroom, so she called students to the front of classroom, instead of showing the picture and asking the same question. She said that, "...my students were interested in their friends more than my picture". (2<sup>nd</sup> Interview of Teaching)

As for another example, in the lesson on chromosomes, genes, and DNA, she used an analogy between a Chinese doughnut and chromosomes, a train and a stand of DNA, a carriage of trains and the parts of genes. After she used these analogies, she understood that these representations were helpful for her students in learning these concepts. She said that:

My students were able to explain about the structures and functions of these concepts [chromosome, gene, DNA] by referring to my analogies. (2<sup>nd</sup> Interview of Teaching)

After she understood more about the strengths and weaknesses of representations and activities, she revised her lesson plans for the next semester. For example, when teaching Mendel's work (Appendix G), she used the activity "a family

of paper animals” for representing what and how genetic information is inherited. After she finished her lesson, she was impressed with this activity because her students had been very interested in it. However, she thought that could improve the directions because she made a mistake. Next time, she will write it more clearly to guide students’ thinking (4<sup>th</sup> Interview of Teaching). Additionally, in the 2<sup>nd</sup> teaching interview, she said that when teaching about DNA, she had her students construct a paper model of DNA, and then thought that she could improve the model. Therefore, she crafted new paper models of DNA, consisting of the position of C, carbon, on sugar as a component of a nucleotide. This will allow her students to understand more about nucleotides on a DNA structure. Also, when teaching about Mendel, she said in the 4<sup>th</sup> teaching interview that she would improve a picture on the worksheet because the picture was not clear, and it was black and white. In addition, she would improve the PowerPoint used for the explanation in this lesson. She wanted to find a number of animations on Mendel’s works and put them in the PowerPoint to help her students understood what he did.

### **3.3 Other Tunya’s Knowledge Emerged from the Activities in the PCK-Based PD Program into Teaching Genetics**

Two types of Knowledge emerged for Tunya while participating in the PCK-Based PD Program: knowledge of the 5E inquiry using student-centered teaching and the curriculum. Information on this is presented below

#### **3.3.1 Tunya’s Knowledge of the 5E Inquiry Relying on Student-Centered Teaching**

Tunya’s knowledge of 5E inquiry related to using activities in her teaching. In 2005 academic year, she used teaching strategies that relied on teacher-centered orientation. She always provided some questions for students and let them search for the answers in 2005. However, she did not know much about 5E inquiry.

Tunya's knowledge of 5E inquiry relied on student-centered teaching impacted on her organizing teaching of lessons. After she had a chance to do hands-on activities using 5E inquiry in the workshop and discuss on cases in the seminars, in her first three lesson plans, she tried to organize her lessons based on 5E inquiry and rely on student-centered orientation. However, her actions relied on teacher-centered teaching. For example, in the 2<sup>nd</sup> researcher's field notes on teaching chromosomes, genes, and DNA, her students draw a chromosome [engagement]. Then, she asked her students to pose their own questions about chromosomes, genes, and DNA. Students were quiet, so she ordered each group of students to note knowledge from the VCD on "DNA and life" [exploration]. Next, her students presented their knowledge, and she always guided the explanations from her students [explanation]. She also explained additional information about chromosomes, genes, DNA, and their relationships thorough a PowerPoint. After that, each group of students constructed and presented a model of DNA, following her directions [elaboration and evaluation]. After she finished her teaching, she said that:

...When I gave the opportunity for my students to ask what they wanted to know about the concepts [chromosome, gene, and DNA] and find the answers by themselves before I played the VCD, they were completely silent, so I had them do work. I thought this was a better way. When they presented their knowledge, they just read their notes, so I had to talk a lot alone. I thought that although they were quiet they still understood some of the concepts. (2<sup>nd</sup> Interview of Teaching)

However, after Tunya had two chances to discuss her teaching through cases and videos of her teaching with the other teachers and the research team in seminars, she was more aware of 5E inquiry emphasized student-centered orientation in the fourth to sixth lesson plans. For example, in the 6<sup>th</sup> researcher's field notes of the lesson on applied genetics, she engaged her students' interests with a famous singer's news of DNA proof and had them ask some questions. After that, she played a VCD of "DNA fingerprinting", while her students searched for their answers. Next, students did an activity on identifying a person. Then, students

investigated about the cloning and presented their findings. Next, she evaluated and assessed her students' learning through a worksheet and the construction of a concept map. She was successful in inquiry teaching in this lesson, because her students understood the concepts by themselves. She said that:

...In this lesson, I tried to give more time for my students to think and construct knowledge by themselves. I talked less than in the previous lesson. I thought that they were interested in my activities and understood the concepts. They also understood how genetic knowledge affected their lives, (6<sup>th</sup> Interview of Teaching).

### **3.3.2 Tunya's Knowledge of the Curriculum**

Tunya's knowledge of curriculum was affected on organizing the contents in her lessons. In the 2005 academic year, she selected and followed the basic genetic concepts and the organization in which they were taught in the text book. She taught all genetic concepts for 20 hours (Table 5.1). After she employed an activity on analyzing and discussing the IPST Science Curriculum in the workshop, Tunya changed the basic genetic concepts, the organization, the order they were taught in, and the duration for teaching to put them in line with the requirements of the curriculum (Table 5.1). She began her class with concepts of Mendel's laws, and then taught about chromosomes, genes, genetic disorders, and applied genetics, respectively. However, in 2006, she looked more carefully at her lessons. She started her lessons with concepts of genetic traits, then, added structure and functions of chromosomes, genes, DNA, their relationships, and cell division to develop her students' understanding from concrete to abstract concepts. After that, she added concepts on Mendel's laws and how to predict genetic traits. She still used teaching applied genetics and benefits of biotechnology in a similar way as with the 2005 lesson plans. From the interview, it is evident that although she added more basic concepts in 2006, she used less time because she understood better how to organize the concepts. She said about her changes that:

...From my previous teaching [in 2005], I found a problem in the organizing sequence of the teaching concepts that I followed from the text book. My students were not able to link their learning to new concepts. So, in 2006, I started my genetic lessons by teaching genetic traits. Based on the IPST text book and my experiences, I thought that genetic traits should be provided first because they were concrete concepts on where and how genetic traits come from, which my students were able to understand, (1<sup>st</sup> Interview of Teaching).

**Table 5.1** Tunya's plan for the basic genetic concepts, the organization and order they were taught in, and the duration for teaching those in the 2005 and 2006 genetics lesson plans

Lesson	2005 academic year		2006 academic year	
	Genetic Concepts	Time	Genetic Concepts	Time
1	Mendel's laws, and dominant & recessive genetic traits	3 hr.	Genetic traits, and dominant & recessive genetic traits	2 hr.
2	Functions of dominant and recessive gene, and relationship between chromosomes & genes	4 hr.	Structures & functions of chromosomes, genes, DNA, and relationship among chromosomes, genes & DNA	3 hr.
3	Autosomes, sex chromosomes, and gene on sex chromosomes	3 hr.	Mitosis division, meiosis division, and comparison between mitosis and meiosis	2 hr.
4	Genetic disorders on chromosome and gene	4 hr.	Mendel's laws, monohybrid cross, genotype, phenotype, and Punnett squares	2 hr.
5	Applied Genetics: genetic engineering, cloning, and GMOs	3 hr.	Genetic disorders on chromosome and gene, and mutation	2 hr.
6	Benefits of biotechnology: medical service, justice, society (e.g. DNA fingerprint), and human quality	3 hr.	Applied Genetics: DNA fingerprint, cloning, GMOs, and benefits of biotechnology: medical service, justice, society, and human quality	2 hr.
Sum		20 hr.		13 hr.

### **3.4 Factors influencing Tunya's PCK Development into Teaching Genetics**

There were many factors that supported Tunya's development of CK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the PCK-Based PD Program; (b) knowledge of student's backgrounds, conceptions, learning styles, and abilities, and (c) personal characteristics, beliefs, and experience teaching genetics.

#### **3.4.1 Activities in the PCK-Based PD Program in Teaching Genetics**

Hands-on activities for teaching genetics and discussing concepts, such as the strengths and weaknesses of the activities, helped Tunya understand both content knowledge and how to teach the concepts in line with 5E inquiry. For example, in activities "How do the cells increase?" (Table 4.1: Activity 3.2) and "How is genetic information transferred from parent to offspring?" (Table 4.1: Activity 3.3 ), Tunya learned hands-on activities and discussed concepts for teaching mitosis and meiosis division. From this, Tunya was able to understand the concepts of cell division in depth, and saw the advantages of role-playing as chromosomes in each stage of mitosis and meiosis.

Also, the research team helped Tunya develop her activities in her lessons and understand teaching that relied on a student-centered approach. After she discussed the strengths and weakness of representations and activities with the research team in the workshop and seminars, Tunya was able to develop her lesson plans based on their suggestions. For example, she planned to use the lesson on genetic disorders to stimulate her students' interests with pictures of a person who had Down's syndrome. After she discussed her lesson with the other teachers and the research team at the seminar, Tunya decided to use a comedy movie that had a Down's syndrome child as an actor, instead of using the picture because of suggestions from the research team. The researcher said, "I think that you should give your students a situation or real event or movie. That would probably interest them

more”, (Discussion in the 2<sup>nd</sup> seminars). After she discussed teaching lessons on genetic traits in the seminar with the research team and other teachers, she had problems teaching by relying on the student-centered approach. So, the science educator suggested to her that she should calm down when she taught and give more time to her students to explain important concepts, (Researcher’s Field Note in the 1<sup>st</sup> Seminar). After that, in fourth to sixth lessons on genetics, she taught the concepts by using inquiry based on the student-centered approach.

In the VDO’s and case discussions on teaching about content knowledge and representations with other teachers and the research team in the seminars, Tunya developed her teaching. She gained an understanding of concepts, and she revised her lesson plans for the future. For example, after discussions on one case, she saw that the strengths of the activities that her friend had used during the teaching of chromosomes, so she revised her lesson based on her friend’s activities. She wrote that:

...after I learned how to write on a case, I wrote my case and brought it in to discuss. I had a chance to discuss my problems with teaching and improve my teaching, (Self-Assessment Questionnaire).

Some activities in the workshop, such as constructing a concept map (Table 4.1: Activity 1.2) and analyzing the IPST science curriculum, (Table 4.1: Activity 1.4) helped Tunya make decisions about what concepts she should teach and how the concepts should be sequenced. For example, she made a decision to teach cell division in the 2006 semester. She wrote her thoughts in a journal and said:

...I thought I should provide cell division related to genetic inheritance to my lower secondary students, although cell division was taught only to the upper secondary students, because when my students understood how genetic inheritances were transmitted, they were able to understand their relationship in depth in the future studies, (1<sup>st</sup> Journal).

### **3.4.2 Tunya's Knowledge of Student's Backgrounds, Conceptions, and Learning Styles**

At first, Tunya's knowledge of her students' background effected her decision on using the activities and instructional media. She knew that her students' backgrounds were from the agricultural and employable families. When she planed her lessons, she was aware of what her students had. For example, she wrote in her journal that:

...when I taught about genetic traits, I provided an activity where my students brought a picture of their family and studied the genetic traits of their families individually. I considered that some of my students did not live with their families, so I adjusted my teaching so that students worked in groups, (1<sup>st</sup> Journal).

From the 1<sup>st</sup> researcher's field notes, it is evident that in class there were a few students who did not bring the pictures. She knew that they did not have parents, so she did not complain. She always observed them while they worked with their friends.

Tunya's knowledge of her students' conceptions impacted her processes of teaching. For example, in the lesson on genetic disorders, she turned on the VCD of a comedy movie that had a Down's syndrome child as an actor. She expressed her understanding of her students' conceptions:

...After I learned about my students' prior knowledge of Down's syndrome, I found that they understood a lot about characteristics of person with Down's syndrome. I changed my sequences of teaching. I did not let my students present their knowledge after watching the VCD, (5<sup>th</sup> Journal).

Additionally, Tunya's knowledge of her students' learning styles also impacted her planning. For example, she knew that her students did not

listen to her explanations, so she tried to add some other teaching strategies. She said that:

...If I used too much time to explain something, my students lost their interest in me. I had to use some questions to stimulate their thinking, (2<sup>nd</sup> Journal).

In addition, she knew that male and female students wanted to do activities separately, so she tried to separate them with some activities, such as the activity of role-playing. The girls were shy when they had to touch a boy's hands in the activity. Therefore, she revised her lesson for the next semester. Next semester, she will divide groups into boys and girls. If girls and boys must do the activity together, she will select students who are willing to do so. (Discussion on case D)

Furthermore, she knew that her students did not like to present in front of the class, so she let them present at their desk. She said, "My students did not like to stand in front of the class for presentations, so I permitted them to present with their groups," (3<sup>rd</sup> Interview of teaching).

Moreover, she knew that her students were not familiar with technical terms [English words] and did not like to say them, so she had her students say the Thai words first, then, gradually, say them in English, (3<sup>rd</sup> Researcher's field notes).

### **3.4.3 Tunya's Personal Characteristics, Beliefs, and Teaching Experiences**

Tunya's personal characteristics, beliefs and teaching experiences impacted her teaching and her students' learning. She always reflected on her own knowledge of teaching and wanted to improve. For example, she said that:

...From my teaching experiences in 2005, I knew that genes, chromosomes, and DNA were abstract concepts. I knew that it was difficult work. These

things are the smallest cell in the body and are not able to be seen. Hence, [in 2006], I studied hard about these in a five day workshop, text books, and other learning resources to understand them, (2<sup>nd</sup> Journal).

### **3.5 Summary Tunya's Development of PCK in Teaching Genetics**

Tunya gradually developed her PCK based on her CK and knowledge of representations and activities. She gained an understanding of genetic concepts and the relationship among concepts [DNA fingerprint, the relationship among chromosomes, genes, and DNA, cell division, and Mendel's laws, genetic traits] Therefore, she planned, selected, revised, and used the representations and activities for teaching these concepts confidentially. In her teaching, she knew about the strengths of using role playing for teaching cell division, the analogies between a train and gene, between a carriage and a DNA stand, animations for cell divisions, VDO for teaching chromosomes, genes, and DNA and DNA fingerprinting, and a movie for teaching Down's syndrome. Her students were more interested in her teaching. Furthermore, she knew the weaknesses of certain representations and activities, like with "a family of paper animals", and she revised or created new representations and activities if she found flaws while using them or if students misunderstood concepts because of them.

Consistent with the above paragraphs, other knowledge also emerged from the PCK-Based PD Program including, knowledge of 5E inquiry and relying on student-centered teaching and curriculum, and integrated that development in her PCK. She enhanced her understanding of 5E inquiry, so she knew how to provide activities and representations to enhance her students' understanding of the concepts, especially when she provided her students with inquiry based on student-centered teaching. Her students became more interested in her activities and understood the genetic concepts better. In addition, when she gained knowledge of the curriculum, she was able to organize the concepts for each lesson to be in line with the IPST Science Curriculum. She gave concrete concepts before abstract concepts, so her students would understand from outside to inside body.

There were many factors influencing Tunya's development of PCK for teaching genetics. First, the activities in the PCK-Based PD Program played important roles for her development of PCK because she had a chance to learn genetic concepts, teaching, and how to improve her teaching. Tunya had a chance to develop her knowledge and teaching through hands-on activities on teaching genetics and discussions about concepts, such as the strengths and weaknesses of an activity and how to teach that concept in line with 5E inquiry. In addition, she also discussed her writing cases, watched videos of her teaching, and prepared lessons on genetics to examine the strengths and weaknesses of the representations and activities with other teachers and the research team in the two seminars. Also she learned how to organize the genetic concepts in the curriculum for her teaching, by discussing and analyzing the curriculum in the workshop.

Also, Tunya's knowledge of her student's context, conceptions, and learning styles impacted her planning and teaching in the classroom. When she planned her lessons, she considered her students' backgrounds and the incomes of their families. In addition, she considered her students' conceptions, during her teaching. If she found that her students did not understand the concepts, she tried to help them immediately. Furthermore, she knew that her students did not like to listen to her explanations, show their work in front of the class, work with the opposite gender, and were not familiar with the technical terms, so she tried to avoid these situations or adjust her teaching.

Finally, her personal characteristics, beliefs, and teaching experiences affected her development of knowledge and teaching. Tunya was a good teacher who reflected on her own knowledge and teaching and wanted to develop her knowledge and teaching continually.

As a result, Tunya's development of her PCK depended on integrating all her knowledge on the CK, representations and activities, 5E inquiry, curriculum from the PCK-Based PD Program, and her own knowledge. Her own knowledge

included knowledge about the students, personal characteristics, beliefs, and teaching experiences, to effectively teach genetics in the future.

## **The Case of Yarinda**

### **1. Yarinda's Background, Students, Classroom and School**

#### **1.1 Yarinda's Backgrounds**

At the time of this study, Yarinda was a 27-year old, female, in-service science teacher working at a secondary school in Suphanburi province. She graduated with a bachelor's degree in general science and was now studying for a master's degree in science education, focusing on chemistry, during the summer.

Yarinda already had five years of experience in teaching science, including two years of specifically teaching genetics since it was a required topic. Her science teaching consisted of a general science course for lower secondary students and chemistry for upper secondary students. She was much more skilled at teaching chemistry rather than general science and she was the only chemistry teacher at her school. She taught chemistry as an advanced topic for three hours a week to one classroom containing grade 10, 11, and 12 students, while she taught basic chemistry for two hours a week to one classroom of the upper secondary grade levels. In this study, she had responsibility for teaching genetics for three hours a week to three lower secondary classrooms of grade nine. When she planned and wrote her previous lessons, she analyzed the 1999 National Education Act, the IPST Science Curriculum, the School Science Curriculum, as well as keeping in mind the student's ability. She particularly relied on the requirements of the IPST Science Curriculum. In this time, she mainly used and followed some activities in a textbook, *Science for Grade 9*, that was published by a private company.

In addition, from the Interview#1, Yarinda wanted to develop in her profession, especially by teaching genetics through a professional development. She had never participated in a science-oriented one before. Usually, she tried to enhance her knowledge from many professional development programs, but she was unable to ask permission from her administrators. She only had two experiences with teacher

professional development programs: action research and curriculum development. In the program focusing on action research, she learned how to do action research in the classroom through lectures. Yarinda hoped that one day she would do the research in her own classroom. Through her other professional experiences, she gained more knowledge on constructing an applicable curriculum.

## **1.2 Yarinda's Students**

In this study, Yarinda's style of teaching genetics was studied in the classroom. There were twenty-four students in her class. Most of students came from families working in agricultural businesses. Twenty-three students had a good attitude toward science. They liked science because they found the knowledge interesting, especially when they did some experiments. Furthermore, they were able to apply this scientific knowledge to real life. Only one student did not like to learn science because she felt sleepy in class and was so serious about learning science. Fifteen students had previously learned about genetics from regular books, textbooks, television, and newspapers, but the rest of them had never learned much about it before. In addition, a few of the students expressed feelings that they enjoyed science because the teacher relied on enjoyable and understandable strategies during the lessons.

## **1.3 Yarinda's Classroom**

In this study, Yarinda taught her genetics lessons in a chemistry laboratory. The room size was suitable for the numbers of students. Inside the classroom there were a whiteboard at the front of the room, a number of windows on the left hand side, a glass cabinet of chemical substances at the back of the room, and a bulletin board on the right hand side. There was also a television. There were six groups of tables and the students were separated into groups by Yarinda. There was a mixture of males and females to make a total of four students in each group.

#### 1.4 Yarinda's School

Yarinda's school is a small, secondary public school in the same district as Tunya's and Tarinee's school. In the academic year of this study there were a total of 360 students in grades 7 to 12. The school is located in a rural area of Suphanburi province. There are rice fields, sugar-cane fields, mango groves, and vegetable gardens growing around the school. People living in the same community of school were generally farmers and their employers. They built their houses very close to their relatives. Most of them are Buddhist and they were always pleased to attend Thai cultural activities in the community. In addition, there are many local learning resources within the community where Yarinda's school is located, including experts that have local wisdom and knowledge, fresh-water fish farms, cow farms, mango groves, rice and sugar-cane fields, temples, a health center, canals, rice mills, and sand ponds.

In summary, Yarinda was a novice chemistry teacher. She had experience in teaching science for only five years and teaching genetics for only two years. She graduated in general science, specifically the area of chemistry. She worked in a small, secondary public school, so she was the only chemistry teacher in the school. She had the duties of teaching four classes of genetics to grade nine and three classes of chemistry to upper secondary students. She had minimal experience in professional development in science although she did attempt to further develop both herself and her teaching. In this study, she was responsible for twenty-four grade nine students who generally had a moderate to high learning outcome in science. They had good attitudes toward science. They came from families employed in farming businesses. In addition, Yarinda used a chemistry laboratory that was suitable for the number of students in the genetics class. Within the classroom there was not a wide variety of instructional media and learning resources. However, the school was located around various learning resources, including agricultural resources and Buddhist cultural things.

## **2. Yarinda's Content Knowledge (CK) Development in Genetics**

In this section, the results from multiple sources are analyzed in terms of: (a) Yarinda's CK development, and (b) factors influencing Yarinda's CK development in genetics.

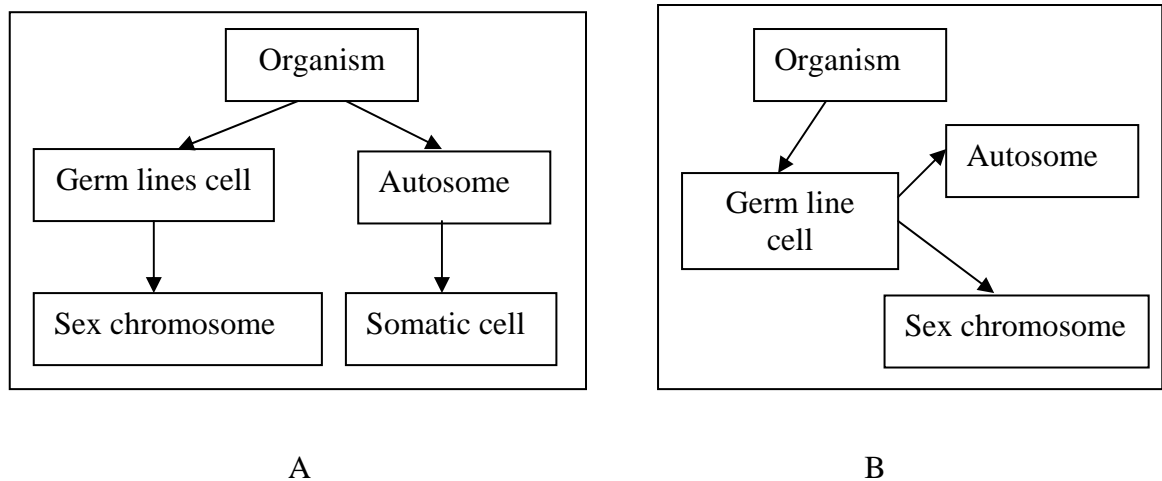
### **2.1 Yarinda's CK Development in Genetics**

In this section, the results of Yarinda's development of CK in aspects of development of genetic concepts and the relationships among concepts were presented.

Yarinda gained a stronger and more thorough understanding of genetics. The concepts that she did not have a good grasp of were studied more. For example, when she was initially asked about DNA fingerprinting in the first interview, she felt that she did not have a full understanding of this concept because it was new knowledge for her. She literally said, "I don't know." After she learned the activity of "Applied genetic" (Table 4.1: Activity 4.2) that she did the activity of DNA fingerprint with other science teachers through 5E inquiry and discussed the importance of DNA fingerprint in real life from a five day workshop, she increased her understanding. From the researcher's observations, she was able to explain this concept correctly. She also wrote in her lesson plan that "DNA fingerprinting is a scientific method for identifying people by extracting DNA and detecting DNA bands." Another example occurred when Yarinda was asked about Mendel's laws at the beginning of the professional development and she said, "I forgot what Mendel's laws were" (1<sup>st</sup> concept interview). While she did the activity of "what does offspring look like?" (Table 4.1: Activity 4.2) in the workshop, she had a chance to relearn these concepts. After the workshop she explained the concepts of Mendel correctly during her lesson. After teaching she was asked to explain a situation related to Mendel's laws (question 5 in Appendix A) and she said that:

...In each sex cell of a couple of rabbits that had the same genotype Bb, B and b were separated individually with the law of segregation. When the rabbits mated, genes B and b independently matched in the offspring's cells (BB or Bb or bb) because of the law of independent assortment. (2<sup>nd</sup> Concept Interview)

In addition, initially, she understood wrong about the division of autosomes and sex chromosomes (Figure 5.2: A). After she discussed these with the research team during her teaching, she had correct conceptions (Figure 5.2: B).

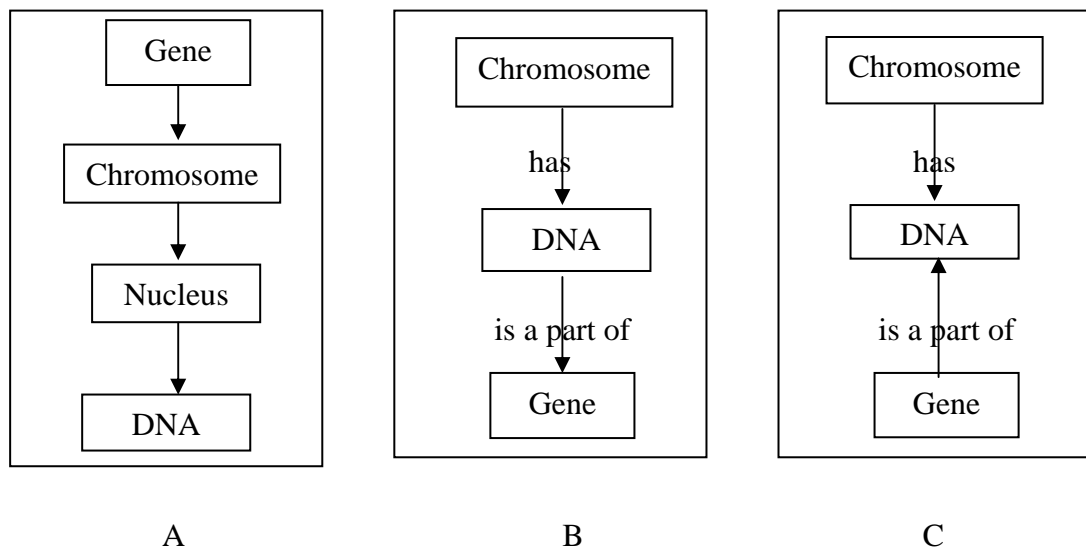


**Figure 5.2** Yarinda's concepts of chromosomes in a cell

Note: (A) At the beginning of the PCK-Based PD Program (from the 1<sup>st</sup> concept interview); (B) after participating in the program (from the 2<sup>nd</sup> concept interview)

Moreover, Yarinda developed her understandings in the relationship among genetic concepts. For example, her improved understanding of the relationship between and among concepts was prevalent when talking about chromosomes, genes, and DNA with the other teachers and the research team. During the 1<sup>st</sup> concept interview, because of a lower understanding of the structure of chromosomes, genes, and DNA, she was confused on the correct placement of these topics in her mind map (Figure 5.3: A). After she developed her knowledge through the activity of

“Relationships among gene, chromosome, and DNA” (Table 4.1: activity 3.1) in the workshop, she continued to remain confused about their relationships (Figure 5.3: B). Because, within the textbook, it said that “genes consist of a nucleic acid, called DNA”, so she understood that a DNA strand is a small part of a gene. After she got a better explanation from a colleague, she finally possessed the correct idea (Figure 5.3: C). At the same time, Yarinda also learned how to use and construct concept maps as a technique for strengthening her understanding of the ideas. She added some linking words to the maps to make the ideas more concrete to her.



**Figure 5.3** Yarinda’s conceptions of the relationship among chromosomes genes and DNA

Note: (A) at the beginning of the program (the 1<sup>st</sup> concept interview), (B) after a five-day workshop (from teacher’s documents), and (C) after her teaching (from the the 2<sup>nd</sup> concept interview)

## 2.2 Factors Influencing Yarinda’s CK Development in Genetics

There were many factors that supported and hindered Yarinda’s development of CK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the professional development program, and (b) Yarinda’s personal characteristics and beliefs.

### 2.2.1 Activities in the PCK-Based PD Program

The activities in the PCK-Based PD Program in teaching genetics strongly impacted on Yarinda's CK development. In the workshop, when the developer described genetic concepts, and Yarinda did hands-on the activities in each lesson plan through 5E inquiry with the other teacher in the workshop, she had a chance to discuss concepts in those lessons and gained her understanding of genetic concepts. For example, she said that:

...From the activity [Relationships among gene, chromosome, and DNA, Table 4.1: Activity 3.1], I discussed these concepts with my peers, I understood more, but I feel that I didn't understand these completely, (Self-Assessment Questionnaire).

Furthermore, in the workshop, some participants asked a scientist some concepts that Yarinda didn't understand, so she gain her knowledge of genetics, too. For example, Tunya asked a scientist that "a dominant genetic trait always is controlled by dominant gene, and a recessive genetic trait always is controlled by recessive gene". After the scientist answered, Yarinda understood that a dominant genetic trait is expressed when dominant a pair of homozygous and/ or heterozygous genes is matched, (Researcher's Field Note in the Workshop). Other example, after she taught about numbers of chromosome in a cell, she didn't feel confidently whether or not she understood right. She asked the researcher immediately, so she understood correctly that every cell had the same numbers of chromosomes, that is, 23 pairs of chromosomes, (Researcher's Field Note).

In addition, in the seminars, when she had a chance to reflect her own understanding of genetics concepts from discussion on case in small group, she gain her understanding in genetic concepts. For example, she said that:

...I was more aware of my conceptions during I wrote on case [case of teaching chromosome, gene, and DNA] that I confused something, and when

we came to discuss on it again, I just understood them completely that a chromosome consists of DNA and histone and non-histone protein, and gene is a small part of DNA strand (Researcher's Field Note of Discussing on Case in the First Seminar).

For a second example, she initially had a misconception about the division of autosomes and sex chromosomes (Figure 5.2: A) and transferred this incorrect knowledge to her students. Actually, she did know the correct way of doing it (Figure 5.2: B). She wrote about this case and brought her thoughts to discuss with other teachers at the second seminar

...After my teaching of cell division, I thought back about it. I just realized I had taught it wrong. I wrongly told my students that males and females had the same autosomes that they didn't determine sex, but different sex chromosomes that determined sex. The 22 pairs of autosomes were divided by mitosis division, while the sex chromosomes (23<sup>rd</sup> pair of chromosomes) were divided by meiosis division. As a result, my students understood it wrong so I would have to explain it correctly during the next period of teaching. I will tell them that sex cell had 23 pairs of chromosomes that are divided by meiosis division. (Writing on Yarinda's Case)

### **2.2.2 Yarinda's Personal Characteristics and Beliefs**

She always improved her knowledge and teaching. For example, after she was interviewed about knowledge of DNA fingerprint, she said that she tried to find more information on the topic, (Researcher's Field Note).

In addition, she was interested in enlarging her knowledge of genetics for more effective teaching. For example, after she finished teaching cell division, she had to question whether or not the process of meiosis division occurred in a child since this division involved a sex cell. She said that "...I need to know more about this. If I had more knowledge about this, I would be able to explain how

meiosis division works in teenagers and women.” In addition, “...I need to know more about similarities and differences between mitosis and meiosis division because the concepts are very complex and deep.” (3<sup>rd</sup> Interview of teaching)

On the other hand, initially, she trusted in an accuracy of text book, so she didn't realize that she possessed misconception of genetic concepts. The text book wrote that “genes consist of a nucleic acid, called DNA”, so she held her misconception in Figure 5.3: B. However, finally she was able to develop her understanding in these concepts.

### **2.3 Summary of Yarinda's CK Development in Genetics**

After Yarinda had been challenged with a variety of the PCK based PD program consisting of describing and discussing on genetic contents in the five-day workshop, writing and discussion on case in seminars and reflecting on her genetic knowledge during teaching with science other teachers and the research team, she enhanced and changed her genetic conceptions of DNA fingerprints, numbers of chromosomes in a cell, Mendel's laws, and the relationship among chromosomes, gene, DNA. In addition, Yarinda's CK development was based on her personal characteristics and beliefs. She wanted to develop herself all time, so she tried to know completely on her insufficient knowledge of genetic concepts.

### **3. Yarinda's Pedagogical Content Knowledge (PCK) Development in Teaching Genetics**

In this section, the results are discussed in terms of Yarinda's PCK development based on the definitions in this study. The development of this knowledge is presented in the aspects of: (a) content knowledge into teaching genetics; (b) knowledge of representations and activities into teaching genetics; (c) other teacher's knowledge emerged from the activities in the PCK-Based PD Program in teaching, and (d) factors influencing development of PCK in teaching genetics.

### 3.1 Yarinda's Content Knowledge into Teaching Genetics

Consistent with development of CK presented above, Yarinda's understandings on genetic concepts was affected on her teaching. For example, in 2005, from the first concept interview, she didn't know concepts of DNA fingerprint. She was not able to explain what it was and had difficulty to teach it. After she had a chance to learn about the concept in the activity of applied genetics in the workshop with the other science teachers, she gained her understandings that it was already explained in topic of development CK. She was confident to teach it. She tried to find some activities for teaching this.

...In the previous year of teaching biotechnology, I didn't know what DNA fingerprint means and what activities should be provide to my students. Because it's new knowledge for me and changed all time. After participating in the workshop [activity of applied genetics], I learned this concept and then I saw a valuable of activity of DNA fingerprints [finding a murder]. I thought that in this year [2006], I was confident to teach it, because I knew more about it. (6<sup>th</sup> Interview of Teaching)

In addition, after Yarinda developed her genetic knowledge, she also more considered on the text book that she and students used. For example, in her textbook it said that "a strand of DNA was called a chromosome", and "genes consist of a nucleic acid, called DNA". Because of that, that is what she thought was true. After she understood correctly the concepts of chromosomes, gene, and DNA from the discussion on case and describing these concepts in the workshop, from the researcher's field note, when she taught these concepts, she didn't provide study these concepts in the text book, but she helped her students construct their own conceptions.

Moreover, when she understood the full relationship among the concepts, she was able to organize her lessons easily. For example, in her lesson plan from 2005 she did not fully understand the relationship between mutation and genetic disorders, Mendel's laws and meiosis division. She organized the two concepts into separate

lessons that were consistent with the arrangement of topics in the textbook that she used. From the 1<sup>st</sup> concept interview, she did not fully comprehend mutation, Mendel's laws, and the processes of meiosis division. However, she showed a much better understanding of these relationships in her lesson plan for 2006, as well as in her improved teaching techniques. For example, from the researcher's field notes during her teaching of genetic disorders and mutation, she gave the students a chance to summarize the relationship between genetics and mutation. Her students explained that mutation was a disorder of the chromosome and/or gene. She was very impressed. She asked them to construct a concept map.

### **3.2 Yarinda's Knowledge of Representations and Activities into Teaching Genetics**

In the beginning of this study, Yarinda had some understanding of the strengths and weaknesses of various representations and activities. She understood what activities she should provide for her students. From her response on teaching cell division at the first case interview (Case A in Appendix B), when she read on a case, she thought back to her teaching and how she taught this concept. Yarinda felt that her students should be shown the stages of mitosis division by pictures and then role-play each stage. She said that "students who had low and high achievement enjoyed, understood, and recognized the different stages of mitosis division through these activities much better than only through a lecture."

During the program, she had many chances to think and discuss about the strengths and weaknesses of the different and activities with other teachers and the research team through several activities in the workshop and two seminars. She drastically gained a better understanding of the advantages and disadvantages of representations and activities. For example, in her teaching of chromosomes, genes, and DNA in 2006, after her learning experiences at a five-day workshop, she started her class by talking about the differences of genetic traits in plants and animals. Then she gave her students a chance to draw a chromosome and then describe the structure and function of a chromosome from their drawing. The school bell rang, so she

stopped her lesson. She then planned her next lesson and decided to explain the structure of chromosomes as a Chinese doughnut and show the structure of DNA with a model. Over the weekend she went to the first seminar and had a chance to discuss the strengths and weaknesses of representations and activities in this lesson on VDO of other teacher's teaching. She came back and revised her lesson. When the time of her teaching came, she started again by talking about the differences of genetic traits in plants and animals, but then she brought real plants and animals into her classroom (see Appendix H). She said that:

...When I did it [started the lesson] again, I decided to use real plants and animals, because my students would be able to clearly identify the differences in the genetic traits. In addition, my students linked their thoughts to easily complete the drawing of a chromosome. In addition, I thought that drawing chromosomes was a good activity, because I was already aware of their prior knowledge. (2<sup>nd</sup> Interview of Teaching)

In addition, Yarinda changed how she explained the structure of chromosomes and DNA. She helped the students learn through a VCD, DNA and Life, and allowed them to present their learning afterwards. Moreover, she kept with her idea of constructing a model for DNA. Furthermore, she used an analogy between DNA and trains, and genes and a carriage of train. She said that:

...I opted to explain more about relationship of genes and DNA by analogy and model because my students understood the concrete representations of it. I was very impressed. (2<sup>nd</sup> Interview of Teaching)

After using a variety of activities in the Mendel lesson, solving the problem of three cats, predicting offspring, and the family of paper animal she still wanted to revise her lesson again. She said:

...I wanted to revise my plan again. I thought that I used too many activities. I still kept the activities of Mendel's work because they stimulated my students

to better understand the process of science. In addition, during the activity of solving the problem of three cats my students were very interested, concentrated hard, and applied their knowledge to the real situation so I decided to keep that. However, I removed the activity of predicting offspring because it was similar to the three cat problem. I still used the family of paper animal because my students' understanding was reinforced through it. However, I improved the worksheet to make it shorter and more relevant. (4<sup>th</sup> Interview of Teaching)

### **3.3 Other Yarinda's Knowledge Emerged from the Activities in the PCK-Based PD Program into Teaching Genetics**

Two types of Yarinda' Knowledge emerged during participating in the PCK-Based PD Program: knowledge of 5E inquiry relied on student-centered teaching and curriculum is presented below.

#### **3.3.1 Yarinda's Knowledge of 5E Inquiry Relied on Student-Centered Teaching**

Yarinda's knowledge of 5E inquiry relied on student-centered teaching impacted on her organizing teaching of lessons. Before her participating in the PCK-Based PD Program, Yarinda held the view that inquiry relied on student-centered teaching. She was not very familiar with 5E inquiry teaching. In her 2005 lessons, she always engaged her students through conversations with them about concepts that she taught. Also, she always asked the students to search for information or knowledge by using one or two activities and prepared learning resources. Afterwards, her students often presented, explained and/or discussed their ideas with her and their friends. Yarinda attempted to give her students opportunities to study and construct their own knowledge by themselves through her activities. For example, at the beginning of the lesson on genetic disorders, Yarinda talked with her students any genetic disorders that her students already knew, and what the symptoms and causes of these genetic disorders were. Then she prodded her students to explore and

discuss any the genetic disorders in their families. After that, they did an activity explaining color-blindness by testing their own color-blindness, then searching for its symptoms and causes, and, finally, presenting the results (Appendix H).

Through the learning experiences of 5E inquiry relied on student-centered orientation of hands-on each activity in the workshop and discussing on cases in the seminars, Yarinda gained more understanding about 5E inquiry and increasingly held views that teaching should be student-centered orientation. For her lesson plans, she selected interesting situations and pictures to engage the students' interests. She tried to give her students a chance to pose their own questions and search for the answers by themselves. She also attempted to create a variety of activities and provided them as a means to better understand the various topics. She further emphasized on students applying their knowledge in new situations or in their real life. She also considered a new way to evaluate the students' learning. For example, at the beginning of teaching Mendel's work, she engaged her students with a picture of Mendel that the students found interesting. When Yarinda asked some questions about him, they competed to raise their hands and answered. After that, she asked a small group of students to find out what, why, and how Mendel worked and then present their discoveries. Next, she demonstrated how to predict genetic traits by using a Punnett square. When her students understood it, she had a chance to ask them to elaborate on their knowledge. She stimulated her students' thinking by predicting the genetic traits of three cats by themselves. Finally, she provided one other activity called "a family of paper animal" where they could apply their learning. In this activity, the students created genetic traits for the hair, eyes, noses, and mouths of a couple of animals on paper and then constructed the offspring (Appendix H). She expressed her feeling:

...I liked this strategy because my students not only thought more, but also seemed to enjoy the learning process much more. (4<sup>th</sup> Interview of Teaching)

### 3.3.2 Yarinda's Knowledge of Curriculum

Yarinda's knowledge of curriculum was affected on organizing the contents in her lessons. In 2005 academic year, Yarinda was able to plan her genetic lessons with knowledge of curriculum. She took a professional development course on curriculum design in 2005 and, as a result, she began to consider the curriculum a lot more before planning her lessons. Previously in her teaching of genetics, when she planned and wrote her lessons, she analyzed the 1999 National Education Act, the IPST Science Curriculum, the School Science Curriculum, and the student's abilities. She particularly relied on the requirements of the IPST Science Curriculum. In this study, after she had gained experience from her redeveloped curriculum in analyzing and discussing on the curriculum, she made a further revision to her lessons before using them in 2006. She still stayed close to the requirements of the IPST Science Curriculum and continued with the same textbook, Science for Grade 9, that her students already had. Her changes of many of the basic concepts, the organization and order they were taught in, and the duration for teaching them are shown in Table 5.2. Concepts that she taught in 2005 were very similar in 2006, but they were organized quite differently. In 2006, Yarinda added the concept of cell division to aid the student's understanding of what processes genetic traits will inherit before they learned about Mendel's law and how to predict genetic traits using a monohybrid cross. Additionally, she changed the concept of mutation related to genetic disorders. She also combined applied genetics and the benefit of biotechnology into the same lesson. Furthermore, she cut out the concepts of complete and incomplete dominant traits and the dihybrid cross since they seemed too difficult for lower secondary students. From the researcher's observation, she used more time to teach each lesson because she had a larger variety of activities for her students and she wanted her students to really understand these concepts. When asked about her changes with the organization and teaching of these concepts, she said that:

...I chose to teach these concepts by looking at the curriculum and textbook. After that I attempted to think about activities and how to link them between topics. I wanted my students to understand from the outside to the inside of

their body. For example, I selected genetic traits first. That way my students saw the traits of themselves and other people and they wondered why they looked like that. Then I provided the concepts of chromosomes and genes. My students were curious about what things could determine genetic traits.

(1<sup>st</sup> Interview of Teaching)

**Table 5.2** Yarinda's plan for the basic genetic concepts, the organization and order they were taught in, and the duration for teaching them in the 2005 and 2006 genetic lesson plans

Lesson	2005 academic year		2006 academic year	
	Genetic Concepts	Time	Genetic Concepts	Time
1	Heredity, genetic inheritance, and continuous & discontinuous genetic variation	2 hr.	Heredity, genetic traits, and continuous & discontinuous genetic variation	3 hr.
2	Structure & number of chromosomes in male & female, autosomes, sex chromosomes, dominant & recessive gene, DNA, and relationship among chromosomes, genes and DNA	2 hr.	Structure & functions of chromosome, gene, DNA, number of chromosomes, genotype, phenotype, dominant & recessive genes, and relationship among chromosomes, genes, and DNA	3 hr.
3	Mendel's laws, complete & incomplete dominant traits, recessive traits, monohybrid & dihybrid cross, mutation, and pedigree	2 hr.	Mitosis division, meiosis division, and comparison between mitosis and meiosis	1 hr.
4	Genetic disorders on autosomes and sex chromosomes	2 hr.	Mendel's laws, monohybrid cross, and Punnett squares	5 hr.
5	Biotechnology: Genetic engineering, cloning, and GMOs	2 hr.	Genetic disorders on chromosomes and genes, and mutation	2 hr.
6	Benefits of biotechnology: medical service, justice, society (e.g. DNA fingerprint), human quality, artificial insemination, selected breed, and mitosis & meiosis division	2 hr.	Applied genetics: DNA fingerprint, cloning, GMOs, Benefits of biotechnology: medical service, justice, society, and human quality	3 hr.
Sum		12 hr.		17 hr.

### **3.4 Factors Influencing Yarinda's PCK Development into Teaching Genetics**

There were many factors that supported and hindered Yarinda's development of PCK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the PCK-Based PD Program; (b) knowledge of student's background, conceptions, and learning styles; and (c) difficulties of teaching.

#### **3.4.1 Activities in the PCK-Based PD Program in Teaching Genetics**

First, hands-on in each activity of teaching genetics and discussing about concepts, the strengths and weaknesses of the activity in the same time with the other teachers helped Yarinda understand both content knowledge and selected the best activities to her students' understanding in genetics. For example, she wrote that:

...During I learned both concepts and how to teach concepts in the hands-on activity and discussed on the activity, I got idea that I will use work sheet, (Self-Assessment Questionnaire).

Second, discussion with the research team helped Yarinda gain more understanding of genetic concepts and selecting instructional media for her students' understanding in right concepts. For example, when the researcher told her that "please be careful on concepts in text book", Yarinda more carefully considered what the text book wrote. She found that it said that "a strand of DNA was called a chromosome", and "genes consist of a nucleic acid, called DNA". From the researcher's field note, when she taught these concepts, she didn't provide students to study these concepts in the text book.

Third, reflecting her own teaching through case discussion and VDO of teaching helped Yarinda understand her strengths and weaknesses of her teaching. For example, she wrote that:

...I knew my weaknesses of teaching and the weaknesses of other teachers' teaching after I wrote a case and watched teaching in VDO of teaching. We helped to suggest how to solve that [weaknesses]. It helped me revise my effective teaching, (Self- Assessment Questionnaire).

Fourth, 5E inquiry relied on student-centered teaching is a process that helped Yarinda being successful her teaching in genetics. She said that:

...I was impressed with my teaching [5E inquiry]. When I provided activities for them, they were able to think, expand their knowledge, and solve some problems by themselves. I felt that when they learned through my lessons they were happy and enthusiastic while they still learned a lot [of genetic knowledge]. They were not so serious while learning my lesson. Every student was confident of showing their explanation and asking additional questions. I was very happy and excited to organize my next lesson, (1<sup>st</sup> Journal).

### **3.4.2 Yarinda's Knowledge of Student's Backgrounds, Conceptions, and Learning Styles**

First, Yarinda's knowledge of students' background effected to planning and using the representations and activities in her teaching. For example, while planning her lesson about cell division and Mendel's laws in 2006, she knew that many of her students came from agricultural families and they were fairly poor. She planned for her students to construct a model of mitosis division by themselves. She guided them to use local materials from their community, such as rice seeds, during the construction. She said, "I didn't want my students to waste money and disturb their parents to construct their models" (3<sup>rd</sup> Interview of Teaching). While teaching Mendel's work, she wanted to complete the activity with the family of paper animal that she had seen at the five-day workshop. She thought about it again before she went through with it. She ordered her students to save used plastic bottles and bring them to her classroom for storage. When it was time to do the activity, the bottles were used instead of paper for constructing the animal families.

Second, Yarinda's knowledge of students' conceptions impacted on her teaching. She knew the extent of her students' prior knowledge, so she. For example, she asked them to draw a picture of a chromosome so that she understood what they already knew about it. She discovered that they knew chromosomes consist of genes and it was a bar. Yarinda gave a VCD and pictures for the next activity to aid with the concept of chromosomes. In another example, she asked about cloning by showing a picture of cloned cows. It was revealed to her that her students knew the meaning of cloning, but they were not aware of the processes involved. As a result, she gave them more opportunities to study cloning.

In addition, when teaching, because Yarinda understood her students' misconceptions, she would try to change their understanding. For teaching chromosomes, genes, and DNA, she gave her students an opportunity to study these concepts through a variety of activities. The researcher's field notes noted that when students presented the concepts of chromosomes, genes, and DNA, most students had the misconception that genes consisted of DNA, DNA had two types, DNA and RNA, and genes looked like a string of beads. Before the time was up, her students summarized these concepts. They still maintained that genes consisted of DNA, so Yarinda hurried to immediately explain the correct concept. Yarinda later discovered that her students had the wrong understanding because they looked at the concept in the textbook.

Third, Yarinda's knowledge of student's learning style impacted her planning and teaching in genetics. For example, she knew that her students liked to show their abilities. When teaching about chromosomes, genes, and DNA, she gave them the task of drawing a chromosome, studying it, and then presenting their picture and conclusions by themselves. She wrote in her journal about this learning style:

...When they [her students] were given a chance to show their thinking and imagination, they were enthusiastic to hurry and finish their task. They really wanted to show what their chromosome look liked. (2<sup>nd</sup> Journal)

She knew that her students also liked to collaborate and learn with their friends. She gave further details:

...When I designed my lesson plans the students would be assigned small groups to complete tasks. I observed that they would like their friend's explanation on some topics and that would aid their understanding together. I felt good that every student was interested and did not deviate from the tasks. They were unified and collaborated very well on their tasks together. (4<sup>th</sup> Journal)

### **3.4.3 Yarinda's Difficulties of Teaching**

Yarinda's difficulties of teaching impacted on her teaching. First, the lack of instructional media and technology to help facilitate the students' learning created Yarinda's difficulty in teaching. She said that:

...When I taught the concept of cloning, I had to show a picture of cloned cows to every group of students. I wanted to use better technology to show the picture, such as a computer or projector. My school did not have them, so I had to use what I had. (6<sup>th</sup> Interview of Teaching)

In addition, Yarinda's focus on the sequence of her teaching and following the written lesson plan was her biggest difficulty while teaching genetics. She forgot to teach something which she wanted to provide to her students. She said:

...Sometimes, I felt that it was difficult to teach. I was serious on trying to use a variety of activities and inquiry teaching based on student-centered learning. I was afraid that my teaching was not following my lesson plan, so occasionally I forgot something. For example, I forgot to discuss the question, "Why the numbers of chromosomes in each organism are different?" That question would have aided understanding the relationship between numbers of chromosomes and genetic traits. (2<sup>nd</sup> Interview of Teaching)

### 3.5 Summary Yarinda's Development of PCK in Teaching Genetics

Yarinda gradually developed her PCK based on her CK and knowledge of representations and activities. She gained her CK of genetic concepts, and the relationship among concepts, which is, DNA fingerprint, the relationship among chromosomes, genes, and DNA, and Mendel's laws. However, she held on a few misconceptions of a number of chromosomes in a cell, mutation, but finally she tried to understand these concepts. Hence, she was careful on concepts in the text book, understood the valuable representations and activities that she selected, and organized her lessons easily. In her teaching, she knew better the strengths and weaknesses of representations and activities. She selected to use role play for teaching cell division, analogy between train and structures genes, analogy between a Chinese doughnut and chromosomes, paper model for teaching DNA, seed plant model for teaching cell divisions, VDO for teaching chromosome, gene, DNA and DNA fingerprint, as good representations and activities. Her students were more interested on her using them. She gradually changed her teaching style and pushed her students to learn genetic concepts by themselves through a variety of activities and representations. Although she got some ideas for activities from her colleagues' experiences, she attempted to carefully consider and select items that would easily represent genetic concepts to aid her students' understanding.

Consistent with her understanding of content knowledge and representations and activities, Yarinda also integrated her knowledge of 5E inquiry teaching that relies on student-centered orientation and knowledge of curriculum that she learned from the PCK-Based PD Program to development of PCK. Yarinda attempted to plan and revise her lesson based on a better understanding of 5E inquiry relied on student-centered teaching. She was successful on inquiry teaching, because her students were happy and fun with this teaching. In addition, her knowledge of curriculum helped her to rearrange and reorganize the order of lessons, the duration for teaching them, and the number of genetic concepts covered, in line with the requirements of the IPST Science Curriculum Standard, the school's curriculum requirements, and the students' ability.

Her successful development of PCK was influenced by the activities in the PCK-Based PD Program, her knowledge of students' background, conceptions and learning style, knowing the difficulty of teaching. First, hands-on in each activity of teaching genetics and discussing about concepts, the strengths and weaknesses of the activity in the same time with the other teachers helped her understand both content knowledge and selected the best activities to her students' understanding in genetics. In addition, discussion with the research team helped her gain more understanding of genetic concepts and selecting instructional media for her students' understanding in right concepts. Furthermore, reflecting her own teaching through case discussion and VDO of teaching helped her understand on the strengths and weaknesses of her teaching. Finally, 5E inquiry activities that she learned from the workshop help her to create her interested lessons.

In addition, Yarinda's understandings of her students' various backgrounds, learning styles, and concepts of genetics help her development PCK in teaching genetics. Fortunately, she had a good relationship with her students; she really knew what they had, liked, and wanted. She spent more time taking her students into consideration when planning lessons. She was aware that her students came from fairly poor, agricultural, and employed families. They loved to learn genetics through a variety of activities, collaborative learning, and by showing off their abilities. She found it easier to plan her lessons based on student-centered orientation and discovered new ways to transform her knowledge into a more understandable and accessible form.

However, Yarinda's PCK development was obstructed by her concentration too much on her lesson plans. She tried to follow the lessons that she planned exactly based on her own knowledge so she occasionally forgot to provide some things. However, she will improve herself. Another thing was that sometimes she found the lack of instructional media and various types of technology added further difficulties to her teaching. However, she tried to plan her lessons within the bounds of what she and the students had by creating some of their own instructional

media and using learning resources from around the community. If she had the opportunity, she would use better technology.

As a result, development of Yarinda's PCK depended on integrating all her knowledge of CK, knowledge of representations and activities, 5E inquiry, curriculum from the PCK-Based PD Program and other her own knowledge including knowledge of students' background, conceptions, and learning styles for effective teaching in genetics in this study and for the future. However, lacking of technology and her concentration too much on lesson were obstructed on her development of PCK.

## **The Case of Tarinee**

### **1. Tarinee's Backgrounds, Students, Classroom and School**

#### **1.1 Tarinee's Backgrounds**

At the time of this study, Tarinee was a 39-year old, female, in-service science teacher working at a secondary school in Suphanburi province. She graduated with a bachelor's degree in general science.

Tarinee already had eleven years of experience in teaching science, including one year of specifically teaching genetics, since it was a required topic. Her science teaching consisted of a general science course for lower secondary students and basic and advanced chemistry for upper secondary students. She was much more skilled at teaching chemistry rather than general science and she was the only chemistry teacher at her school. She taught chemistry as an advanced topic for three hours a week to one classroom containing grade 10 and 11 students, while she taught basic chemistry for three hours a week to one classroom of the upper secondary grade levels. In this study, she had the responsibility of teaching genetics for three hours a week for two lower secondary classrooms. In this time, she mainly used and followed some activities in a textbook, Science for Grade 9, that was published by a private company similar to Yarinda's text book. She was not only teaching science; she was responsible for other tasks in her school, such as head of director for further study of students.

In addition, from the Interview#1, Tarinee wanted to develop her profession of chemistry and genetic knowledge and teaching skills through a professional development program. She had never participated in a professional development program on teaching genetics; however, she had a variety of experiences from many professional development programs. She joined a one-day workshop on learning about Venus. She got knowledge of astronomy and constructed a telescope for observing Venus. In addition, she had a chance to participate in a one-day

workshop for solving science problems. She learned how to teach students to design their experiment and solve problems by themselves. Moreover, she was a participant in a two-day workshop on action research. She learned about processes of doing action research in classrooms. Tarinee liked participating in short-time professional developments, such as one or two day programs. She said, “I used to participate in a ten-day seminar about chemistry. It was headache and difficult to learn in the long days of the professional development program.”

### **1.2 Tarinee’s Students**

In this study, Tarinee taught genetics for thirty-five grade nine students in one classroom. They consisted of twenty females and fifteen males in that classroom. Most of the students came from employed families and agricultural families. Thirty-one students had a good attitude toward science. They liked science because they liked to do some experiments. Furthermore, they had a chance to investigate the interesting situation. The rest of students did not like to learn science because they did not understand science and it gave them a headache. They wanted Tarinee to teach science by using fun and understandable instructional media, experiments, and explaining science knowledge in depth. In addition, they wanted a kind teacher. Twenty-five students had previously learned about genetics from the health care course, regular books, textbooks, library, hospital, website and homes. However, the rest of them had never learned much about it before.

### **1.3 Tarinee’s Classroom**

In this study, Tarinee taught her genetics lessons in a chemistry laboratory similar to Yarinda’s classroom. The room size was too small for the thirty-five students. Inside the classroom was a blackboard in the front of the room, a number of windows on the left hand side, a glass cabinet of chemical substances at the back of the room, and a bulletin board on the right hand side. Although there were a few fans, it was a little hot in the classroom. There were six groups of tables and the

five to six students were placed in groups. Three groups of students were females and two groups of students were males and only one group was of mixed genders.

#### **1.4 Tarinee's School**

Tarinee's school is a small, secondary public school in the same district as Tunya's and Yarinda's school in Suphanburi province. Her school was far from the center of the district, around 8 kilometers in length. In the 2006 academic year, there were a total of 310 students in grades 7 to 12. The school is located in a rural area. There are rice fields, mango groves, canals, and a temple around the school. People living in the same community are generally employers and farmers. They built their houses very close to their relatives. Most of them are Buddhist and they were always pleased to attend Thai cultural activities in the community. In addition, there are many local learning resources within the community, where Tarinee's school is located, including experts that have local wisdom and knowledge, fresh-water fish farms, cow farms, mango groves, rice fields, a temple, a health center, canals, and rice mills. In addition, her school policy was based on teaching with a student-centered approach.

In summary, Tarinee was an experienced chemistry teacher in a small, secondary public school in the same district of Tunya and Yarinda's school. She had experience teaching science for only eleven years. She graduated with a bachelor's degree in general science. Usually, she is the only chemistry teacher in the school, so she also has the responsibility of teaching chemistry for upper secondary levels. However, she only had experience teaching genetics for one year. Genetics was a required topic for lower secondary students. Her needs of professional development programs were enhancing knowledge of chemistry and genetics and teaching skills, so she was willing to participate in the PCK-Based PD Program. In this study, she taught thirty-five students in a chemistry laboratory that was too small. Her students came to class with moderate to low learning achievement in science, but they had good attitudes toward science. They came from employable, agricultural, and Buddhist families. They were not able to learn science through many learning resources, such as the agriculture and Buddhist culture around the school.

## **2. Tarinee's Content Knowledge (CK) Development in Genetics**

In this section, the results from multiple sources are analyzed in terms of: (a) Tarinee's CK development; and (b) factors influencing Tarinee's CK development in genetics.

### **2.1 Tarinee's CK Development in Genetics**

In this section, results from multiple sources were analyzed and presented on the development of Tarinee's CK to show her understanding of genetic concepts and their relationship.

Tunya possessed a few correct conceptions of genetics. Initially, Tarinee possessed incorrect knowledge of some concepts. For example, dominant gene was only expressed that is seen in heterozygous on a pair of chromosomes. After she participated in the hands-on activity and discussion on the concepts (Table 4.1: Activity 1.3) with the other teachers and the research team in the workshop, she was more confident that she had the correct concepts.

However, she possessed many misconceptions, but she didn't change her misconception. She also initially possessed some misconceptions of genetic concepts. For example, she wrote on her lesson in 2005 that, "dominant genetic traits were a genetic feature expressed in all generations as recessive genetic traits were a genetic feature expressed in some generations". In addition, from the first concept interview, she understood incorrectly that somatic cells and sex cells of a person have the same genetic information. In addition, she was not able to predict correctly about genetic traits of a rabbit's offspring. (Appendix A: question 4). She had never heard of Punnett squares. She didn't know about mitosis and meiosis divisions. She also didn't know about DNA fingerprinting. She said, "I don't know the processes of identifying a person by using DNA".

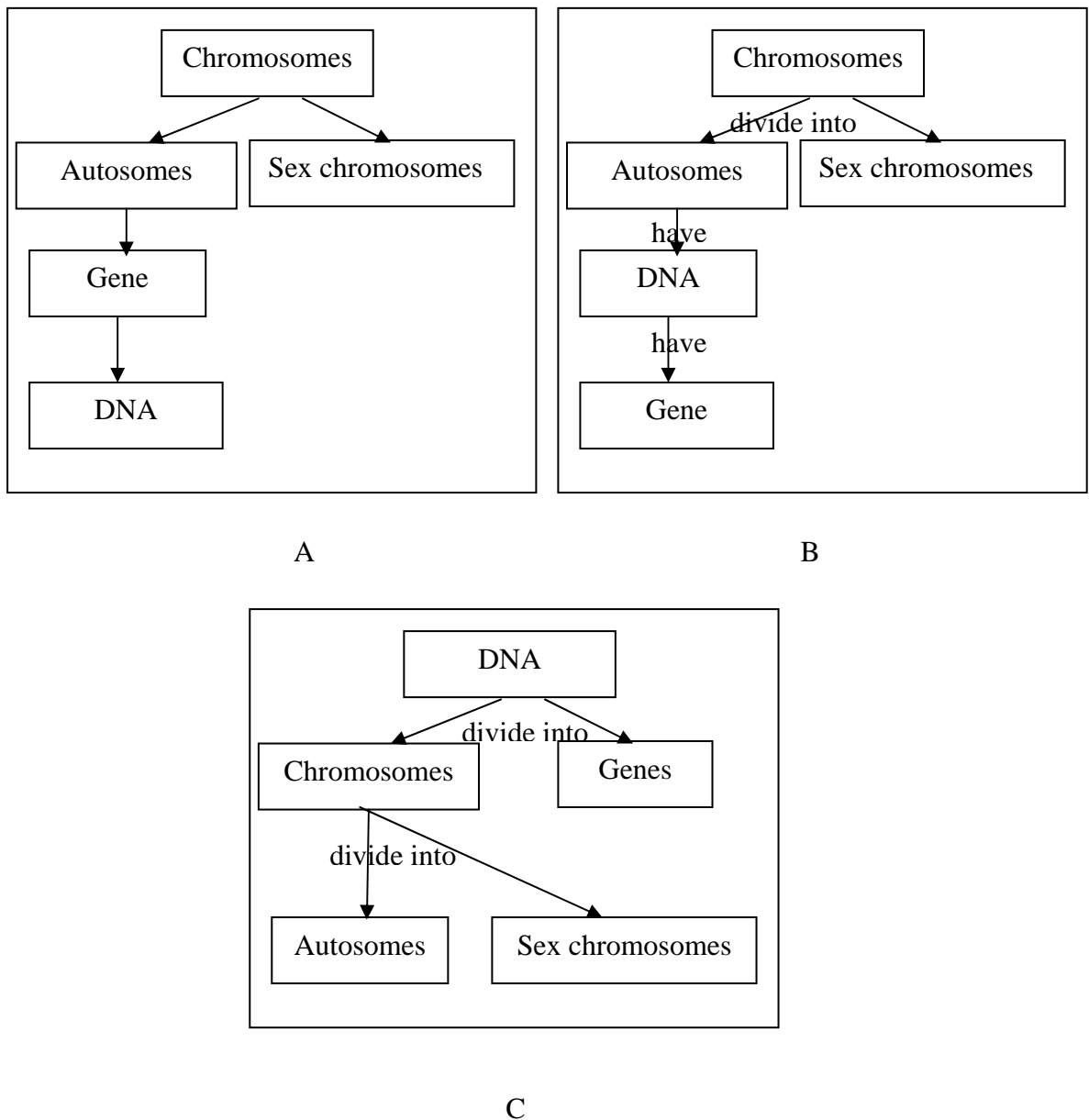
After Tarinee learned genetic concepts through describing of concepts, hand-on activity related to these concepts, discussing on her conception, reflecting her conception in case and VDO of teaching, and reflecting on teaching in the PCK-Based PD Program, in the interviews of teaching, she still had some wrong concepts because she didn't realize that she had misconceptions. For example, from her teaching it was obvious she still possessed the wrong concepts of dominant and recessive genetic traits. In addition, she was mistaken about the concept of chromatin being a chromatid. In fact, they are different. Furthermore, she didn't understand differences of meiosis divisions I and II, especially the number of chromosomes in each stage of the division. She didn't know a germ line cell is a stem cell of a sex cell. She also didn't understand that the final products of meiosis divisions are sperm or egg cells. Moreover, she said in the sixth teaching interview that she didn't understand what the GMOs meant. She also didn't know the processes of cloning or DNA fingerprinting.

In addition, initially, Tarinee made a mistake on the relationship among genetic concepts. On the first concept test (Appendix A), when she was asked why we separated gene B and b for predicting an offspring's genetic traits, she was not able to explain the relationship between meiosis division and Mendel's laws. She answered confused, "because the sex cell had X and Y, it had dominant and recessive genetic traits...(quiet)...I don't know what the phenotype and genotypes are in this situation". After she had learned these concepts from the workshop and seminars, during her teaching of the Mendel lesson it was apparent she still didn't understand the relationship. She didn't mention that it was consistent with her misunderstanding of the meiosis division. However, in the second concept interview after her teaching, she incompletely answered this question. She said correctly that the Mendel's laws were related to this separation of genes, but she didn't say anything about the relationship between Mendel's laws and meiosis. Other example, when she was asked the relationship between genetic disorders and mutations in the fifth teaching interview, she understood incompletely that mutation is a disorder that occurs only in genes. In that were true, mutation could possibly occur in genes and chromosomes. She also

didn't understand the differences of genetic disorders on chromosomes and genes. However, she understood correctly that all genetic disorders come from mutations.

Another example, she showed her confusion about relationships among chromosomes, genes, and DNA. She initially understood incorrectly that genes and DNA are only found in autosomes and DNA is part of gene (Figure 5.4: A). After she studied these concepts in the activity of "Relationships among gene, chromosome, and DNA" (Table 4.1: activity 3.1) the workshop with the other science teachers and research team, she understood correctly that DNA consists of genes, however, she misunderstood that only autosomes have DNA and genes (Figure 5.4: B). However, after she taught them in her class, she had misunderstand that DNA consists of chromosomes and genes (Figure 5.4: C). Consistent with her interview, she said:

...I didn't know that I understood correctly that when I chopped the chromosome into a small piece, the small piece is DNA. That is, all chromosomes consist of DNA. (2<sup>nd</sup> Interview of Teaching)



**Figure 5.4** Tarinee's concepts of chromosomes, genes and DNA

Note: (A) At the beginning of the PCK-Based PD Program (from the 1<sup>st</sup> concept interview); (B) after participating in the workshop (from concept map); (C) after her teaching (from the 2<sup>nd</sup> concept interview)

## **2.2 Factors Influencing Tarinee's CK Development in Genetics**

There were many factors that supported and hindered Tarinee's development of CK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the professional development program; and (b) Tarinee's personal characteristics and beliefs.

### **2.2.1 Activities in the PCK-based PD Program**

The activities in the PCK-Based PD Program in teaching genetics impacted on Tarinee's CK development. In the workshop, when the developer described genetic concepts, and Tarinee did hands-on the activities in each lesson plan through 5E inquiry with the other teacher in the workshop, she had a chance to discuss concepts in those lessons and gained her understanding of a few genetic concepts. For example, she said that:

...From the activity [What does an actual DNA strand really looks like? Table 4.1: Activity 4.1], I had more understood of DNA, (Self-Assessment Questionnaire).

In addition, the research team helped her develop her understanding of concepts. For example, when her students asked her question whether or not chromatid means chromatin, she wasn't sure that she answered correct answer. She asked the researcher about it after her teaching.

### **2.2.2 Tarinee's Personal Characteristics and Beliefs**

She was not enthusiastic to participate in activities in the workshop and seminars. For example, she didn't write her own case for discussing in the workshop. She didn't share her idea during discussion on the concepts that she didn't know such as chromosome, gene, and DNA. She also missed some activities during the program such as planning a lesson plan of cell division with the other teachers.

In addition, she trusted the accuracy in the text book, so she possessed her misconception similar to writing in the text book. Furthermore, she didn't want to know the concepts in depth. She said that:

...I knew the meaning and detail of concepts based on the text book wrote. I thought that it was enough for teaching in lower secondary levels, (6<sup>th</sup> Interview of Teaching).

### **2.3 Summary of Tarinee's CK Development in Genetics**

In summary, Tarinee came to the PCK-Based PD Program with misunderstandings in many genetic concepts and their relationships. After she had a chance to learn concepts through activities of describing of concepts, hand-on activity related to these concepts, discussing on her conception, reflecting her conception in case and VDO of teaching, and reflecting on teaching, she gained her understanding in a few concepts [Mendel's laws, dominant and recessive gene, mitosis division]. However, she still held on many misconceptions: dominant and recessive genetic traits, meiosis division, the relationship among chromosome, gene, and DNA, numbers of chromosomes in a cell, mutation, genetic disorders and DNA fingerprints. Important factor influencing her misconception was her personal characteristics and beliefs. She wasn't enthusiastic to develop herself. However, she gained understandings in some concepts because the activities that describing genetic concepts, and did hands-on the activities in lesson plans through 5E inquiry with the other teacher in the workshop, and asking her confusion from the research team.

### **3. Tarinee's Pedagogical Content Knowledge (PCK) Development in Teaching Genetics**

In this section, the results are discussed in terms of Tarinee's PCK development based on the definitions in this study. The development of knowledge is presented in the aspects of: (a) content knowledge into teaching genetics; (b) knowledge of representations and activities into teaching genetics; (c) other teacher's

knowledge emerged from the activities in the PCK-Based PD Program in teaching; and (d) factors influencing development of PCK in teaching genetics

### 3.1 Tarinee's Content Knowledge into Teaching Genetics

Consistent with development of CK presented above, Tarinee understood she had incorrect genetic concepts, but she didn't change anything, so her misconceptions affected her teaching. For example, while teaching mitosis and meiosis divisions, from the researcher's field notes and teaching interviews, it was clear she didn't understand the difference between meiosis I and II, especially the number of chromosomes in each stages of the division. Hence, during teaching, she skipped teaching meiosis and comparisons between mitosis and meiosis, although she had planned to teach these in her lesson plan. She said:

...I didn't understand and wasn't sure how meiosis I and II were different, although I knew they were not similar. I didn't teach them because I didn't know how to explain them, (3<sup>rd</sup> Interview of Teaching).

In addition, she had insufficient concepts, so she didn't know how to organize it in her teaching. For examples from her teaching of genetic traits, she said:

...I confused the organization on teaching dominant genetic traits and dominant genes. I didn't know which concepts should be provided first, (1<sup>st</sup> Interview of Teaching).

Furthermore, when she possessed her misconceptions, she was not confident to teach. For example, during teaching genetic disorders, she realized that she didn't understand the relationship of mutations and genetic disorders. She planned to teach this relationship, but just talked a little about mutations and didn't emphasize the relationships.

Moreover, Tarinee didn't know her own misconception, so her incorrect information affected her student' understandings. In the previous and present lessons, she still had wrong the wrong idea that, "dominant genetic traits are a genetic feature expressed in all generations as recessive genetic traits are a genetic feature expressed in some generations". She didn't realize that she possessed misconceptions, so provided this incorrect information to her students. As a result, her students developed misconceptions similar to Tarinee (1<sup>st</sup> Researcher's Field Note). When students asked her if all dominant genetic traits are perfect genetic traits, she confusingly answered to her students that that is not true. However, she said in her first journal that she was confident about her knowledge on this lesson. Another example is that during the teaching of chromosomes, when students asked Tarinee whether or not a chromatin was chromatid, she said that it was. Also, she was confused about the relationship among chromosomes, gene, and DNA. So, when she provided her students information about their relationships, they had misunderstandings similar to their teacher.

### **3.2 Tarinee's Knowledge of Representations and Activities into Teaching Genetics**

In the beginning of the PCK-Based PD Program in teaching genetics, Tarinee was limited in her understanding of the strengths and weaknesses of her representations and activities. In her interview on case A [Appendix B], she explained that she thought that for teaching cell divisions, activities of constructing models of cell divisions and role-playing were only suitable for high ability students.

During the program, Tarinee had many chances to think and discuss about the strengths and weaknesses of the different activities with other teachers and the research team, through several activities in the workshop and two seminars. She gained a better understanding of the advantages and disadvantages of representations and activities. For example, during the researcher's observations of the teaching of genetic traits, she provided her students with an activity for classifying genetic traits, but her students were not able classify them. So she tried to find some more pictures

of genetic traits for students to more easily classify. She wrote on her case for discussion in the seminar that: “this activity was good; however, it had some faults that I already solved in my classroom”. Another example, after teaching chromosomes, genes, and DNA, she gave a test to her students. She said in her teaching interview that while the students took the test, she found that her test was not consistent with her teaching. Some questions were not taught, so she stopped her students from taking test. Another example, while teaching about genetic disorders, she showed a picture of a funny actor who had Down’s syndrome. Her students were very interested in her picture and were able to explain characteristics of a person who had Down’s syndrome because they knew who he was. In addition, she had a good work sheet for her students to study about causes and symptoms of genetic disorders. The sheet consisted of pictures and short descriptions and some questions. She said in her teaching interview that she thought that her students had thought critically using the work sheet.

Sometimes, she did not see advantages and disadvantages of representations and activities. From the researcher’s field notes, it is apparent that while teaching a lesson on chromosomes, genes, and DNA with a PowerPoint she taught herself, her students didn’t listen to her explanations. She felt that this activity was not suitable for her students. She said in the journal that, “when I used the PowerPoint, I felt that my students and I were not as close while I stood in front of classroom. I was not comfortable explaining it using the technology.” She did not know that the PowerPoint was interesting to her students, but they did not like to listen to her explanations, so they talked loudly. In addition, she had her students read about genes, DNA, and chromosomes from the text book and draw pictures of chromosomes. She did not know that the text book had some incorrect information about these concepts. She thought that the text book consisted of much detail and pictures of chromosomes. However, her students liked this activity. She said in her second journal that “my students were interested in this activity.” Another example is when teaching cell division, at first, she planned for her students to make a model of mitosis division with plasticine, but before teaching she changed her lesson and had her students read and draw a picture of mitosis division. When the students presented

their pictures, she found that the students had tried to copy a picture from the text book. In the text book, the picture was not able to represent each of the divisions in mitosis because the black picture was not clear. Her students didn't understand where chromosomes were and what they looked like. She explained that:

...I gave my students the chance to read and draw the pictures [mitosis division] instead of playing with the plasticine, because my teaching time was reduced by the school. I preferred my students to play with the plasticine because it has color, so my students would probably understand the concepts more, (2<sup>nd</sup> Interview of Teaching).

### **3.3 Other Tarinee's Knowledge Emerged from the Activities in the PCK-Based PD Program into Teaching Genetics**

Two types of Tarinee' Knowledge emerged during participating in the PCK-Based PD Program: knowledge of 5E inquiry relied on student-centered teaching and curriculum is presented below.

#### **3.3.1 Tarinee's Knowledge of 5E Inquiry Relied on Student-Centered Teaching**

Tarinee's knowledge of 5E inquiry related to using activities in her teaching. At the beginning of the PCK-Based PD Program, Tarinee used teaching strategies based on teacher-centered orientation. She always only used some questions to ask students and let them search for the answers in all six genetic lessons in 2005. She did not know much about 5E inquiry (Appendix I). Consistent with her responses on Case A (Appendix B), she thought that teacher should explain the concept to students first, then, provide an activity for them.

Tarinee's knowledge of 5E inquiry relied on student-centered teaching impacted on her organizing teaching of lessons. Through the learning experiences of 5E inquiry relied on student-centered orientation in each activities of

workshop and discussing on cases in the seminars, during the first lesson plan (Appendix I), it can be observed from the researcher's field notes that Tarinee tried to use a variety of activities based on 5E inquiry with emphasis on the student-centered approach. While teaching genetic traits, she attempted to engage her students by having her students observe genetic traits in their friends [engagement]. She then had her students survey their own genetic traits and present it by themselves [exploration and explanation]. After that, she had her students survey their family's genetic traits [elaboration] and explain the meaning of genetic traits [evaluation]. She always guided students with their explanations when they were quiet. She was successful in teaching using the 5E inquiry. She said:

...Most students were more interested in the activities and were curious about their own genetic traits. They were able to explain the concepts, but used too much time to present. (1<sup>st</sup> Interview of Teaching)

However, in later lesson on genetics, she went back to relying on the teacher-centered approach. For example, during her teachings of cell division, she wrote on her lesson plan to rely on 5E inquiry with emphasis on student-centered teaching. She provided the knowledge on the study sheet and then had students draw a picture of mitosis division individually. After that, student presented their pictures and did a worksheet of mitosis division. However, during the presentations of their drawings, the students were not able to explain. Instead, the teacher explained it because she was concerned about limited time and her students' understanding. In addition, in her lesson, students didn't have a chance to pose their interesting questions. The teacher talked more than the students in this lesson.

When she came back from the seminar with the other science teachers and research team, she had more emphasis on student-centered teaching again in the fifth lesson plan on genetic disorders. From the researcher's field notes, her students were engaged by a funny actor who had Down's syndrome. They were very interested in him. After that, they did an activity on genetic disorders with autosomes and sex chromosomes and presented their results. They critically studied

symptoms and causes of genetic disorders and answered some questions in an activity. During their explanations, they posed some interesting questions. However, the teacher did not give the students a chance to respond to their questions, instead, the teacher answered them by herself.

### 3.3.2 Tarinee's Knowledge of Curriculum

Tarinee's knowledge of curriculum was affected on organizing the contents in her lessons. In 2005, she didn't know much about genetic content in the IPST Science Curriculum. Although she had many experiences in teaching science, this was her first time teaching genetics. She picked up a pattern of genetic lesson plans from a document and followed all the sequences and activities from the documents. She began her classroom with concepts of Mendel, and then taught about chromosomes, genes, genetic disorders and applied genetics, respectively (Table 5.3). She emphasized concepts related to inside the body and then concepts related to outside the body. She taught all concepts for 20 hours. She said:

...I wanted my students to know chromosomes and genes first. After that they could learn differences of genetic traits. Then, they will understand where different genetic traits come from, (1<sup>st</sup> Interview of Case A).

From discussions on genetic contents in the curriculum with other science teachers in the workshop, Tarinee changed the basic genetic concepts, the organization and order they were taught in, and the duration for teaching those to be closer to the requirements of the IPST Science Curriculum. Her changes were presented in Table 5.3. In 2006, she looked more carefully at her lessons. In contrast with the 2005 academic year, she emphasized teaching concepts related to outside of the body first and then taught concepts related to inside the body. She started her lessons with concepts of genetic traits, genetic variations, phenotypes, and genotypes. She then added structure and functions of chromosomes, genes, DNA, their relationships to each other, and concepts of cell division for her students' understanding. After the concepts of Mendel's laws, genotype, phenotype, how to

predict genetic traits, and pedigree were organized, she still taught genetics and benefits of biotechnology similar to the 2005 lesson plans. In these lessons, she tried to organize her teaching and added more concepts that were different from the 2005 lesson. She mixed her understanding of genetic concepts taught from the workshops and concepts in the text book together, so she taught too many concepts in this study and was confused. For example, she taught repeatedly some concepts such as phenotype and genotype. She said, “after I teach dominant and recessive genetic traits, I will provide concepts of phenotypes and genotypes, but not in depth and provide them again in when teaching lessons on Mendel.” In addition, she reduced the duration of teaching from 20 hours to 17 hours because she allowed time to teach other topics in this semester.

**Table 5.3** Tarinee’s plan for the basic genetic concepts, the organization and order they were taught in, and the duration for teaching those in the 2005 and 2006 genetics lesson plans

Lesson	2005 academic year		2006 academic year	
	Genetic Concepts	Time	Genetic Concepts	Time
1	Mendel’s laws, and dominant & recessive genetic traits	3 hr.	Genetic traits, and dominant & recessive genetic traits, phenotype, genotype, dominant & recessive genes and continuous & discontinuous genetic variation	3 hr.
2	Functions of dominant and recessive gene, and relationship between chromosomes & genes	4 hr.	Structures & functions of chromosomes, genes, DNA, and relationship among chromosomes, genes & DNA, autosomes and sex chromosomes	3 hr.
3	Autosomes, sex chromosomes, and gene on sex chromosomes	3 hr.	Cell cycle, mitosis division, meiosis division, and comparison between mitosis and meiosis	2 hr.
4	Genetic disorders on chromosome and gene	4 hr.	Mendel’s laws, genotype, phenotype, hybrid & pure line, Punnett squares, monohybrid & dihybrid crosses and pedigree	5 hr.
5	Applied Genetics: genetic engineering, cloning, and GMOs	3 hr.	Genetic disorders on autosomes and sex chromosomes and mutation	2 hr.
6	Benefits of biotechnology: medical service, justice, society (e.g. DNA fingerprint), and human quality	3 hr.	Applied Genetics: DNA fingerprint, cloning, GMOs, and benefits of biotechnology: medical service, justice, society, and human quality	2 hr.
Sum		20 hr.		17 hr.

### **3.4 Factors Influencing Tarinee's PCK Development in Teaching Genetics**

There were many factors that supported and hindered Tarinee's development of PCK during the PCK-Based PD Program in genetics. These factors were: (a) activities in the PCK-Based PD Program; (b) knowledge of student's learning styles, (c) difficulties of teaching, and (d) personal characteristics, and beliefs.

#### **3.4.1 Activities in the PCK-Based PD Program in Teaching Genetics**

First, discussion with the research team helped Tarinee gain more understanding of instructional media for her students' understanding in right concepts. For example, in the seminar, she got science's educator suggestion on constructing worksheets, using the situation in real life. As a result, from the researcher's field note, in teaching genetic disorders, she constructed a worksheet consisting of directions, picture and short description and short-answer questions. Her students were able to do a worksheet without problems. In addition, she used a picture of a funny actor who had Down's syndrome for engagement her students.

Second, reflecting her own teaching through case discussion and VDO of teaching helped Tarinee understand her strengths and weaknesses of her teaching. For example, she wrote that:

...When I wrote my case, I recognized my teaching. I was more aware of my weak teaching. I knew that I had to chance my teaching. When I watched my actions [VDO of teaching], I knew my problems and difficulties of teaching, (Self-Assessment Questionnaire).

### **3.4.2 Tarinee's Knowledge of Student's Learning Styles**

Tarinee's knowledge of student's learning style effected to using the representations and activities in her teaching. She did not consider that her students did not like to show their abilities in front of the class. The researcher's field note show that when she had her students present their knowledge or works in front of class, they were slow to go and tried to avoid presenting. Tarinee often called on her student repeatedly or if she could not wait, she talked herself. She still used presentations for almost every lesson and she often talked more. In addition, she knew that her students did not like to read the documents, but she did not know another way of teaching. When her students read from a sheet or text book, some students who were interested in the lesson read it, while others did not. They talked very loudly during this activity. In addition, when the teacher spoke in front of classroom, most students interrupted her explanations, especially, students who sat in the back of classroom.

### **3.4.3 Tarinee's Difficulties of Teaching**

Tarinee's difficulties of teaching impacted on her development of PCK. She thought her only difficulty in teaching was her inability to use technology. She said:

...I do not like teaching using many instructional media, specifically, technology such as PowerPoint. I do not feel comfortable when I use this. I prefer to write on the blackboard. (2<sup>nd</sup> Interview of Teaching)

In addition, the amount of time for teaching created difficulty for teaching genetics. She did not have enough time to teach the topics and she thought that the activities in her genetic lessons took more time to teach. Sometimes, her school would also reduce her teaching time because students did other activities outside the classroom.

#### **3.4.4 Tarinee's Personal Characteristics and Beliefs**

Tunya's personal characteristics and beliefs impacted on development her PCK in teaching genetic. For example, she was too confident that she had completely conceptions, so she didn't prepare herself. When she taught the concepts, she realized that she didn't have sufficient knowledge, so she didn't teach that concepts. From the researcher's field notes it can be observed that, she didn't know much about mutation; she didn't explain it well to her students. Hence, she did not provide some concepts to her students, although she planned to teach them, such as meiosis and the comparison between meiosis and mitosis divisions.

In addition, Tunya knew her students' learning styles, but she didn't change anything for her students' understanding. She said that:

...I knew my students did not like reading, however, I did not know what other activity should be provided. (2<sup>nd</sup> Interview of Teaching)

#### **3.5 Summary Tarinee's Development of PCK in Teaching Genetics**

Tarinee gradually developed her PCK based on her CK and knowledge of representations and activities. Tarinee gained her CK of a few genetic concepts in depth: dominant and recessive gene, Mend's laws, and mitosis division that she already understood. However, Tarinee didn't understand many concepts since she came to the PCK-Based PD Program, but she still held on misconceptions until after her teaching in 2006. These concepts were dominant and recessive genetic trait, meiosis division, a number of chromosomes in a cell, the relationship among chromosome, gene, and DNA, mutation, genetic disorders, and DNA fingerprint. When she had insufficient conceptions, she had difficulty to teach, to organize, and her misconceptions were translated to her students' understanding. Consistent with her limited CK, she less considered on the strengths and weaknesses of representations and activities before she used them, but she will be aware of them during her teaching. She attempted to select the activities and some work sheets from

the workshop that she thought that it was suit for her students and applied them in her teaching while she created new things. In her teaching, she used the work sheets for teaching genetic traits; however, she had to find pictures to help her students to classify genetic traits in the work sheets. She also used drawing pictures to represent concepts of mitosis division, but students didn't understand it. She used drawing, PowerPoint, and text book for teaching the relationship of chromosome, gene and DNA, but students didn't understand them.

Consistent with her limitation of content knowledge and representations and activities, when Tarinee integrated her knowledge of 5E inquiry teaching that relies on student-centered orientation and knowledge of curriculum, that she learned from the PCK-Based PD Program to development of PCK, into her teaching, she didn't feel comfortable to teach and organize her lessons. Although she gained an understanding of the 5E inquiry emphasizing student-centered teaching, she was able to provide student-centered teaching in some lessons. However, when she was concerned about time for teaching, she became teacher-centered. As a result, her students understood less.

Factors supporting on her PCK development was the activities in the PCK-Based PD Program. When she had a chance to reflect and discuss her problems with the research team, and through case discussions, and VDO of teaching, she was able to change her CK, knowledge of representation and activities and inquiry relied on student-centered teaching. In contrast, her limitation of students' learning style, difficulty of teaching, and personal characteristics and beliefs importantly obstructed her PCK development. Tarinee rarely understood her students when she planned her genetic lessons. She did not realize what her students liked or knew. In addition, she knew what her students did not like, but she did not change anything. She also too focused on her time of teaching, so she didn't follow her teaching based on her plans. Furthermore, she thought that she had sufficient knowledge of concepts, so she didn't prepare herself. In fact, she didn't know. Finally, she realized that she limited on knowledge of concepts and teaching, but she didn't change anything.

As a result, activities of the PCK-Based PD Program consisting of reflecting through case discussion, and VDO of teaching, discussing with the research team helped Tarinee develop her CK, knowledge of representations and activities, 5E inquiry and curriculum. However, she had limitation of integrating all knowledge into development of PCK because her insufficient CK and knowledge of representations and activities, students and her personal characteristics and beliefs.

### Cross-Case Comparisons

Cross-case comparisons were derived from analysis of each in-service science teacher's CK and PCK development during the PCK-Based PD Program. The findings are presented below.

#### 1. The Three In-Service Science Teachers Entered the PCK-Based PD Program with Differences in Backgrounds, CK, Representations and Activities, Inquiry, Needs, Personal Characteristics, and Beliefs.

##### 1.1 Backgrounds

Prior to attending the PCK-Based PD Program in teaching genetics, the three in-service science teachers (Tunya, Yarinda, and Tarinee) had different science teaching experiences and backgrounds in the secondary levels shown in Table 5.4. All teachers graduated with a bachelor's degree in the science discipline. Tunya was an experienced biology teacher. Yarinda was a novice chemistry teacher, while Tarinee was an experienced chemistry teacher. In addition, Yarinda had two more years of experience teaching genetics than Tarinee and Tunya.

**Table 5.4** Background information of the three teachers who were case studies

Information	Tunya	Yarinda	Tarinee
Gender	Female	Female	Female
Education	Certificate Higher Education	B.S./Certificate Education/ Studying M.S.	B.S.
Science Background	General Science	General Science/Science Teaching/Science Education in Chemistry	General Science
Science Teaching Experiences	Biology & General Science	General Science & Chemistry	Chemistry & General Science
Science Teaching Years	Twenty-Eight	Five	Eleven
Genetic Teaching Years	One	Two	One

## **1.2 Content Knowledge (CK)**

Three in-service science teachers came to the PCK-Based PD Program with limitations in their content knowledge in genetics. They did not finish their studies in genetics and also had less experience teaching genetics. However, all three teachers used the same text book but knew only about the genetic concepts and the relationships written in the text book. They did not know that there were some misconceptions in the text book such as gene, DNA, so they did not realize that they had incorrect information. In addition, they did not have in depth genetic knowledge. Tarinee and Yarinda did not have new knowledge about genetics such as DNA fingerprint, cloning, and were sometimes unable to give examples about genetics. However, Tunya who was a biology teacher had new knowledge and was able to give some examples of genetics in her classroom.

## **1.3 Knowledge of Representations, Activities and Inquiry**

The three teachers had different knowledge about the representations, activities and inquiry activities in the previous genetic lessons. Tunya and Tarinee, who were experienced teachers, used the same lesson plans on genetics. They copied all their lesson plans from somebody. Their lesson plans used inquiry based on teacher-centered teaching. However, Tunya tended to know more about 5E inquiry than Tarinee because she was always enhancing her knowledge of teaching. Yarinda created her lesson plans by herself but copied some activities from the text book. She thought that she had to plan her own lessons because she used them. Her activities in her lesson plans were based on student-centered teaching. She knew a little about 5E inquiry from her studies on teaching science. Her activities used some stages of 5E and allowed students to construct their own meaning. In addition, Tunya and Yarinda understood the strengths and weaknesses of representations and activities used in their lesson on genetics. They knew what representations and activities were suitable for their students. In contrast, Tarinee did not know this because she wanted activities that were ready to use. She was not confident enough to indicate whether these representations and activities were good or not.

#### **1.4 Needs, Personal Characteristics, and Beliefs**

All of the three teachers wanted to develop their knowledge of genetic concepts and teaching skills. The three teachers were willing to participate in the PCK-Based PD Program in teaching genetics. However, the schools supported their needs for developing their professions differently. Tunya and Yarinda's schools did not give them time for participating in professional development programs in which they were interested. Tarinee was always able to ask permission to attend the professional development programs she was interested in. After the three teachers learned new knowledge and skills from various professional development programs, Tunya and Yarinda always applied the knowledge in their practices as soon as they had a chance and dared to encounter the problems later. In contrast, Tarinee said she did not have time to apply the knowledge. She was not confident to do something if she did not have an example of it first.

#### **2. The Three In-Service Science Teachers Gradually Developed Their CK during the PCK-Based PD Program in Teaching Genetics**

As the PCK-Based PD Program progressed, the three science teachers' development of CK in genetics gradually developed differently. Three teachers gained their similar content knowledge of Mendel's laws, mitosis division, but had misconceptions of mutation, and a number of chromosomes in a cell. Tunya and Yarinda also gained their similar content knowledge of DNA fingerprinting, chromosomes, genes, and DNA, meiosis, while Tarinee still held on misconceptions of them. They developed their CK because they participated in the activities of the PCK-Based PD Program including describing the content knowledge, hands-on activities and discussing on genetic concepts with other teachers and the research team in the workshop and discussing on genetic concepts through case discussion and watch VDO of teaching. As a result, the teacher possessed correct concepts related to these activities. In addition, Tunya and Yarinda was curious person. If they did not understand some genetic concepts well, they tried to find some more information from books, the internet, asking the research team, and consulting with the other

science teachers. They were more aware of their misconceptions. They considered concepts carefully before they provided them to their students. They realized that some of their misconceptions came from the text book. In contrast, Tarinee did not attempt to change her mistakes. Her main reason for this was her limited time to prepare her lessons. So, she had many misconceptions. In addition, Tunya developed her CK well, because she had more teaching experiences in genetics than Yarinda and Tarinee. As a result, Tunya and Yarinda developed their CK more than Tarinee because of the activities in the PCK-Based PD Program, personal characteristics, beliefs, and teaching experiences.

### **3. The Three In-Service Science Teachers Developed Differently Their PCK in Teaching Genetics.**

Tunya, Yarinda and Tarinee developed the different knowledge related to development of PCK: content knowledge, and knowledge of representations and activities. First, understanding own genetic content knowledge was considered as a key learning outcome of PCK. Tunya and Yarinda developed their understanding of content knowledge, so they improved their knowledge before, during and after their teaching and they were aware of misconception in the text book. They made fewer mistakes and passed less of their misconceptions to students. As a result, they were able to teach confidently. In contrast, Tarinee did not understand the correct concepts and their relationships, so she kipped her teaching or didn't organize her insufficient concepts that she planed already to teach. In addition, she didn't realize on her misconceptions, so she passed her mistake to students' understanding.

Second, all three teachers transferred their different understandings of the strengths and weaknesses of representations and activities into teaching genetics. Tunya and Yarinda selected and developed the representations and activities based on what they learned in the workshop and teaching experiences. They applied more representations and activities from the workshops rather than copying representations and activities, such as role-play, work sheets, DNA model. In addition, they created new representations and activities that were different from what they learned in the

workshop such as using pictures of their own family for representing genetic traits. However, sometimes, Yarinda saw the strengths in Tunya's representations and activities and adopted them such as analogy between a DNA stand and a train, using VCD of "DNA and Life". When both teachers found weaknesses in their representations and activities during or after their teaching, they improved them immediately. In contrast, Tarinee copied some representations and activities from the workshop such a work sheet of paper animal. Also, she sometimes did not see the strengths of activities that she used such as the PowerPoint about chromosome, gene, DNA. She tended to improve her representations and activities if she saw the weaknesses of them only after her unsuccessful teaching such as the work sheet of classifying genetic traits.

In addition, not only two types of knowledge presented were a component of development PCK, but also knowledge of 5E inquiry and curriculum emerged from hands-on activities through 5E inquiry and analyzing the curriculum in the workshop were integrated into development of PCK in teaching genetics.

First, three teachers knew the 5E inquiry relied on student-centered teaching and acted differently, so they differently organized activities. Tunya and Yarinda believed in the effectiveness of 5E inquiry and that it was able to let learners construct their own knowledge and have fun with a variety of activities, if teachers emphasized on student-centered teaching. However, Tarinee thought that she would lose time for doing activities because her students still did not understand genetic concepts. Tunya and Yarinda wrote their lesson plans based on the 5E inquiry and relied on student-centered teaching because of the suggestions from the PCK-Based PD Program. However, Tunya and Yarinda tried to organize their lessons based on their planning. Although Tunya sometimes did not follow her planning, finally, she was successful. Tarinee showed her development of teaching with the 5E inquiry based on student-centered teaching and teacher-centered teaching alternately. After she discussed her teaching, she taught her lessons based on student-centered lessons but she came back to teacher-centered lessons later.

Second, three teachers had similar knowledge of curriculum. They were able to organize genetic concepts based on the requirements of the IPST Science Curriculum by analyzing the objectives and learning outcomes before their planning. They selected and organized genetic concepts from concrete concepts to abstract concepts. In contrast, although Tarinee understood and analyzed the curriculum before her planning, she added additional concepts from the text book, so she selected more genetic concepts for teaching. Due to having too many concepts for teaching lower secondary science students in her lessons, she sometimes confused how to organize them in her lessons.

Three teachers developed differently their PCK into teaching genetics because of: (a) activities in the PCK-Based PD Program; (b) knowledge of students' background, conceptions, and learning styles; (c) difficulties of teaching; and (d) personal characteristics, beliefs and teaching experiences.

First, the activities in the PCK-Based PD Program provided a solid foundation for developing PCK into teaching genetics related to CK and knowledge of representation and activities. Three teachers enhanced their above knowledge from similar experiences of describing content knowledge, hands-on activity through 5E inquiry, and discussing on genetic concepts with the other teachers and research team, reflecting their own content knowledge through case discussion and VDO of teaching in the workshop and seminars.

Second, teachers' knowledge of students' background, conceptions, and learning styles were supported their PCK development. Tunya and Yarinda especially thought about their own students' background when they planned their activities and instructional media. They also knew about their students' backgrounds and families. Tunya and Yarinda also understood their students' different learning styles and attempted to provide the genetic concepts for students in different ways because of their different learning styles. In addition, during their teaching in the classroom, they reflected on their students' prior knowledge and misconceptions and helped them to

learn the correct information. In contrast, Tarinee did not mention her students' background, conceptions and learning styles as an important factor in her planning.

Third, both Yarinda and Tarinee, except Tunya, had difficulties of teaching, hindering their PCK development. Yarinda's PCK development was obstructed by her concentration too much on her lesson plans, and lacking of technology for teaching genetics. However, she tried to improve herself, and creating some of their own instructional media and using learning resources from around the community. In contrast, Tarinee had difficulties of using technology and time of teaching. She didn't know how to eliminate her difficulties.

Finally, teachers' personal characteristic, beliefs and teaching experiences supported and/or hindered their PCK development. Tunya and Yarinda always reflected on her own knowledge and teaching and wanted to improve them all time. In contrast, Tarinee knew her weakness in genetic contents, but she didn't want to change anything.

### **Summary**

In this chapter, the results of this study found that the activities in the PCK-Based PD Program in teaching genetics had important influences on the in-service science teachers' CK and PCK development. Tunya and Yarinda gradually developed their CK and PCK, while Tarinee developed her knowledge slowly into appropriate teaching for genetic lessons. In addition, in this study revealed that their own knowledge of students' background, learning styles, and genetic conceptions, difficulties of teaching, and personal characteristics, beliefs and teaching experiences impacted on PCK development. They had to integrate all knowledge into teaching for students' understanding in genetics.

In Chapter 6, conclusions, discussions, and recommendations from the results of the study were presented.

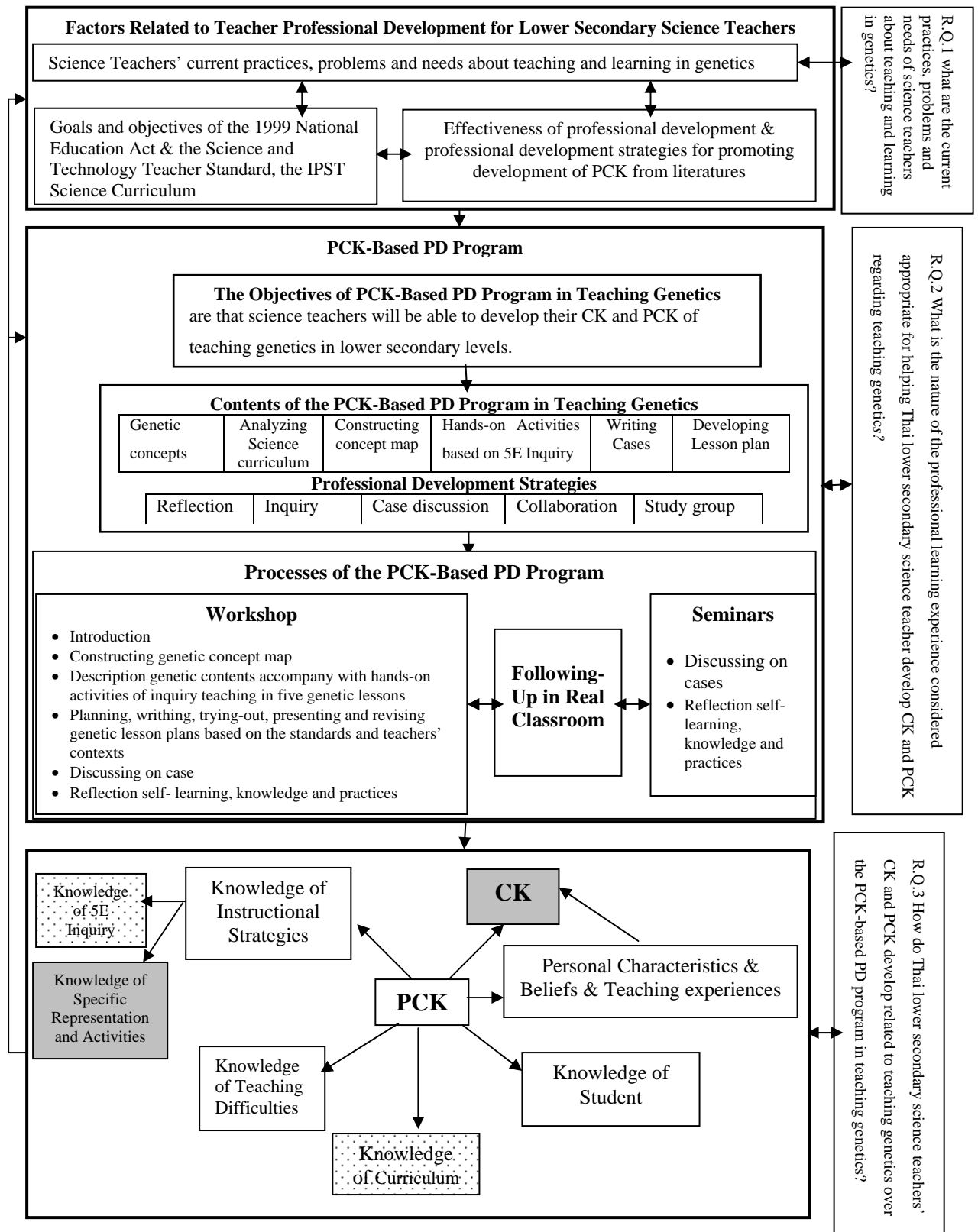
## **CHAPTER VI**

### **CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS**

This chapter is divided into three main sections. The first section presents the discussions of the study's research findings and conclusions generated from this thesis. The second section presents the recommendations for teacher professional developers, science educators, and school. The third section presents the suggestions for future researches.

#### **Conclusions and Discussions**

The conclusions drawn from this research study are presented as a model of teacher professional development of lower secondary science teachers' development of CK and PCK shown in Figure 6.1. The conclusions are presented in correspondence with the three research questions: (a) What are the Thai lower secondary teachers' current practices, problems and needs about teaching and learning in genetics?; (b) What is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teachers develop content knowledge and pedagogical content knowledge regarding teaching genetics?; (c) How do Thai lower secondary science teachers' content knowledge and pedagogical content knowledge develop related to teaching genetics over the course of a teacher professional development experience?



**Figure 6.1** Teacher professional development model for lower secondary science teachers' development CK and PCK in teaching genetics

Note:  means knowledge focused from the PCK-based PD program  
 means knowledge emerged from the PCK-based PD program

### **1. The PCK Based-PD Program in Teaching Genetics Response to the Lower Secondary Science Teacher's Problems and Needs**

The first research question is what are the lower secondary Thai teachers' current practices, problems, and needs in teaching and learning genetics? The researcher surveyed this question to lower secondary science teachers in the Educational Area 1, Suphanburi province before designing the PCK-based PD program in teaching genetics. The results indicated that the lower secondary science teachers struggled to teach and learn these genetic concepts, including Mendel's laws, genotypes, Punnett squares, chromosomes, genes, genetic traits, genetic disorders, and applied genetics, because of its difficult concepts, findings that were similar to the work of Stewart, (1982), Ratanaroutai, (2006), Settapukdee, (2004). In addition, they wanted to be able to teach these abstract concepts in concrete ways to help students understand genetics. Thus, it was implied that the teachers needed strengthened PCK for teaching genetics (Loughran, 2006), especially if they had never participated in a teacher professional development program about teaching genetics. All the teachers needed to enhance their professional knowledge in teaching genetics. They needed more simplified and correct contents, new and interesting teaching strategies, VCD's, electronic media, and documents about teaching genetics. In addition, they were aware that inquiry teaching to help a learner construct their own meaning is important. However, they were not successfully using inquiry teaching with an emphasis on the student-centered approach because of students' learning styles, time, and lack of learning resources. These findings are consistent with the research of Wallace and Kang (2004). As a result, the survey results indicated that a professional teaching development program for teaching genetics should be designed, relating to teachers' problems and needs (Loucks-Horsley *et al.*, 2003).

The results of the study in chapter 5 indicated that the PCK-based PD program in teaching genetics was able to help science teachers solve problems with difficulty of learning genetics. In addition, the program responded teachers' needs of how to teach genetics and teaching with inquiry that emphasized student-centered orientation. Two of the teachers gained a better understanding of difficult genetic concepts, and

they were able to select and create activities and representations for teaching genetics. They were able to transform their understandings of genetics into learning experiences for their students by using inquiry teaching that emphasized a student-centered approach. Their students had a better time learning some genetic topics, after genetics was taught by an inquiry process that emphasized a student-centered approach. The finding was consistent with the research of the IPST Research Department, (2001) and Sudsin (2001). However, another teacher gained little understanding of genetics and how to teach the topics. Sometimes, she was able to use inquiry teaching that relied on a student-centered approach in the genetic lessons, but, many times, she needed more suggestions and time for solving the problems of her limited genetic content knowledge and how to organize the lessons in suitable way for students. As a result, it was decided that the PCK-based PD program in genetics responded to the teachers' needs and problems.

## **2. The PCK Based-PD Program in Teaching Genetics was Considered Appropriate for Helping Thai lower Secondary Science Teachers Develop CK and PCK in Teaching Genetics**

The second research question is: What is the nature of the professional learning experience considered appropriate for helping Thai lower secondary science teachers develop content knowledge and pedagogical content knowledge, regarding teaching genetics? The results revealed that many professional learning experiences in the PCK-based PD program, consisting of a five-day workshop, two seminars, and observations of the teachers in their classroom, were able to help Thai lower secondary science teachers development of CK and PCK in teaching genetics in line with the objectives of the program. The results are shown in Figure 6.1.

First, developing an understanding of genetic content knowledge and representations and activities based on a teachers' context in the program was able to help science teachers develop their CK and PCK in teaching genetics. The finding was consistent with the works of Darling-Hammond and McLaughlin (1995), Garet (2001), Liebman (1995), Loucks-Horsley *et al.* (1998), (2003), Magnusson *et al.*

(1999), and ONEC (1999). When three teachers had a chance to learn genetic content knowledge during the workshop and seminars, they understood their own genetic concepts and improved some of their misconceptions. In addition, when the three teachers did new hands-on strategies for teaching genetics and they discussed the strengths and weaknesses of the representations and activities, they gained their considerations and understandings of effective teaching strategies.

Second, reflections and inquiry were processes to help the teachers develop their CK and PCK in teaching genetics. In the workshop, the three teachers had a chance to reflect on their knowledge of genetics and genetic teaching. They understood what knowledge they should improve. In addition, when they reflected on their knowledge and actions through written cases in the seminars and their journals, Tunya and Yarinee developed their understanding of genetic knowledge, problems of genetic teaching, and what and how they taught. As a result, reflection was a process to develop the teachers' understanding of CK and PCK (Fress, 2006; Luft, 2001; Osborn, 1998; Zembal-Saul *et al.*, 2000). Not only reflection was used for developing CK and PCK in teaching genetics, but also inquiry was a part of the process of making these developments. When the teachers learned contents in the workshop through the inquiry processes, the teachers were able to construct their CK and how to represent the material for students' to understand by themselves. This finding was consistent with the works of Khourey-Bowers and Simonis (2004), Magnusson *et al.* (1999), and Pringle (2004). In addition, they reflected on how their students learned and if it was the same as how they had learned genetics. They realized that if students constructed their own meaningful understanding of the genetic contents, the knowledge would last for a long time.

Third, case discussions were able to increase science teachers' development of CK and PCK in teaching genetics, consistent with Loucks-Horsley *et al.* (2003). When the three teachers had chances to discuss other teachers' cases in the workshop as a group, they learned about the other teachers' understanding of CK and their teaching. This helped them to rethink their own knowledge and teaching. The finding is consistent with Koballa and Tippins (2004) discussion of the effects of case writing

and discussion on teacher learning. In this study, when the teachers wrote and discussed their own cases, they reflected on their CK and their particular problems in teaching, and tried to solve those problems with the other teachers.

Additionally, collaboration with the research team, which included science educators, scientists, researchers, and other teachers, was able to enhance their development of CK and PCK in teaching genetics, consistent with Loucks-Horsley *et al.* (2003), and ONEC (1999). When the teacher did activities in the workshop and seminars, they worked in small groups with the other teachers and members of the research team. This provided an opportunity for the teachers to focus on particular genetics concepts and strategies for teaching the topics and to help each other improve on these problems. In addition, they shared ideas to create a lesson plan on teaching genetics together. All these activities provided opportunities for all the teachers to develop and examine their understanding of CK and PCK in teaching genetics.

However, from this study, it is apparent that some professional teaching experiences in the PCK-based PD program could be improved. The activities should use more time for providing new genetic concepts in depth and try to help more of the teachers who did not have sufficient CK, such as Tarinee. In addition, the activities should add discussions on the teachers' knowledge of their students. Furthermore, time should be added for planning lessons in the workshop. Teachers need time to share their ideas and to develop lessons on genetics together. Moreover, the teachers who participated in the workshop should have more time to clarify their own genetic contents, before attending to the program.

As a result, many professional development activities and processes of the PCK-based PD program in genetics presented above were integrated to develop lower secondary science teachers' development of CK and PCK in teaching genetics.

### **3. In-Service Science Teachers Gradually Developed Their PCK and CK for Teaching Genetics during the PCK-Based PD Program**

Research question 3 is: How do Thai lower secondary science teachers' content knowledge and pedagogical content knowledge develop, related to teaching genetics, over the course of a teacher's professional development experiences? The three in-service science teachers developed their CK and PCK in teaching genetics differently.

The findings revealed that the program helped the science teachers develop their CK. Tunya and Yarinda gained a better understanding of genetics and the relationship among genetics concepts from the program, such as, genetic traits, chromosome, gene, DNA, genotype, phenotype, cell divisions, Mendel's laws, Punnett square, genetic disorders, and applied genetics. In contrast, Tarinee showed less understanding of genetic concepts than two teachers.

The three teachers changed their understanding of genetic concepts because the activities in the PCK-based PD program. When the three teachers had opportunities to discuss the genetic concepts with the research team and other teachers and reflected their understanding of genetic concepts through reflection, they gained their understanding of these concepts. In addition, the teachers' teaching experiences, personal characteristics, and beliefs also had an effect on their development of CK. Tunya and Yarinda developed their genetic understanding more than Tarinee because their characteristic of curiosity. They were more aware of their misconceptions, and improved their understanding of CK all the time. In addition, Tunya is a biology teacher who was more familiar with genetics than Yarinda and Tarinee, she continued to develop her learning continuously.

In addition, the findings suggest that the three teachers developed their PCK in teaching genetics. First, teachers' development of CK enhanced their confidence of teaching, organizing lessons, awareness of the important concepts, and students' understanding of genetic concepts. Consistent with Shulman (1987), Magnusson *et al.*

(1999), Morine-Dersheimer and Kent (1999), and Veal (2003), the development of a teacher's own PCK depends on having a rich conceptual understanding of the content knowledge that they teach. The evidence that appeared in this study was that Tunya and Yarinda possessed stronger genetic content knowledge than Tarinee. Both were confident in teaching and providing successful content knowledge through learning activities for their students. In contrast, Tarinee skipped over topics in her teaching, if she found that she had insufficient content knowledge in that area. Second, teachers' knowledge of representations and activities affected the selection and improvement of lessons for helping students' understanding genetic concepts. The three teachers were able to select and create representations and activities for teaching specific concepts. They attempted to improve the activities and instructional media, if they found weaknesses in them, during and after teaching. Third, teachers' knowledge of 5E inquiry relied-on student-centered teaching helped them organize sequences of activities. Fourth, teachers' knowledge of curriculum gained teachers' organizing genetic concepts in line with the requirements of IPST. As a result, the teachers integrated genetic content knowledge, knowledge of representations and activities, knowledge of inquiry teaching, and knowledge of curriculum for developing their PCK into forms for students' understanding in genetics.

The teachers developed their PCK because of the activities in the PCK-based PD program in genetics. When the teachers had opportunities to discuss genetic concepts, and teaching with the research team and other teachers, and when they reflected their teaching and understandings of representations and activities through cases, they gained their understandings of genetic concepts, the strengths and weaknesses of representations and activities, and were able to improve their knowledge and teaching of genetics in effective way. In addition, the teacher's knowledge of students' backgrounds, learning styles, and conceptions, personal characteristics and beliefs, and knowledge of teaching difficulties influenced on their development of PCK in genetics. PCK is the knowledge that teachers develop over time, through experiences, about how to teach particular content in particular ways, in order to lead to enhanced student understanding (Loughran *et al.*, 2006). The results

of this study revealed that Tunya and Yarinda wanted to develop their knowledge and teaching continuously, so their development of PCK progressed.

In summary, the findings suggest that the processes of in-service science teachers learning how to teach a particular subject is complicated and multifaceted (Loughran *et al.*, 2006; van Driel *et al.*, 1998). PCK is a particular expertise with individual idiosyncrasies and important differences that are influenced by content, teaching experiences and teaching context (Loughran *et al.*, 2006). The three teachers had different abilities that helped them transform their knowledge for students' understanding by integrating many different aspects, such as genetic content knowledge (CK), knowledge of specific representations and activities, knowledge of the 5E inquiry, and curriculum knowledge, that focused and emerged in the PCK-based PD program. In addition, their own knowledge of students' learning, conceptions, backgrounds, abilities, teaching experiences, personal characteristics, and beliefs was integrated into the development of their PCK. As a result, the PCK-based PD program in genetics appears to be helpful for lower secondary science teachers' CK and PCK development in teaching genetics.

### **Recommendations**

To conclude this study, a number of recommendations are derived from the findings of the study for teacher professional developers, secondary schools, the IPST, and pre-service science teacher education.

First, contents and activities in the professional development program should be considered based on a teacher's needs and problems in their context. In this study, development of the PCK-based PD program suggested what teachers needed. The developer should understand what contents and activities should be designed to be in line with their needs and problems. When the program is planned and implemented in this way, its effectiveness will be in line with the responses from the teachers based on their needs and problems.

Second, development of CK should be considered as a part of PCK development in the professional development program. If a teacher had stronger content knowledge, they were able to plan and teach their lessons confidently.

Third, this study suggests that reflective practices through case discussions during the PCK-based PD program should be considered as significantly impacting the lower secondary science teachers' development of CK and PCK. With reflective practices, science teachers can see the strengths and weaknesses of their own teaching and actions and can improve their teaching continually.

Also, collaboration between the research team, consisting of science educators, scientists, researchers, and science teachers should be considered as an important role in the PCK-based PD program for developing teacher's CK and PCK in teaching genetics. In their role as content experts, science educators and scientists strived to help teachers build confidence in teaching science by providing them with new insights and experiences. Working collaboratively with scientists and science educators, science teachers were able to learn more about how the scientific process works and how teaching strategies and activities can be provided for students.

Additionally, following up the teachers in their actual classes should be considered as an importance in the program. When the teachers learned many things in the workshop that they did not use in their classrooms, the following up with observations and discussions showed the teachers what and how their new knowledge could be applied. During this following-up, the research team had an opportunity to assist them in gaining knowledge and confidence to teach it.

Furthermore, constructing relationships between participants should be considered important in the professional development program. This would allow them to contact each other and share ideas and experiences about teaching the same topics, after they come back to their school. In this way, they could help develop their own knowledge and teaching together.

In addition, the results of this study suggest that secondary science schools should supply teachers with enough instructional media, especially, technology for science teachers. The science teachers can use these devices to provide students with a better understanding in science. In addition, the school should support teachers' professional development continuously.

Furthermore, the results of this study suggest to the IPST who has a responsibility to develop in-service science teacher professional development in many aspects. First, the science teachers should be developed their understandings of genetics continually because the genetics still is the most difficulty for teachers' teaching and learning. In addition, IPST should more consider about genetic contents in the curriculum. They should help the teachers clarify what concepts should be taught. The IPST also should work corporately with Faculty of Education and Faculty of Science in professional development programs for helping in-service science teachers develop their knowledge and teaching in difficult topics.

Moreover, the results of this study suggest to the pre-service science teacher education that should emphasized on the pre-service science students' content knowledge in science for developing their PCK. The pre-service science teacher education should work with the Faculty of Science to construct correct science content knowledge for pre-service students in teaching. When the students have their own correct content knowledge in science, they are able to design, select, and improve suitably activities and representations for effective teaching science concepts. In addition, if the pre-service students understand the science concepts, when they teach, their students will also understand the concepts.

### **Suggestions for Future Research**

Teachers' personal characteristics and beliefs were difficult to change and interrupted teachers' development of CK and PCK. In the future, the research will find out way to improve and develop continuously teachers' personal characteristics and beliefs for effective teaching in science. In addition, the research of development PCK should study students' achievements, because the achievements will be an additional evidence for convincing the effectiveness of teacher professional development on PCK development.

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## **APPENDICES**

**Appendix A**  
Concept Interview

### Concept Interview

#### Concepts:

Question	Concepts
1	relationship of genetics concepts
2	Cells, genetic information and chromosomes
3	Cells, genetic information and chromosomes
4	Genetic inheritant
5	genotype and phenotype, dominant and recessive genes
6	Monohybrid cross and Mendel's law
7	Numbers of chromosome and cell division
8	Numbers of chromosomes and genetic information
9	Cell division and DNA replication
10	DNA fingerprint and its application

**Objective:** To explore three Thai lower secondary science teachers' understanding of genetics concepts (CK)

**Procedures:** The teachers will read each question and be asked to answer ten questions in following

#### Question 1: Relationship of Concepts

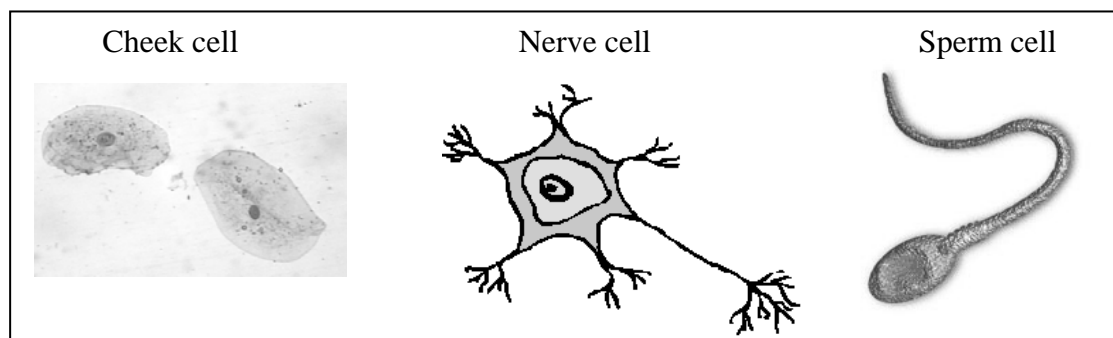
1. Concept map of these words in below is used by a teacher. The ten biological items in the list below are all parts of living systems. If you a student, now place these items to show their relationships.

Somatic cells      Chromosomes      Organism      Autosome

X and Y chromosomes      Genes      Nucleus      Sex cells      DNA

**Question 2, 3:** Cells, Genetic information and Chromosomes

2. Shown below are different cells from Suwat. If you can take one of Suwat's cheek cell, nerve cell, and one of Suwat's sperm cell, will the genetic information in them be same or different.



Students responded to this question. Consider each student's response and indicate whether or not each student response to a questions in correct or incorrect and then explain why?

A. They are the same because *"no distinction of genetic information between cheek cell or nerve cell and sperm cell in one individual because the sperm carries all the genetic information so it will contain the cheek cells."* (incorrect)

B. They are different because *each sperm cell contains half the chromosome of the other cells. It is chance which decides which information is in which sperm cell* (incorrect)

C. Reproductive cells must contain more genetic information than specialize somatic cells (incorrect)

3. If you can take two of Suwat's sperm cells, will the genetic information in them be the same or different?

Student said that *"different because "each sperm cell carries a diffident combination of genetic information because sperm cell only contains half the*

chromosome of the other cells. It is chance which decides which information is in which sperm cell”,What do you think from this student’s response?

**Question 4:** Genetic Inheritance

In a classroom, a teacher shows a photo of a white couple and asks a question “if a white couple moved to live in Africa, what is the skin color of their offspring? .Students response in following:

A. *“the skin colors of the offspring at birth should be white (correct).*

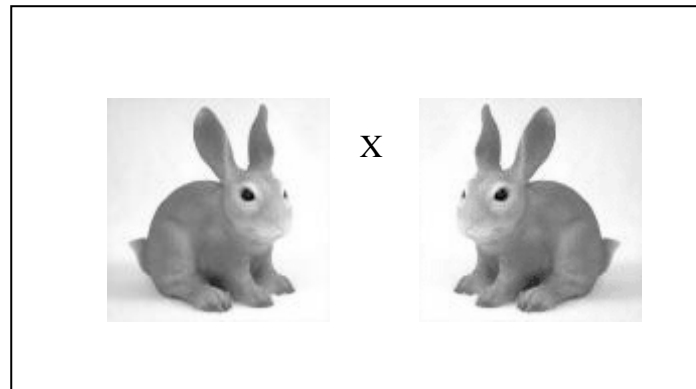
B. *the skin color may become darker because the skin color is a continuous variation (incorrect).*

C. *As generations pass on, the skin of offspring will become black since they born because of environment change (incorrect).”*

Consider each student’s response and identify correct answers and explain how the teacher should answer this question.

**Question 5:** Genotype and Phenotype, Dominant and Recessive Genes

In one classroom, a teacher shows a mating pair of brown rabbits mate (shown in picture). The female is pregnant. Then, she asks her students “what will be the color of the rabbits’ offspring? Why?. Students answer this question in below. What are your responses if you are a student?







What is color of rabbit offspring? Why?

**Question 6:** Monohybrid cross and Mendel's laws

B is allele for grey color and b is allele for brown color. When Bb crosses Bb, what are all possible offspring genotypes from this cross? Students use Punnett squares to solve this problem. When the students are asked **“Why did you put one B over each side of the boxes and one B next to each?”**

Student A answered that “I don't know, that's just the way we do it in class”. What is your answer for this question?



	B	b
B	 BB	 Bb
b	 Bb	 bb

**Question 7:** Number of Chromosomes and Process of Cell Division

An animal has three pairs of chromosomes in each cell. When sperm fertilizes egg, Could you draw numbers of chromosomes in the fertilized egg and explain why?

**Question 8: Numbers of Chromosomes and Genetic Information**

New Siam Twin born at Khon-Kan



You read about Siam twin in the news. From this news, one student wondered “how many the chromosomes of each individual (two boys)? Do they have the same genetic information?”

Nunnon and Nuntawat are Siam twin who are given birth in the seventh month of pregnancy at Khon-Kan hospital. Doctors worked successfully to separate their bodies on August 14, 2004. “The boys’ weights are totally 5,590 grams. Their mother is Aoy Onlaew. She is twenty –eight years old. She was pregnant thirty- nine weeks. Their father is Kombu TaSoong. They are farmers and work in the shoes factory at Khon-Kan province. They are poor. They have the first son. These twins are the second birth in their family. No one in their families had given birth to twins” Doctor Wittaya said.

In the seventh month of her pregnancy, the mother felt that her baby is too big. She checked the ultrasound and found that her babies are twin. Thus, doctors worked on her babies immediately. The older twin had good health, but the younger twin had his body together with the older one. The younger twin was not in good health and wasn’t screaming when he was born. However, the doctors can rescue him.

“When I took ultrasound, I am afraid that my babies didn’t divide completely. However, I waked up and saw my twins. I was very happy although their body didn’t separate. I and my husband gave their name, Nunnon and Numtawat”. Aoy said

The doctors tried to dissect the twins. Twin parents were concern about the dissection, but they were confident the work of doctors. Finally the twins can be dependent person.

**Question 9:** Cell Division and DNA Replication

From the news in question 8: When and where does DNA replicated itself? Why?

**Question 10:** DNA Fingerprint and Its' Application

Your students read this news and doubt that “how DNA proofing will identify that he is really father’s baby. What parts of our body can be used for DNA proofing? How will you explain these doubts? Is it right that we used blood for DNA proofing?

**Title: Proved DNA “Dak Big Ass”**



Finally, Dak Big Ass who is famous singer went to a hospital to identify his son as the teenager girls who had a son will go with her son to check their DNA. The doctor asserts that the results will be shown within one week.

This is hot news in Thailand. Dak Big Ass or Akarat Wongchalad was defendant in the offending case to a teenager girl. She is a model. Her name is Fay. In addition, he was accused that he is father of the girl’s son. He denied the accused and challenge the girl to proof her DNA and her son’ DNA.

At 2.30 pm on February 24, 2006, Dak went to the institute of medical jurisprudence for identify his son. However, the model girl didn’t go there. After he

gave his blood for proofing DNA, the singer announced briefly to news writers that “I came here for proofing whether Justin was my son, or not. My life was changed because of this situation”. Then he took a van. He didn’t say anything about the case.

Source: Manager Newspaper on February 24, 2006: 4.20 pm

## **Appendix B**

### **Case A: How Do You Represent Concepts of Cell Division and Genetic Information?**

### Case A: How Do You Represent Concepts of Cell Division and Genetic Information?

**Overview:** The following is a list of questions asked by the researcher every time a teacher responds to this case. The directions will be given to the teachers each time before the administration.

**Directions:** Please read the following case. I would like you to comment on what you like or dislike about the case. I will then ask you some questions.

**Objective:** This case will be used to examine teachers' PCK in aspect of how to represent these concepts of cell division and genetic information.

Tussika is a new teacher in a secondary science school. She graduated with a biology major. In her first year, she was teaching grade 9<sup>th</sup> student in basic biology topics. Genetics is one topic that she taught students. Concepts of cell divisions are required to teach in the first lesson of teaching genetics. The students learned concepts of cells, structures and functions of cells in grade 7<sup>th</sup>.

She consulted a co-teacher, Ajan Naljan, who is an experienced science teacher in the school. The co-teacher graduated general science and she is also teaching genetics in the same level, but different classes. Ajan Naljan's students have high scores of science. She borrows and looks at Ajan Naljan lesson plan about concepts of cell division (mitosis and meiosis) and related genetic concepts. "Please look at my lesson plan, if you have new idea on this activity, please let me" Ajan Naljan said. In her lesson plan, first, she shows pictures in each stage of mitosis, and then explains change. Then she gives the students the worksheet that let students to match the pictures and technical terms (ex, prophase) and write down their explanation in each stage of development. After that, she will go to the stage of meiosis by using the pictures and try to ask the questions "Do you guess which stage" "what happened in each stage of meiosis by comparing stage of mitosis. " What are the similarities or/and differences between mitosis and meiosis"?. After that, she divides her students into groups. Then her students construct the model of mitosis and

meiosis from pipe cleaners on the big board. The students have to write down the name and what happened in each stage and send this model within the next week.

The majority of students in Tussika classes do not like science subjects. Their science score are low. They always say that science learning involves rote memorization. They have difficulty understanding the content. Thus, she tries to modify and create new activities that differ from Ajan Naljan. She thinks that Ajan Naljan lesson plan is not suit for her students because the students are different science score. She thinks that if she let her students to construct the mitosis and meiosis model, they will be bored. They may not send their model to her.

She started by looking at the textbook and then at the other resources before creating her lesson plan. She wanted her students to enjoy learning science and to able to explain the applications of genetics in their real lives. Thus, she tries to create activities that enable her students to understand the concepts in concrete ways.

In the classroom, the long tables were arranged to accommodate groups of students. A long table was place in front of the class for the teacher. When the bell rang in the afternoon, she was so excited. She was confident that all students would like her science activities, especially, the students who sit in the back of the classroom. In her lesson, she begins her lesson by asking a questions “What stages of growth in human life?” after that she shows the pictures of each stage of human life (baby, children, adult, old) and shows the pictures of each stage of mitosis division and explain what happened in each stage. After that, she divides students into two groups for role-play activities. The students are fun when they can go outside of classroom. One group of students represents the cell membrane and another group represents the chromosome. The group students who act as human chromosomes wear caps and shirt tags that have gene (E, e, D, d letters). One student represent the sister chromatids. Two students who wear the same caps and shirt tags will act as a chromosome. Tussika poses the questions for role play in the following. “What are the stages of mitosis?, what happens in Prophase? Metaphase? Anaphase? and Telophase?, Is the number of chromosomes reduced or preserved in mitosis?” Some

students don't understand in each stage. Then, Tussika let the students go back and review each stage again.

After that, she goes to explain stages of meiosis. Her students feel that it is difficult. A student, Mali complains "why it has many stages". As Tussika explains each stage of meiosis, she tries to compare stage in mitosis. After that, she let her students to go outside again. Then, a student roles play as a human sister chromatid. A chromosome is a pair of male or pair of female. During the prophase stage, a pair of male chromosome matches with a pair of female chromosome who has the same caps and shirt tags. Students role play following the same questions as they act in mitosis division. "Is the number of chromosomes reduced or preserved in meiosis? If reduced, when does it occur? and does crossing-over occur? independent assortment? segregation? If so, where?" are additional questions asked to students. During the students role play the meiosis, Tussika knows that students may be not confident to role playing. Thus, she brings the big board with pictures of each stage of meiosis in the field. After the class finishes activities, she knows that a few students confuse in many points. For example, differences of numbers of chromosomes in mitosis and meiosis division. However, most of students can do this activity. They always ask her to help them role play in each stage. When she asks some questions, for example, what will you do in next phase?, the students can explain although it is not complete. Thus, she intends to explain these concepts more in the next lesson.

When she finished her lesson planning, she consulted with Ajan Naljan. She liked Tussika's lesson plan. "This is a great activity. I think the students would like it" Ajan Naljan said. Ajan Naljan also asked Tussika to borrow her lesson. Tussika said proudly, "O.K. I 'm please that you would use it"

**Questions:**

- 1) What do you like best about what the teacher did (Ajan Naljan and Tussika), and why?
- 2) What are advantage and disadvantage of two activities (from Ajan Naljan and Tussika)?
- 3) If you are Tussika, do you think Ajan Naljan can represent the concepts in effective way?
- 4) If you are Ajan Naljan, will you do the same or different from Tussika to teach the students who has low science scores?.
- 5) If you are Tussika, would you have done something different? How?
- 6) Was the content of the lesson correct in Tussika's teaching?
- 7) Should these concepts be taught in the first lesson of genetics? Why?
- 8) What will you do during the next time before you respond to this case again?

## **Appendix C**

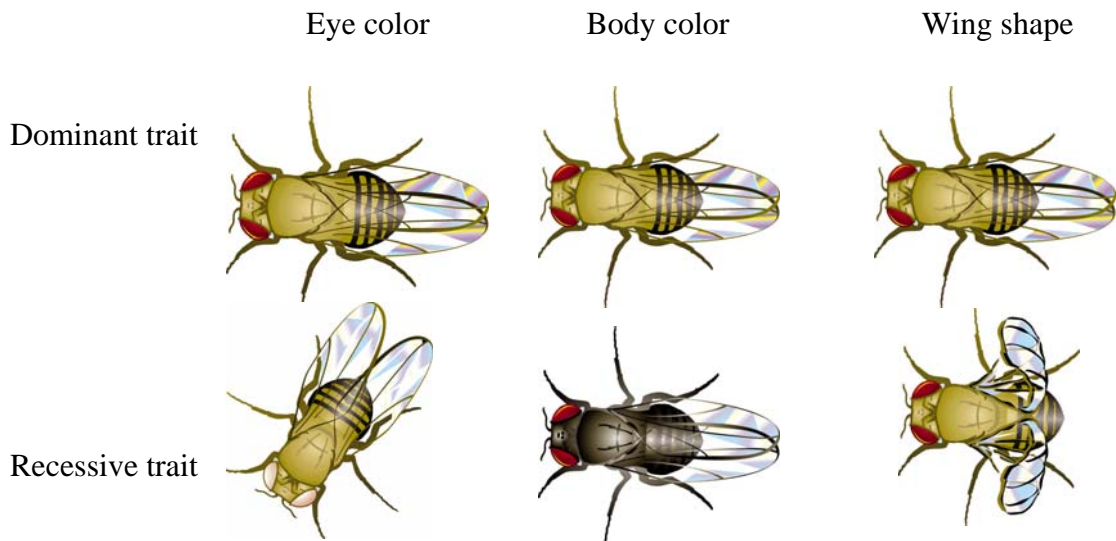
### Case B: Genetic Problem Solving

**Case B: Genetic Problem Solving**  
**(Adapted from Koballa & Tippins, 2000)**

**Objectives:**

1. This case was presented as an example for teachers in a five-day workshop.
2. The case was used for increasing teachers' understanding concepts of phenotype, genotype, dominant and recessive gene, monohybrid cross and how to teach in ways that enable students to understand these concepts.
3. The case was used for development of how to represent the genetics concepts (development of PCK).

Malinee is a student teacher. She attempted a problem solving laboratory with a ninth grade biology class. She wanted to provide her students with real-world science examples and allow them to use their own thinking skills. She expected that her students would make some important connections between genetics concepts and the real world as they determined the genotypic and phenotypic ratios for fruit flies. She knew that fruit flies' genetic traits (eye color, body color and wing) are determined by a pair of gene on one chromosome. These traits should be good example for studying genotype, phenotype, dominant and recessive gene, and monohybrid cross



Malinee was enjoying her Saturday afternoon preparing crossing between dominant and recessive traits of the fruit flies in a science laboratory with her friend, Lalita. She was doing liquid food for feeding fruit flies. As she selected pure females and males, Malinee put one male and female in the a bottle of liquid food in each trait (red eye x white eye; brown body x black body; and straight wing x curly wing), she realized that her laboratory illustrated the concept of phenotype that she had been teaching in biology class over the last few weeks. “ Hey, this fruit fly in the second generation ( $F_2$ ) shows a three-to-one-phenotype ratio, she said to Lalita. “If I use this in class, the students will be able to see how dominant and recessive alleles are expresses in real life. They can see the phenotypic ratio and reason backward to the genotypic ratio. What a great ‘aha’ experience!” After that she began thinking about her lab on the way home, excited that she had come up with a concrete idea for teaching that week.

After Malinee had shown the fruit flies to her cooperating teacher to make sure it did express the genetic characteristics she though it did, she wrote her lesson plan and prepared a worksheet to go with the lab activity. When she finished, she was very pleased with her products. The students were going to count the numbers of offspring in the first generation ( $F_1$ ) and the second generation ( $F_2$ ) from a pair of fruit flies, infers the phenotype, and then from the phenotype infers the genotype. She included some thought-provoking questions on the lab worksheet that tied several important genetics concepts together. This lab was going to be an opportunity for her students to do some thinking and apply what they had learned about dominant and recessive genes, genotypes, and phenotypes. Malinee remembered from her method class that it was important to have students engage in problem solving, not just follow cookbook labs by rote. She also agreed with her methods professor that to understanding biology, students need to see a relationship between abstract concepts and real organisms. She though that using fruit flies would motivate her students and encourage them to make connections between genetic terms and their meanings. She also thought that the three-to-one phenotypic ratio illustrated by offspring of fruit flies parents was so obvious that her students would jump on the problem and quickly arrive at solutions.

On Monday of the next week, (fruit flies had their offspring ( $F_1$  and  $F_2$ ), Malinee started her first-period biology class by reviewing the basic concepts that the students had been using in their study of genetics. She then announced that the class was going to have the chance to discover the phenotype and genotype of fruit flies in their lab groups. She quickly went over what she expected them to do and explained that the fruit flies had their offspring that had different traits. Each group of students would be engaged to sleep fruit flies and count a bottle of offspring ( $F_1$ ) and a bottle of offspring ( $F_2$ ). With a smile, she passed out the laboratory worksheets and waited for the students to begin work.

The first minutes seemed to go very smoothly. The students chose two bottles of fruit fly offspring, went back to their groups, and dutifully began make them sleep and count them. Malinee circulated among the groups, making sure everyone was on task. Soon, she began to here murmur of discontent. Several students began making negative comments, and it was apparent she was meant to hear them. “What does she want us to do? I don’t know what to do. Does she know that she wants us to do?” “What are  $F_1$  and  $F_2$ ?” The talk began getting louder. Malinee went to over to help Napat, Janjira, and Marut. “I don’ know what you’re asking”, Marut whined. As Malinee began to patiently explain how they should think about the ratio of their red eye and white eye offspring, she realized the class was really beginning to get noisy. She looked up. Ratwipa, Kan, Samapon were discussing the new episode of the Harry Potter movie. Sunisa and Kengjai were passing notes and giggling. Sumita and Chanchai were beginning to argue in loud voices about what the numbers of fruit fly offspring meant. Haruthai screamed and said “worm! worm!” Malinee’ heart began to beat a little faster. A bad feeling was rising in her stomach. She was afraid the class was getting out of control. Then, Tawatchai, who often disrupted the class, began clapping his hand with the fruit fly and shook his bottle of fruit fly offspring. Narit had the same behavior with Tawatchai and laugh. Malinee felt herself blushing. Gathering her determination, she stopped the class, informed the students that their behaviors was not going to be tolerated, and led them through the analysis of their eye and body color and wing characteristics frequencies and questions together as a class.

After the students left the room, Malinee closed the door, and slumped into a chair. She was thinking what she should do when the third period came. She thought that the phenotypic ratio was so obvious! Why didn't the students recognize the three-to-one ratio after all the Punnett Square problems we did in class? Why did they become frustrated so easily? She thought they would really enjoy the lab. They seemed to be the most frustrated of all! Maybe asking students to apply concepts is too hard. Or she thought that she didn't prepare them emotionally for this lab?

**Questions:**

1. Do you agree with her that students should have opportunities to solve real world problems and apply concept? Why or why not?
2. What are the advantages and disadvantages of doing this lab?
3. What would you do with Malinee's third period class?
4. What events of first period influenced your decision?
5. How will you teach this concept?

## **Appendix D**

Interview# 1: Teachers' Background

### **Interview# 1: Teachers' Background**

**Objective:** To understand teacher's background including age, education, teaching experiences, teacher professional development experiences.

**Questions:**

1. How old are you?
2. Could you tell me about your background in science education and science teaching and genetic teaching?
3. Could you tell me about your background in science education and science teaching?
4. Could you tell me about your professional development experiences?  
(specific to science and genetics)

**Appendix E**  
Interview of Teaching

## Interview of Teaching

**Objective:** To examine teachers' development of CK and PCK in genetics.

**Questions:**

1. What are your goals of teaching on topic of .....? (PCK)
2. During your teaching, what did you change from your lesson plan? How? Why? (PCK)
3. Do you have problems about your own understanding of genetic concepts that you taught? (CK)
4. What do the activities, instructional media, and teaching strategies you use in lesson of...? Why?, and How do these activities, instructional media, and teaching strategies influence on your students' learning? (PCK)
5. Do you think that the activities, instructional media, and teaching strategies that you use are relevant to the requirements of the curriculum, and purposes of teaching? How? (PCK)
6. After you teach the lesson of..., What are the strengths and weaknesses of representations and activities?, What representations and activities do you want to improve?, and How? (PCK)
7. Before you teach in the lesson of..., Do you ask students' prior knowledge of genetic concepts?, and after you teach, what genetic conceptions do your students have, and change? (CK)
8. If students have misconceptions in..., how would you help them correct the misconceptions? (CK)

**Appendix F**  
Researcher's Field Note

### Researcher's Field Note

**Objectives:** To examine teachers' development of CK and PCK in genetics

**Focus on:**

1. Context of classroom (arrangement of tables, learning resources, environment of classroom) and students' learning (learning styles, relationship with teachers)
2. Relationships between teacher and students, between students and students
3. How do teachers teach the lesson of...? Does the teachers' teaching relevant to their lesson plans? What do the teachers change during their teaching the lesson of...?
4. What teaching strategies do teacher use (inquiry?)
5. What activities and instructional media do teachers use? Do their students learn genetic concepts from these activities and instructional media?
6. What are teachers' problems of teaching genetic concepts? How?, and How do the teachers solve that problems?
7. What are teachers' understandings of genetic concepts of...? (correct/not correct)
8. What are students' understandings of genetic concepts of...? (correct/not correct)

## **Appendix G**

Tunya's Teaching Methods of Genetic Concepts

### Tunya's Teaching Methods of Genetic Concepts

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
1	<p>-Students did pre-test.</p> <p>-Students searched for <b>Mendel's work</b> from a library in small groups.</p> <p>-Students did hybrid cross, and discussed on Mendel's work.</p> <p>-Teacher and students summarized Mendel's work.</p> <p>-Students searched for and summarized about <b>dominant &amp; recessive genetic traits</b> from a library in small groups.</p>	3 hr.	<p>-Teacher showed a picture of a woman and asked some questions of genetic traits.</p> <p>-Students did an activity (A) of classifying genetic traits in small group.</p> <p>-Teacher explained &amp; gave examples of <b>genetic traits, dominant &amp; recessive genetic traits.</b></p> <p>-Pair of students did an activity (B) of surveying their own genetic traits.</p> <p>Teacher &amp; students discussed &amp; summarized genetic traits of the activity B.</p> <p>-Each student did an activity (C) of surveying genetic traits of their relations.</p>	2 hr.
2	<p>-Students searched for and discussed on meaning of function of <b>dominant &amp; recessive gene</b> from a library &amp; internet in small groups.</p> <p>-Students searched for, made a chart of, presented about <b>relationships between gene &amp; chromosome</b> from a library &amp; internet in small group.</p> <p>-Students did an activity of surveying their genetic traits and summarized it in small group.</p>	4 hr.	<p>-Students drew a picture of chromosome.</p> <p>-Teacher played a VCD of DNA and Life while students noted about chromosome &amp; DNA from the VCD.</p> <p>-Students presented their knowledge of chromosome &amp; DNA.</p> <p>-Teacher &amp; students summarized structure &amp; functions of chromosome, gene &amp; DNA through a PowerPoint.</p> <p>-Students constructed &amp; presented a model of DNA following teacher's direction in small groups.</p> <p>-Teacher explained about <b>.relationship among chromosome, gene &amp; DNA</b> by analogy (movement between fingers and chromosomes).</p>	3 hr.

### Tunya's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
2 (Cont.)			-Small groups of students did a concept map of <b>meaning, structures &amp; functions of chromosome, gene, &amp; DNA.</b>	
3	-Students searched for, discussed & summarized on meaning of <b>autosome, sex chromosome &amp; gene on sex chromosome</b> from a library & a knowledge sheet in small groups. -Students searched for and discussed on <b>differences of male and female chromosomes.</b>	3 hr.	-Teacher showed a picture of a child while students looked his growth & answered some questions about it. -Students did and presented a work sheet of explanation about processes of mitosis division in small groups. -Teacher explained more about <b>mitosis &amp; meiosis division</b> through a PowerPoint. -Students did a role-play of chromosome in mitosis & meiosis division in groups. -Students did a work sheet of <b>comparisons of mitosis &amp; meiosis division</b> in small group.	2 hr.
4	-Students searched for, discussed, & summarized on <b>genetic disorders on chromosome and gene</b> from a library & internet in small group. -Students searched for, made a chart of, discussed, & summarized on <b>importance of genetic disorders, preventable disorders, &amp; solving problems</b> from a library & knowledge sheet in small groups.	4 hr.	-Teacher showed a picture of Mendel and asked some questions. -Students did a work sheet of <b>Mendel's work</b> in small group. -Teacher explained concepts of <b>gene, phenotype, genotype</b> through PowerPoint and demonstrated <b>monohybrid cross</b> through a <b>punnett square.</b> -Teacher gave a solving problem and students thought and solved the problem by themselves. -Students did an activity of "a family of paper animal" and presented their results in small groups. -Teacher & students summarized	2 hr.

### Tunya's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
4 (Cont.)			Mendel's laws, punnett square. -Students played a game.	
5	<ul style="list-style-type: none"> <li>-Teacher randomized students to tell meaning of genetic engineering and give its examples.</li> <li>-Students searched for genetic engineering from a text book.</li> <li>-Pair of students did a worksheet of GMOs.</li> <li>-Students did &amp; reported a project of growth of beans in small group.</li> <li>-Teacher &amp; students summarized genetic <b>engineering, cloning, &amp; GMOs.</b></li> </ul>	3 hr.	<ul style="list-style-type: none"> <li>-Teacher showed a picture of human chromosomes and asked some questions about disorders.</li> <li>-Teacher asked students what they wanted to know about genetic disorders.</li> <li>-Teacher played a movie of Down's syndrome while student watched and took note <b>symptoms &amp; causes of genetic disorders.</b></li> <li>-Each group of students searched for &amp; presented each genetic disorder.</li> <li>-Teacher explained the genetic disorders more by a PowerPoint.</li> <li>-Teacher gave examples of <b>mutation</b> in animals &amp; plants and importance of mutation.</li> </ul>	2 hr.
6	<ul style="list-style-type: none"> <li>-Pair of students searched for &amp; presented <b>the benefit of biotechnology in aspect of medical service, justice, society (e.g. DNA fingerprint), &amp; human quality.</b></li> <li>-Small group of students did &amp; presented a work sheet of animal reproduction.</li> <li>-Teacher &amp; Students summarized the benefit of biotechnology in aspect of medical service, justice,</li> </ul>	3 hr.	<ul style="list-style-type: none"> <li>-Teacher asked some questions of chromosome, DNA through the news of DNA fingerprint.</li> <li>-Each group of students took notes &amp; presented about benefits, processes, results of DNA fingerprint.</li> <li>-Students did a work sheet of DNA fingerprint.</li> <li>-Each group of students search for cloning in topics of meaning, processes, history, example, advantages &amp; disadvantages from a knowledge sheet and presented them.</li> <li>-each student did a work sheet of cloning.</li> <li>-Each group studied <b>benefit of</b></li> </ul>	2 hr.

**Tunya's Teaching Methods of Genetic Concepts (Continued)**

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
6 (Cont.)	society & human quality. -Students did a post test.		<b>biotechnology in aspect of medical service, justice, society, &amp; human quality</b> and then did a concept map.	

Note: Bold letters mean genetic concepts in that lesson.

## **Appendix H**

Yarinda's Teaching Methods of Genetic Concepts

### Yarinda's Teaching Methods of Genetic Concepts

Lesson	2005 Academic years		2006 Academic years	
	Teaching	Time	Teaching	Time
1	<ul style="list-style-type: none"> <li>-Teacher &amp; students talked about the student's and their relatives genetic traits.</li> <li>-A pair of students surveyed their genetic traits.</li> <li>-Teacher &amp; students discussed the <b>meaning of heredity, genetic inheritance &amp; genetic variation</b> using a textbook as a guide.</li> <li>-Students did two activities about genetic variation in small groups on their own.</li> <li>-Each group of students presented their results.</li> <li>-Teacher &amp; students summarized the meaning of heredity, genetic inheritance &amp; genetic variation.</li> </ul>	2 hr.	<ul style="list-style-type: none"> <li>-Students wrote &amp; presented what <b>genetic traits</b> they liked and did not like.</li> <li>-Students explained the meaning of <b>heredity</b>.</li> <li>-Teacher showed a picture of her family and asked students some questions about genetic traits.</li> <li>-Students did an activity (A) where they classified genetic traits into small groups.</li> <li>-Pairs of students did another activity (B) where they surveyed and presented their own genetic traits.</li> <li>-Students studied <b>genetic variation</b> from a textbook.</li> <li>-Each student did homework that consisted of surveying the genetic traits of their relatives (activity C).</li> <li>-Teacher &amp; students summarized genetic traits, genetic variation, and gave some examples.</li> </ul>	3 hr.

### Yarinda's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 Academic years		2006 Academic years	
	Teaching	Time	Teaching	Time
2	<p>-Teacher &amp; students talked about why each species is different.</p> <p>-Teacher &amp; students discussed the meaning of <b>chromosomes, structures, the numbers of chromosomes in males and females, and genes</b> in a textbook.</p> <p>-Groups of students exchanged ideas and summarized their new knowledge about chromosomes.</p> <p>-Teacher &amp; students talked about <b>dominant &amp; recessive genes</b>.</p> <p>-Students completed a work sheet on the <b>relationships among chromosomes, genes &amp; DNA</b>.</p>	2 hr.	<p>-Teacher gave examples of genetic traits occurring in real plants &amp; animals.</p> <p>-Two students showed genetic traits and the teacher asked some questions about them.</p> <p>-Students drew and presented a picture of a chromosome.</p> <p>-Teacher explained more about the <b>structure &amp; numbers of chromosomes</b> by asking some questions.</p> <p>-Students posed some questions about chromosomes, <b>genes &amp; DNA</b>.</p> <p>-Teacher played a VCD called <i>DNA and Life</i> while the students took notes about the chromosomes, genes &amp; DNA mentioned in the movie.</p> <p>-Students presented their knowledge.</p> <p>-Students, working in small groups, looked, constructed and presented a model of DNA by following the teacher's directions.</p> <p>-Teacher &amp; students summarized the structure, functions, and <b>relationships among chromosomes, genes, and DNA</b> through analogies.</p> <p>-Teacher explained about <b>genotype and phenotype</b>.</p>	3 hr.

### Yarinda's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 Academic years		2006 Academic years	
	Teaching	Time	Teaching	Time
3	<p>-Teacher &amp; students studied <b>Mendel's work</b>, as well as <b>complete and incomplete dominant and recessive traits</b> from a textbook.</p> <p>-Teacher &amp; students discussed about <b>monohybrid &amp; dihybrid crosses</b>.</p> <p>-Teacher &amp; students summarized Mendel's work while the students took notes and created a chart of genetic inheritance.</p> <p>-Teacher explained <b>mutation</b> from the textbook.</p> <p>Students did an activity about <b>pedigree</b>.</p>	2 hr.	<p>-Teacher asked a question about the difference in the number of chromosomes of humans and animals.</p> <p>-Teacher showed a picture of a child while students looked at his growth and answered some questions about it.</p> <p>-Students studied and presented the processes of <b>mitosis division</b> in small groups.</p> <p>-Teacher explained more about mitosis division through a model of mitosis and using an analogy.</p> <p>-Students presented their understanding of mitosis in small groups.</p> <p>-Students did homework that consisted of constructing a model of mitosis division.</p> <p>-Teacher <b>compared mitosis &amp; meiosis division</b>.</p>	1 hr.
4	<p>-Teacher &amp; students discussed the symptoms of <b>genetic disorders on autosomes</b>.</p> <p>-Students did an activity about color-blindness.</p> <p>-Each group of students did an activity on genetic disorders where they used the library and internet to search for and present the symptoms, causes and</p>	2 hr.	<p>-Teacher reviewed genes, genotypes, and phenotypes.</p> <p>-Teacher showed a picture of Mendel and asked some questions.</p> <p>-Students did a work sheet about <b>Mendel's work</b> in small groups and then presented their results.</p> <p>-Teacher demonstrated a <b>monohybrid cross</b> through a <b>Punnett square</b>.</p> <p>-Teacher showed a picture of three cats and gave a problem that the students thought about and solved by themselves.</p>	5 hr.

### Yarinda's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 Academic years		2006 Academic years	
	Teaching	Time	Teaching	Time
4 (Cont.)	<p>preventions for the disorders.</p> <p>-Teacher &amp; students summarized genetic disorders and talked about <b>sex chromosomes</b>.</p>		<p>-Students did an activity about predicting offspring and presented it in small groups.</p> <p>-Teacher explained more about monohybrid crosses.</p> <p>-Students did an activity called "a family of paper animal" and presented their results in small groups.</p> <p>-Teacher explained <b>Mendel's laws</b>.</p>	
5	<p>-Teacher &amp; students discussed artificial insemination in fish, plants and animals.</p> <p>-Students studied <b>genetic engineering, cloning in plants &amp; animals, and GMOs</b>.</p> <p>-Each group of students did an activity about growth by themselves.</p> <p>-Teacher &amp; students summarized biotechnology.</p>	2 hr.	<p>-Teacher showed a picture of a person who has Down's Syndrome in a textbook and asked some questions about its symptoms and causes.</p> <p>-Each group of students searched for and presented different genetic disorders.</p> <p>-Teacher explained more about the <b>genetic disorders and mutation</b>.</p> <p>-Each group of students created a concept map of genetic disorders.</p>	2 hr.
6	<p>-Teacher &amp; students talked about the advantages and disadvantages of science and technology.</p> <p>-Teacher &amp; students discussed the <b>benefits of biotechnology related to medical services, society (e.g. DNA fingerprinting), and human quality of life</b>.</p>	2 hr.	<p>-Teacher showed cloned cows and asked some questions about cloning.</p> <p>-Students studied about cloning and GMOs from a knowledge sheet.</p> <p>-Each group of students searched for and presented processes of <b>genetic engineering, cloning, GMOs, and biotechnology related to medical services, justice, society, and human quality of life</b>.</p>	3 hr.

### Yarinda's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 Academic years		2006 Academic years	
	Teaching	Time	Teaching	Time
6 (Cont.)	<p>-Each group of students did an activity on <b>artificial insemination</b> in animals and presented it.</p> <p>-Teacher &amp; students summarized the benefits of biotechnology and artificial insemination in animals.</p> <p>-Students did homework about <b>selected breed</b> and <b>cell division</b> using a knowledge sheet and the internet.</p>		<p>-Each group played a game to reinforce concepts.</p> <p>-Students did homework by finding news that applied genetic knowledge.</p>	

Note: Bold letters refer to the genetic concepts used in that lesson.

## **Appendix I**

Tarinee's Teaching Methods of Genetic Concepts

### Tarinee's Teaching Methods of Genetic Concepts

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
1	<ul style="list-style-type: none"> <li>-Students did pre-test.</li> <li>-Students searched for <b>Mendel's work</b> from a library in small groups.</li> <li>-Students did hybrid cross, and discussed on Mendel's work.</li> </ul>	3 hr.	<ul style="list-style-type: none"> <li>-Students stood in front of classroom, and then teachers asked some questions of genetic traits.</li> <li>-Students did a pre-test individually.</li> <li>-Teachers showed pictures of a woman and asked some questions of genetic traits.</li> <li>-Students did an activity (A) of classifying genetic traits in small groups and discussed about it.</li> <li>-Teacher explained &amp; gave examples of genetic traits, dominant &amp; recessive genetic traits.</li> </ul>	3 hr.
	<ul style="list-style-type: none"> <li>-Teacher and students summarized Mendel's work.</li> <li>-Students searched for and summarized about <b>dominant &amp; recessive genetic traits</b> from a library in small groups.</li> </ul>		<ul style="list-style-type: none"> <li>-Pair of students did an activity (B) of surveying their own genetic traits and discussed about it.</li> <li>-Students read about phenotype and genotype in a knowledge sheet and teacher gave a solving problem.</li> <li>-Teacher &amp; students summarized the meaning of <b>genetic traits, dominant &amp; recessive genetic traits, phenotype, genotype</b>, continuous &amp; discontinuous genetic variation.</li> <li>-Each student did an activity (C) of surveying genetic traits of their relations.</li> </ul>	
2	<ul style="list-style-type: none"> <li>-Students searched for and discussed on meaning of function of <b>dominant &amp; recessive gene</b> from a library &amp; internet in small groups.</li> <li>-Students searched for,</li> </ul>	4 hr.	<ul style="list-style-type: none"> <li>-Teacher showed pictures of animals and asked a question "why they were different?".</li> <li>-Students studied about chromosome, gene and DNA from a text book, then drew a picture including explanation, and presented their picture individually.</li> <li>-Teacher &amp; students summarized <b>structure</b></li> </ul>	3 hr.

### Tarinee's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
2 (Cont.)	made a chart of, presented about <b>relationships between gene &amp; chromosome</b> from a library & internet in small group. -Students did an activity of surveying their genetic traits and summarized it in small group.		<b>&amp; functions of chromosome, gene &amp; DNA</b> on the blackboard. -Students did a test.	
3	-Students searched for, discussed & summarized on meaning of <b>autosome, sex chromosome &amp; gene on sex chromosome</b> from a library & a knowledge sheet in small groups. -Students searched for and discussed on <b>differences of male and female chromosomes.</b>	3 hr.	-Teacher asked some questions about mitosis division -Students studied a knowledge sheet of <b>mitosis and meiosis division</b> , and then drew and presented pictures of mitosis division individually. -Students explained each stages of mitosis from teacher's model of mitosis. -Teacher explained more about mitosis. -Students did a work sheet of mitosis. -Teacher explained about <b>comparisons of mitosis &amp; meiosis division.</b> -Teacher & students summarized mitosis & meiosis division through a PowerPoint.	2 hr.

### Tarinee's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
4	<p>-Students searched for, discussed, &amp; summarized on <b>genetic disorders on chromosome and gene</b> from a library &amp; internet in small group.</p> <p>-Students searched for, made a chart of, discussed, &amp; summarized on <b>importance of genetic disorders, preventable disorders, &amp; solving problems</b> from a library &amp; knowledge sheet in small groups.</p>	4 hr.	<p>-Teacher showed a picture of Mendel and asked some questions.</p> <p>-Students did a work sheet of <b>Mendel's work</b> in small group.</p> <p>-Teacher explained concepts of <b>pure &amp; hybrid line, a punnett square, monohybrid &amp; dihybrid cross</b> including a solving problem.</p> <p>-Students did an activity of "a family of paper animal" and presented their results in small groups.</p> <p>-Teacher explained about <b>phenotype &amp; genotype</b>.</p> <p>-Students did a work sheet of predicting offspring.</p> <p>-Students studied about <b>pedigree</b> from a knowledge sheet, described how to write a pedigree, did a work sheet and presented their answers.</p> <p>-Teacher &amp; students summarized pedigree.</p>	5 hr.
5	<p>-Teacher randomized students to tell the meaning of <b>genetic engineering</b> and gave its examples.</p> <p>-Students searched for genetic engineering from a text book.</p> <p>-Pair of students did a worksheet of <b>GMOs</b>.</p> <p>-Students did &amp; reported a project of growth of beans in small group.</p> <p>-Teacher &amp; students summarized genetic engineering, <b>cloning</b>, &amp; <b>GMOs</b>.</p>	3 hr.	<p>-Teacher showed a picture of a funny actor who had Down's syndrome.</p> <p>-Students did an activity of <b>genetic disorders on autosomes and sex chromosomes</b>.</p> <p>-Students studied of symptoms &amp; causes of genetic disorders on autosomes and sex chromosomes, did a work sheet of them, and presented it</p> <p>-Teacher additionally explained the genetic disorders more and <b>mutation</b>.</p>	2 hr.

### Tarinee's Teaching Methods of Genetic Concepts (Continued)

Lesson	2005 academic years		2006 academic years	
	Teaching	Time	Teaching	Time
6	<p>-Pair of students searched for &amp; presented the <b>benefits of biotechnology in aspect of medical service, justice, society (e.g. DNA fingerprint), &amp; human quality.</b></p> <p>-Small group of students did &amp; presented a work sheet of animal reproduction.</p> <p>-Teacher &amp; Students summarized the benefits of biotechnology in aspect of medical service, justice, society &amp; human quality.</p> <p>-Students did a post test.</p>	3 hr.	<p>-Teacher showed a picture of cloned dogs and asked some questions of <b>cloning.</b></p> <p>-Teacher &amp; student discussed on meaning of biotechnology, <b>genetic engineering</b> in the text book.</p> <p>-Students studied of cloning in animals and plants.</p> <p>-Each group of students studied of the benefits of <b>biotechnology in aspect of medical service, justice, society, &amp; human quality</b> from the text book, did a work sheet and presented it.</p> <p>-Teacher &amp; students summarized about biotechnology.</p>	2 hr.

Note: Bold letters mean genetic concepts in that lesson.

## **CURRICULUM VITAE**

**NAME** : Miss POJCHANA MAGROOD-IN

**BIRTH DATE** : March 15, 1979

**BIRTH PLACE** : Suphanburi, Thailand

<b>EDUCATION</b>	<b><u>YEAR</u></b>	<b><u>INSTITUTE</u></b>	<b><u>DEGREE/DIPLOMA</u></b>
	2002	Kasetsart Univ.	B.Sc. (Biology)
	2003	Kasetsart Univ.	Grad Dip. (Science Teaching)

**POSITION/TITLE** : -

**WORK PLACE** : -

**SCHOLARSHIP/AWARDS** : The scholarship to study B.Sc. and Grad. Dip. at Kasetsart University under the Project for the Promotion of Science and Mathematics Talented Teachers (PSMT) which conducted jointly by the Royal Thai Government Agencies and the Institute for the Promotion of Teaching Science and Technology (IPST) from 1999 to 2003

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