THESIS

ENHANCING TEACHING AND LEARNING OF GENETICS USING SOCIOCULTURAL APPROACH

PINIT KHUMWONG

GRADUATE SCHOOL, KASETSART UNIVERSITY

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NAME: Mr. Pinit Khumwong

THIS THESIS HAS BEEN ACCEPTED BY

______________________________ **THESIS ADVISOR**

(Associate Professor Bupphachart Tunhikorn, Ph.D.)

______________________________ **COMMITTEE MEMBER**

(Associate Professor Pawinee Srisukvatananan, Ph.D.)

______________________________ **COMMITTEE MEMBER**

(Professor Michael J. Padilla, Ph.D.)

______________________________ **COMMITTEE MEMBER**

(Associate Professor Arinthip Thamchaipenet, Ph.D.)

______________________________ **DEPARTMENT HEAD**

(Miss Sudarat Sarnswang, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON ______________________________

______________________________ **DEAN**

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

ENHANCING TEACHING AND LEARNING OF GENETICS USING SOCIOCULTURAL APPROACH

PINIT KHUMWONG

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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The purposes of this study were to investigate 1) adaptation and implementation of the instructional unit performed by the teacher participant, 2) the effectiveness of the sociocultural approach-genetics instructional unit on students learning science, 3) the reflections of the participants on the sociocultural approach-genetics instructional unit. The Sociocultural Approach-Genetic Instructional Unit (SA-GIU) was developed on the basis of sociocultural perspective. There were five steps of learning processes used in each lesson: initiation, doing the task, making a group agreement, sharing and negotiation, and making the product of understanding. There were thirteen lessons in the SA-GIU. The SA-GIU was implemented in a 12th grade biology classroom by a volunteer biology teacher in 2007. There were 16 students in this classroom which consisted of 3 boys and 13 girls.

The findings showed that the teacher participant mostly followed steps and used activities and media suggested in the SA-GIU. The teacher participant could adjust her teaching to be in line with the roles of a teacher under sociocultural perspective. Due to time constraints, the teacher participant abstained or created strategies to use some of the activities. The SA-GIU could enhance student participants' genetic understandings as most student participants' genetic concepts had been moved from a lower-order category of concept before the SA-GIU implementation to a higher-order category of concept after the SA-GIU implementation in most studied concepts. Some students, however, still held alternative concepts after the SA-GIU implementation, especially in the concepts of the law of segregation, the law of independent assortment gene, allele, and chromosome. The student participants also gained abilities of idea expression, knowledge inquiry, self learning, cooperative working, and industriousness from learning in the SA-GIU. The scheme of effective factors that enhanced learning were activity, learning media, social interaction, human mediation, and attitude.

The teacher participant and student participants both positively valued learning in the SA-GIU. The lessons used in the SA-GIU were interesting and real-life relevant. The SA-GIU created a learning environment which students actively participated in classroom activities and happily learned. However, the teacher participant and student participants both encountered difficulties from teaching and learning in the SA-GIU. The study provides evidence that the sociocultural perspective can be a useful guideline for enhancing student understanding about genetics, desired behaviors, and the happiness of learning.

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Student's signature Thesis Advisor's signature

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CHAPTER I

INTRODUCTION

Background of the Study

Scientific understanding and skill are considered essential to an improved quality of life in both the present and future society. That is because we live in and interact with a world that is described by and oriented to science. For one to make a decision, solve a problem, engage in a public discourse and debate about socio-scientific issues, or to work in a workplace requires scientific literacy (National Research Council (NRC), 1996).

Unfortunately, the Thai educational curriculum B.E. 2521 (1978) (revised B.E. 2533 (1990)) had limitations and weaknesses in producing competent citizens for a socially and economically changing world (Department of Curriculum and Instruction Development, 2002). To overcome that failure, the National Education Act B.E. 2542 (known as NEA 1999) was promulgated in order to deal with globalization and to serve knowledge-based society under the principle that all learners are capable of learning and self-development and should be regarded as important (Office of the National Education Commission (ONEC), 2003: 13). The goals of the whole educational system are to educate Thai citizens as competent, healthy human beings with wholesome minds, intelligence, knowledge, morality, proper behaviors and cultural life (ONEC, 2003). To be in line with NEA 1999, all teaching and learning must develop a learner's physical and mental capabilities; promote a learner's understanding; and assess a learner's development by various strategies, especially, authentic learning, collaborative learning, and learning from nature. Schools are responsible for prescribing curriculums relating to the needs of the community, society, local wisdom, and attributes of a desirable family member, community, society, and nation.

Consequently, The Institute for the Promotion of Teaching Science and Technology (IPST), which is responsible for the promotion of teaching and learning science in Thailand, developed the National Science Curriculum Standards (IPST, 2002) to guide a reform in science education in Thailand. The standards have resulted in all aspects of science education system (Bhasomsap, 2003). According to the national educational principles, schools must develop curriculums that are effective in educating students, (Ministry of Education, 2002). Previously, all schools had followed a national curriculum; developing a curriculum by themselves is a very challenge task for many schools (Bhasomsap, 2003). As a result, it was found that most teachers could not create a learning environment that relied on a principle of education reform (Office of the Education Council (OEC), 2005).

This study is a response to education reform. The aim is to develop a guideline for science teaching and learning that is based on the National Science Curriculum Standards and is effective in promoting scientific understandings. This study will give science teachers knowledge on how to teach science that is both effective in promoting scientific concepts and congruent with the standards and principles of the National Science Curriculum.

Significance of the Study

In this section, I will provide a significance of this study. The section begins with an introduction to the importance of genetics in biological education and lives in societies. Then, an overview of the difficulties that students encounter in learning genetics will be reviewed. Finally, the need to bring teaching and learning ideas under the sociocultural umbrella into genetic classroom are discussed. In the rest of this chapter, the purposes of the study, research questions, and anticipated outcomes, are discussed. Operational definitions of terms in this study are provided at the end of the chapter.

It is interesting that for at least two decades there has been a continuous growth of studies dealing with teaching and learning genetics in the area of biological education (reviewed by Knippels, Waarlo and Th Boersma, 2005). This growth implies the importance of genetics and the need to understand genetics. It can be summarized that there are two aspects of importance of genetics: educational and societal. In an educational aspect, one of the important domains of biology is for understanding the world in which we live (Kindfield, 1994; Knippels *et al.*, 2005; Moll and Allen, 1987; Stewart, 1982; Tolman, 1981). Therefore, genetics is a basic conceptual framework for understanding other biological phenomena, such as the reproduction of living things, evolution, and biodiversity.

Based on several biology textbooks (e.g. Miller&Levins, 2006, Solomon, Berg and Martin, 2004), in the aspect of society, genetics, and the technologies subsumed under it, are increasing their roles in our lives and communities. Knowledge of genetics is basically related to understanding why we are what we are. In addition, genetic technologies are now very useful for the improvement of our life. In medical science, genetic knowledge is applied to detect diseases and disorders by means of gene testing and it is possible to cure those illnesses by means of gene therapy or tissue engineering. Also, with the increasing global population, trait selection and improvement, and GMOs can be means to solving global food shortages. In another way, DNA finger printing is very useful to solving questions arising from crime and litigation. On the other hand, many current socio-scientific issues are related to genetics, such as the controversies surrounding GMOs or ethical concerns related to cloning. In order to debate and make decisions on these issues, understanding genetics is necessary.

Based on the possible applications of genetics, knowledge of genetics is very useful for the economic growth of Thailand. A reason for this is that the Thai economy is mostly dependent on agricultural products; the highest value export product of Thailand is agricultural products (Ministry of Commerce, 2008). Genetic knowledge and its derivative technologies can effectively be applied to Thailand's agricultural economy in many areas, such as trait improvement, trait selection, and cloning to produce high-yield and tolerant industrial crops and domesticated animals. In addition, socio-scientific issues regarding genetically modified papayas emerged in Thai society in 2003 and have been discussed until now (e.g. Manager Online, 2007, 2008a, 2008b). A more frequent real situation regarding genetics in Thai public press is about solving crimes and litigations. In order to select, use, or at least participate in meaningful discussions regarding genetic knowledge and technologies with the least danger of threats or side effects, having adequate knowledge and understanding of genetics is very important for people of the future (Bhumirat *et al.*, 2001; Garton, 1992; Lewis and Wood-Robinson, 2000a). Consequently, it is a challenge for science educators to think of ways to assist students' understanding of genetics. The present study is an attempt to enhance teaching and learning genetics by means of sociocultural approaches.

In spite of its importance, genetics has been reported by many researchers as being a great hardship for students in biological disciplines to learn (Bahar, Johnstone and Hansell, 1999; Banet and Ayuso, 2000; Johnstone and Mahmoud, 1980; Hackling and Treagust, 1984; Moll and Allen, 1987). A large number of studies conducted in different times and places revealed many students' alternative conceptions (e.g. Edlin, 1987; Hackling and Treagust, 1984; Kindfield, 1994; Knippels *et al.*, 2005; Lewis, Leach, and Wood-Robinson, 2000a, 2000b, 2000c). In Thailand, alternative concepts in genetics were reported by the researchers in this field, Mungsing (1993) and Sukpimontree (1988). Those alternative concepts included the beliefs that cells only contained the genetic information needed to carry out their functions (Hackling and Treagust, 1984; Edlin, 1987; Banet and Ayuso, 2000), that sex chromosomes were only in gametes (Banet and Ayuso, 2000; Edlin, 1987), and that there was no relationship between the concepts of DNA, genes, alleles, chromatids and chromosomes (Banet and Ayuso, 2000; Lewis and Wood-Robinson, 2000; Lewis *et al.*, 2000a, 2000b, 2000c). The students in those reports also had a poor understanding of the meiosis process and the model of chromosomes (Moll and Allen, 1987; Stewart *et al.*, 1990; Kindfield, 1994; Lewis and Wood-Robinson, 2000).

Besides student difficulty in learning genetics, teachers are also confronted with difficulty in planning their teaching to promote student understanding of genetics (Banet and Ayuso, 2000; Banet and Ayuso, 2003; Finley, Stewart and Yarroch, 1982). To investigate this situation, Khumwong (2006) distributed questionnaires to all the biology teachers and a sample of students from all high schools in Suphan Buri province. The questionnaire surveyed teachers' and students' perceptions of difficult topics in biology. The finding was that genetics was the most difficult topic, or at least one of the three most difficult topics, for teachers to teach and for students to learn.

A student's learning is very connected to a teacher's teaching. ONEC (2001) reported that teachers' teaching processes did not contribute to students' learning as expected in the national education development plan. It was reported later that many Thai science teachers still used a teacher-centered approach; teachers took an important role in the classroom by directing learning activities, directing transmission of knowledge, and emphasizing teaching for tests by rote learning. Such teaching was not in accordance with the curriculum. Moreover, that teaching style resulted in students lacking the abilities of creative thinking, analyzing and synthesizing, problem solving, and knowledge acquisition (ONEC, 2001: 12; Panom, 1998; Rapeepan, 1998). This situation was very similar with what the researcher had observed in high school biology classrooms. The researcher found that the teacher always selected to tell students scientific knowledge using few learning resources and did not vary the activities. Questions asked during classroom activities were often close-ended questions. The students relied upon the teacher's explanations, their textbooks, and on solving algorithmic problems without consideration of their prior knowledge. In addition, the teacher started teaching genetics by defining abstract concepts. These findings support a claim that Thai science teachers teach by teacher-centered approaches, lecture, and direct knowledge transmission, teaching approaches that differ from principles of the IPST's science curriculum standards. Moreover, such teaching in Thailand was also similar to the teaching style in Spain reported by Banet and Ayuso (2000) who reported that students could not develop meaningful understanding of genetics through this kind of teaching.

Based on the above situation, there is a need to create genetics teaching and learning activities that are in accordance with the Thai educational goal and context and also promote students' understandings. This study's purpose is to design effective genetics lessons that both are congruent with IPST's science curriculum standards and can promote students' genetics understandings. These genetics lessons are under sociocultural perspectives of learning. Teaching and learning based on the sociocultural approach encourages students to actively construct understanding by participation in cooperative learning activities and negotiation of shared activities in social contexts (Teemant et al, 2005). The sociocultural view of learning also argues that learners are active meaning-makers (Hatano, 1993) through interaction and cooperation (Driver *et al.,* 1994; Leach and Scott, 2003; Shepardson, 1999), availability of multiple sources of information enhances knowledge construction (Hatano, 1993), and adults, peers and communities play important roles in learning (Driver *et al.,* 1994; Kozulin *et al.,* 2003). The sociocultural perspective has been receiving more and more interest in the area of education. The evidence for this claim can be found in a number of translations and writings about this perspective (e.g. Moll, 1990; Forman, Minick and Stone, 1993; Lemke, 2001; Kozulin *et al.*, 2003). However, despite the upsurge in interest in the sociocultural perspective, its direct application to science education has been rather limited (Moll, 1990, Shepardson, 1999). This study is an attempt to fill the gap between theory and practice revealed from the literature about the sociocultural perspective. Consequently, this study tries to utilize the sociocultural perspective by placing it into research and classroom practice. Moreover, there is not any evidence of applying the sociocultural perspective in a study in Thailand. Therefore, this study will add an understanding about how a science teacher adjusts and uses sociocultural approaches in a real classroom and how sociocultural approaches may help to promote scientific understanding in Thailand.

Research Purposes

As has been reviewed, genetics is a great challenge for high school students to understand. The primary question inspiring this study is how to organize teaching in order to promote high school students' understandings of genetics. The researcher also believes that the sociocultural learning approach would offer teaching and learning strategies students would find helpful in moving toward their goal of understanding genetics. Thus, there are four purposes of this study, which are as follow:

1. To develop a genetics instructional unit designed on the basis of sociocultural perspective that has practical value in the Thai classroom context

2. To document adaptation and implementation of the instructional unit performed by the teacher participant

3. To evaluate the effectiveness of the sociocultural approach- genetics instructional unit on students learning science

4. To investigate the reflections of the participants on the sociocultural approach- genetics instructional unit

Research Questions

The research questions examined in this study are as follows:

1. How does the teacher participant adapt and implement a sociocultural approach - genetics instructional unit?

2. What student accomplishments can be identified as a result of their learning genetics through a curriculum unit created from a sociocultural perspective?

3. What are the participants' reflections toward the genetics instructional unit which was created from a sociocultural perspective?

a) What are the teacher participant's reflections on the sociocultural approach - genetics instructional unit?

b) What are the student participants' reflections on the sociocultural approach - genetics instructional unit?

Anticipated Outcomes

1. This study provides a guideline of an effective teaching approach for a biology teacher teaching genetics. Another biology teacher may adapt and adopt techniques, strategies, materials and activities in this study for their genetics teaching. Also, this guideline may also be used as a guideline for teaching the other science disciplines.

2. The process of learning unit construction of this study may serve as a model for science teachers on how to develop or organize effective genetics instructional units.

3. This study investigates teacher instructional unit adaptations and reflections of students and a teacher toward the sociocultural approach. These findings may illustrate some difficulties relating to the use of the sociocultural approach in a science classroom, therefore, this study may guide science teachers on how to prepare to use the sociocultural approach in their classrooms.

Operational Definitions of Terms

Sociocultural Approach-Genetics Instructional Unit (SA-GIU)

Sociocultural approach-genetics instructional units are a set of genetics lessons which consist of unit objectives, content, learning activities, instructional material, and evaluation procedures that help students to construct their own shared meanings developed through engagement in social interaction and using signs and tools. Through the unit, students are perceived as active learners. They will be encouraged to actively participate in learning activities in order to construct their own meanings of particular events or situations. To contribute to learning, students must engage in social interaction and participate in socially shared activities and scientific discourses. Students must engage in social interactions with more knowledgeable people and artifacts such as textbooks, CDs and computers. The use of various tools and learning resources contributes to effective learning, so a variety of learning media and resources will be provided. In addition, because of the impact of cultural forces on meaning making, the unit encourages the use of teaching and learning resources and interesting issues that are available in the community or that are familiar to students in order to contribute to effective learning. The role of the teacher (and also of other adults and more knowledgeable peers in the community) is to introduce scientific ideas and tools to students where necessary, and to provide learning circumstances, support, and guidance for students to make sense of the concepts taught themselves. For assessment, teachers and learners will work together to set goals and procedures and will use a wide range of assessment methods.

Teacher's Instructional Unit Adaptation

The teacher's instructional unit adaptation is the profile of changes that the teacher participants may adjust, such as sequences of lessons, activities or strategies originally created by the researcher. The teacher's instructional unit adaptation can be revealed from the teacher's discussions during meetings, the teacher's journals, and classroom observations.

Teacher's Instructional Unit Implementation

The teacher's instructional unit implementation involves the profile of the teacher participants teaching genetics during the implementation of the genetics instructional unit based on the sociocultural approach in their real classrooms. The teacher's instructional unit implementation can be revealed from the teacher's discussions during meetings, the teacher's journals, and classroom observations.

Student Accomplishments

Student accomplishments are the students' outcomes in terms of abilities, skills, talents and genetics conceptions that the students develop during learning in the sociocultural approach-genetics instructional unit. Abilities, skills, and talents can be classified from what they reveal during student interviews and their actions in the classroom. As for the students' concept of genetics, the ideas of the students are presented by explaining definitions, giving examples, and using concepts to make connections to related concepts. These were measured by a genetic concepts survey.

Reflection on the Sociocultural Approach-Genetics Instructional Unit

Reflections on the sociocultural approach-genetics instructional unit will illustrate the opinions of the participants about; 1) effective elements that enhance science teaching and learning, 2) difficulties or limitations of teaching and learning science and 3) suggestions. Teacher reflections can be recognized by analyzing data from journals and conversations during meetings. Student reflections can be recognized by analyzing student journals and semi-structured group interviews.

Summary and Preview

This chapter begins by discussing the background and significance of the study. The purposes and research questions are set accordingly. Genetics is very important both in the aspect of science learning and society, but it has been found that

Thai students have possessed alternative concepts of genetics. Besides that, science teachers also cannot design learning that accomplishes the goals of the science reform. This study aims to develop an intervention to promote scientific understanding of genetics that is aligned with the National Science Curriculum Standards and to examine whether and how sociocultural approach genetics lessons can enhance students' genetics learning.

Chapter 2, Review of Literature, is devoted to a review of the literature relating to the framework of science education in Thailand, genetics education in Thailand, concept of genetics, genetics teaching and learning, and the sociocultural perspective. Chapter 3, Methodology, describes research methodology, research design, data collection, data analysis, dealing with ethical concerns, and strategies for ensuring trustworthiness of the study. Chapter 4, Development of the Sociocultural Approach-Genetics Instructional Unit, provides a descriptive summary of guiding principles, development process, and an outline of the instructional unit. Chapter 5, Instructional Unit Implementation and Evaluation, reports the results of the study which include context of the study, adaptation and implementation of the instructional unit, students' accomplishments, and reflections toward the instructional unit. Chapter 6, Summary, Conclusions, and Recommendations, provides a summary of the findings, the conclusions, and the recommendations for future research. This study concludes with a reference listing of all citations and resources used in this study.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter reviews some important ideas regarding this study including teaching and learning genetics and sociocultural approach. The chapter has five sections. The first section discusses framework of science education in Thailand. This is relevant to the national education act and science curriculum standards. In the second section genetics education in Thailand is described. Alignment of contents and standards regarding genetics in science curriculum are reviewed. The third section, previous researches on genetics teaching and learning, discusses genetics alternative conceptions that students commonly hold. Also in this section, nature of difficulties in genetics and suggestions for genetics teaching from literature are discussed. The fourth section, sociocultural theory, presents fundamental thoughts of sociocultural theory and its application for teaching and learning. At the last section, theoretical framework of the study is described.

From the synthesis of the information from the literatures, the researcher examines learning science as social activity. Scientific knowledge is a product of social processes. Therefore, engaging in social interaction and using signs and tools to communicate must be able to promote effective learning science resulting understanding development. The information from literature review provides a guide for designing learning objectives, genetics topics, learning activities, learning materials and assessment. Fundamentally, all lessons are based on a sociocultural perspective of learning.

Framework of Science Education in Thailand

At present, science education in Thailand must be based on the National Education Act 1999 and Amendments (Second National Education Act A.D. 2002) and the IPST's science curriculum standard. They provide principles and guidelines for the mission and development of Thai education. Their main purpose is to prepare all Thai people for a learning society. On behalf of the Constitution of the Kingdom of Thailand 1997, the National Education Act was prepared to provide principles and guidelines for the reform of education. To ensure an equity and quality in the science education, the science curriculum standard was prepared in accordance with the National Education Act. In this section, the ideas in these documents relating to education will be summarized.

1. National Education Act

In order to meet the requirements of the 1997 Constitution, the fundamental law for the administration and provision of education and training was issued in 1999 and was revised in 2002, the so called National Education Act 1999 and Amendments (Second National Education Act 2002) (ONEC, 2003). In this study it will be called the NEA1999 It includes 9 chapters including the objectives and principles; educational rights and duties; educational system; national education guidelines; educational administration and management; teachers, faculty, staff and educational personnel; resources and investment for education and technologies for education.

The ultimate goal of the NEA1999 is to fully develop the Thai people 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 (section 6). In addition, education must be aimed to inculcate, promote and maintain identity, culture, and natural resources of Thailand (section 7). At all educational forms and levels, all segments of society shall participate in the process in order to obtain fully developed Thai citizens in all aspects and lifelong learning (section 8).

The main concept of the national education guidelines is that “education shall be based on the principle that all learners are capable of learning and self-development, and are regarded as being most important. The teaching-learning process shall aim at enabling the learners to develop themselves at their own pace and to the best of their potentiality” (Section 22). Then to organize learning processes, teachers shall provide substance and arrange activities that connect to authentic experience; are in line with the learners’ interests, aptitudes and differences; motivate thinking and managing skill; and enable learners to achieve a balanced integration of development (Section 24). Education shall enable learners to access knowledge of; disciplines application of knowledge and skills, wisdom in community, proper use of language, and knowledge and skills for career and a happy life (Section 23). To assess learning, educational institutions shall assess learners through a variety of methods (Section 26). According to Section 27, the basic curriculum commission shall prescribe core curricular for basic education in purposes of preserving Thai identity, good citizenship, desirable way of life and livelihood. Based on the core curricular, it is each school’s responsibility to develop curriculum substance relating to needs of the community and the society, local wisdom and attributes of desirable members of the family, community, society, and country. In addition, learners have the right to develop their capabilities for utilization of technologies for education as soon as feasible so that they shall have sufficient knowledge and skills in using these technologies for acquiring knowledge themselves on a continual lifelong basis (section 66). Thus there is a need to offer learners educational technologies as a teaching and learning media and/or resources.

In Accordance with the Basic Education Curriculum 2001 (Department of Curriculum and Instruction Development, 2001), there are 4 grade levels including; first level-primary education grades 1-3 (grade 1-3), second level-primary education grades 4-6 (grade 4-6), third level-secondary education grades 1-3 (grade 7-9) and fourth level-secondary education grades 4-6 (grade 10-12). The NEA1999 stipulated 9 years for compulsory education (grade 1-9).

2. Science Curriculum Standard: the Basic Education Curriculum

In manner of section 27 in the NEA1999, the Institute for the Promotion of Teaching Science and Technology (IPST) is responsible to develop a science curriculum standard. This standard is called science curriculum standard: the basic education curriculum (IPST, 2003). The document indicates science strands and science standards. In each standard, IPST indicates learning standards, expected learning outcomes and science contents of expected learning outcomes for different grade levels.

Science strands are groups of core science contents that all Thai students must learn. IPST defines science contents into eight strands. These strands are:

Strand 1: Living Things and Living Processes
Strand 2: Life and environment
Strand 3: Matters and Properties
Strand 4: Forces and Motion
Strand 5: Energy
Strand 6: Processes that Shape the Earth
Strand 7: Astronomy and Space and
Strand 8: Nature of Science and Technology

Learning standards are learners' qualities in knowledge, skills, procedures, morality, right behavior, and value for each strand (Department of Curriculum and Instruction Development, 2001). Standards of strand eight, nature of science and technology, are standards of process, nature and limitation of science, attitude, moral, ethic and value. They should be learned by doing a wide range of activities during learning of all other science strands.

It is stressed that schools must develop school curriculum that covers these strands and basic content. Also, school should prescribe school curriculum to be suitable for community and school context by adding contents that are relevant to community's context, problems, wisdoms and values. In addition, schools may set up special standards relating their context, local wisdom, and community's problems (IPST, 2003: 32).

In organizing science content for grade level 4, students may choose to learn according to their interests. Some students may have interest in science professions but the others may not. Therefore, school curricula in each school should set science into 2 groups; basic science and advance science. Basic science is science subjects that all grade level 4 students must learn. On the other hand, advance science is science subjects which are organized in accordance with interests and abilities of students. For instance, schools may set more advance science for students who are interested in professions that very emphasize in science or those who have talent in science but less for students who are interested in social science.

As prescribed in IPST's science curriculum standard, learning science must emphasize a learner-center approach. Learners shall have chances to learn and discover by themselves. To be in accordance with vision of learning science, learning science must develop learners in all aspects of development according to their interests and potentials. Moreover, learning must be suitable to community's context. In accordance to this document, organizing science learning must aim for the learners;

1. To understand principles and basic theories

2. To understand scope, limitations and nature of science

3. To have basic skills for discovery and creation in science and technology

4. To develop thinking process, creativity and problem solving, management, communication skill and decision making

5. To be aware of the interrelationship between science, technology, human and environment in term of effect and impact to one another

6. To apply understanding of science and technology for the benefit in everyday life

7. To develop the scientific mind, morals, ethics and values in proper use of science and technology

Accordingly with NEA1999 (IPST, 2003), IPST encourages learning that is on a basis of learner is most important. IPST also encourages using inquiry, problem solving, hands-on and mind-on activity and cooperative learning to organize science learning activity. In a classroom, students should take actions in most activities. Science teachers should act as motivator, organize and prepare learning resources for students. In aspect of learning resources, IPST encourages science to use a wide range of learning resources both inside and outside school: especially learning resources in students' community. However, science teachers must have key textbook as main resource of learning and students must have this version of book. To assess students' science learning, science teachers are encouraged to use authentic assessment, performance assessment and portfolio assessment.

Summary

From all three important education papers, it can be concluded that all science learning shall be based on the principle that all learners are most importance and are capable of learning and self-development. The learning process should enable learners to develop at their own pace and to maximize their potential in all aspects in order to be able to live in harmony with other people, and to maintain Thai identity and competitive ability at the international level. Learning activities therefore shall be in accordance with learners' interests, differences, and the context of the community. Moreover, learning should connect classroom with life in the community. Modern knowledge and local wisdom should be taught together. Besides understanding of genetic content, learners should develop process and skill of critical thinking, questioning, and researching and scientific mind. Teachers should act as facilitator, organize and prepare learning resources for students. By the time they graduate, learners should not only understand content, but also know how to apply it. During the process of learning a variety of assessment methods shall be regularly used.

Genetics Education in Thailand

According to science curriculum standard designed by IPST, divided into eight strands, genetics is in the first strand: living things and living processes (IPST, 2003). Genetics is part of standard SC1.2 which states that students should understand processes and significances of genetic inheritance, evolution, biological diversity and using of biological technologies that impact human and environment; carry inquiry processes, knowledge and science attitudes; communicate and apply what is learned (IPST, 2003). There are standards regarding genetics for all grade level (Table 2.1). That means genetics must be learned at all level according to students' development.

Table 2.1 Grade level science standards regarding genetics in grade level 1-4

Level standards Grade level 1	**Level standards Grade level 2**	**Level standards Grade level 3**	**Level standards Grade level 4**
Observe, explore various characteristics of living things in the neighborhood and explain in inheritance of characteristics from father and/or mother to progeny	Explore, observe, compare one's own characteristics with members of family and also for living things nearby and explain inheritance of characteristics of living things through generations, also characteristics that differ from ancestors	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	- Search for information, discuss and explain the process of inheritance through genetic material, genetic variation, mutation and biodiversity - Search for information, discuss and explain positive applications of biotechnology and biodiversity on the society and environment

Sources: Science Curriculum Standard: The Basic Education Curriculum (IPST, 2003: 10)

In the fourth grade level of education (grade 10-12), population of this research, genetics is a part of the biological discipline. As IPST (2003) indicated, the expected learning outcomes and basic learning contents for grade level 4 students regarding genetics are shown in Table 2.2.

Table 2.2 Expected learning outcomes and basic science learning contents for grade level 4

Expected learning outcomes	Basic science learning contents
1. Search for information, understand and discuss about genetic materials, chromosomes and genetic inheritances (Sc 1.2-1) 2. Search for information, understand and discuss about genetic variation and mutation (Sc 1.2-1) 3. Search for information, understand, discuss and present about applications of biotechnologies and their impact on society and environment (Sc 1.2-2)	1. Exploring and searching for information about genetic material and genetic inheritance 2. Searching for information about abnormality of genetic inheritance, genetic variation, mutation and genetic disorders 3. Exploring and searching for information about interaction between heredity, genetic inheritances and environment 4. Searching for information about application of biotechnology for improving and increasing productivity of plants and animal and its impact on society and environment

Source: IPST (2003: 155)

Therefore, after graduation from high school, Thai senior high school students should at least learn about the structure and function of genetic material, the process of heredity transmission, genetic variation and mutation, breed selection and improvement, and biological technologies and applications. Moreover, the nature of science and technology must be integrated into all lessons. Stand 8-standards for grade level 4 are following.

1. Pose questions based on knowledge and understanding of science or personal interest or current issues which are subject able to explore or experiment.

2. Set up hypothesis which is supported by theory or construct model or pattern for investigation.

3. Research and collect data which involve important variables and factors, factors that affect other factors, factors that cannot be controlled and number of replicates to achieve sufficient reliability and significance.

4. Choose material, technique, equipments for observation, measurement, exploration both qualitatively and quantitatively.

5. Collect data and record results from investigation systematically both in qualitative and quantitative aspects, while checking for probability, appropriateness or error of data.

6. Manage data by considering numerical report with high quality and properly present data.

7. Analyze and interpret data, evaluate correlation of conclusion or key issue for checking with set hypothesis.

8. Construct models or pattern representations or mathematical models or point out trends of data from investigation.

9. Scrutinize reliability of methods and results from investigation based on errors in principles measurement and observation and propose improvements on method of investigation.

10. Bring methods and new knowledge from investigation to bear on new question, solve new problems in new situations in real life.

11. Realize the importance of shared responsibility in explaining, expressing opinions and concluding for the scientifically correct presentation to the public.

12. Record and explain with reasons results from investigation using referenced and researched evidence to obtain reliable support and concede readily that knowledge is subjected to change when new data and additional evidence crop up to challenge or oppose old views giving rise to the need of careful checking and perhaps to acceptance new knowledge.

13. Prepare presentations, write reports and/or explain concepts, processes and results from the project or work to others (IPST, 2003: 27-30).

According to the NEA1999 and IPST's science standards, at high school level each school may align genetics at different grade according to structure of school curriculum. However, when the time arrives for students to graduate, they must accomplish genetic standards set in science curriculum standards. Science teachers are responsible to design learning activities and prepare learning resource themselves. These activities and resources should be aligned with students' interests and abilities and context of school and community.

Previous Researches on Genetics Teaching and Learning

I believe that in order to create effective teaching it is essential to prepare to confront upcoming difficulties. Under this topic, I will review the most frequently misunderstood concepts or topics, as well as the nature or sources of difficulties in genetics learning. Some suggestions from previous research will be summarized at the end of this topic.

1. Genetics Alternative Concepts

Under this sub-topic, I will try to identify the concepts or topics most frequently reported as difficult in the subject matter of genetics. According to the literature regarding students' understanding of genetics, some students' alternative understandings and difficulties are presented in Table 2.3. Regarding genetic topics that appear in IPST's science, I will summarize the table into sub-topics of the structure and function of genetic material, the process of heredity transmission, genetic variation, and mutation.

Regarding the structure and function of genetic material, the major difficulty is about the confusion of structure, basic function, location and the relationship between organisms, cells, nuclei, chromosomes, chromatids, genes, alleles and DNA (e.g. Lewis, 2004; Lewis, Leach and Wood-Robinson, 2000a, 2000b, 2000c; Stewart, 1982). Most of these concepts have both functional and structural definitions; most students often recognized either one of them (Mardach-Ad, G. 2001). Moreover, some students cannot order the relative sizes of those terms (Lewis *et al.,* 2000b). The literature reports that, as some students do not understand the concepts of these terms, they cannot correctly use pictures or a symbolic system to represent genetic phenomena or to locate genes and alleles on chromosomes (e.g. Moll, and Allen, 1987; Stewart, Hafner and Dale, 1990). Another common difficulty is about genetics material in cells of living organisms. Frequently, students held the belief that each cell in the same individual contains different genetic information depending on different function and location of the cell (e.g. Banet and Ayuso, 2003; Lewis, 2004; Lewis *et al.*, 2000a, 2000b, 2000c). The structure of chromosomes is also one of difficult topics for students. There is general confusion about being able to distinguish the concepts of chromosomes, chromatids and homologous chromosomes (Kindfield, 1994). Interestingly, some students could explain individual definition of DNA, genes, enzymes, and traits, but they failed to explain how these concepts work together to create phenotypes (Marbach-Ad and Stavy, 2000; Stewart, 1982)

About the process of heredity transmission, the most common barrier is that students neither understand cell division nor are they able to connect cell division with heredity transformation. The main problem is that students do not understand the activities of chromosomes and genes during cell division. In particular, they are unable to associate alleles with chromosome and chromosome behavior and the segregation and random assortment during the first division of meiosis (Moll, and Allen, 1987; Tolman, 1982). Students tend to fail to identify activities and products of processes in replication and cell division. Students also find it difficult to distinguish between mitosis and meiosis (Lewis, 2004; Lewis *et al*., 2000a, 2000b, 2000c). It was found that students were unable to explain the mechanisms and the intermediate stages involved in the relationship between DNA - traits, gene - traits, gamete - chromosomes; and zygote - alleles. These knowledge gaps are grouped together under the topic of transmission genetics.

Regarding genetic variation and mutation, the common alternative concepts were that mutation was a response to environmental change and that it was an adaptation to survive (Jimnez-Aleixander *et al*., 2000 and Banet and Ayuso, 2003). For example, a finding from Jimnez-Aleixander *et al.*'s research (2000) indicated that students thought that the color of chickens in a farm differed from the color of their parents because of mutation, and the causes of mutation were the food and the color of the farm. It might be because students were confusing adaptation with mutation. When students combined those concepts together, living things changed their traits or behaviors to adapt to the environment and mutation was trait changing, so mutation was a response to environmental change. Also, students were unable to tell which disease was a genetic disorder; this might be as result of inability to clearly identify what hereditary characteristics were.

Another line of research regarding genetic difficulty is about problem solving. Focusing on solving basic genetic problems regarding monohybrids, and dihybrids, Stewart (1982) examined the knowledge and problem-solving strategies of ninth grade students who were successful solvers in previous situations. Using a think-aloud protocol, the researcher revealed students' alternative conceptions and difficulties. For the first point, due to weak understanding of the relationship of meiotic division to monohybrid and dihybrid cross problem, students could not develop meaningful solutions for genetic problems. The evidence was that students in the study were unable to explain why they placed symbols (alleles) in their Punnett square in the way they did nor could they explain when to perform the algebraic method. Even though some students could easily perform the algebraic manipulations, they could not identify the genotypes of a gamete in the problem they were solving. Stewart (1982) also found that the students lacked knowledge to relate the random segregation of chromosomes (or alleles) to dihybrid crosses. In short, students could solve problems they did not understand that why and how they had to perform as they did in order to solve problem. This study suggested that students could not connect meiosis, a basic ideas underpinning those problem solving methods, to Mendelian genetics. Some students had difficulty describing how particular concepts such as gene-allele, allele-chromosome, allele-trait, gene-trait, gamete-chromosome, and zygote-allele were related.

Furthermore, based on a procedure of solving genetics problems used by college students, Moll and Allen (1987) found common mistakes made by those students. They found that most of the students who could not complete genetics problem solving could not correctly place alleles on a chromosome. Particularly, most unsuccessful students could not correctly combine gametes, or they placed different alleles of different genes on the same locus. Beside that, some of them placed two different alleles of the same gene on the same chromosome. Another student placed only one homologue of each pair of homologous chromosomes. The others could not make correct genetic combinations of gametes, and then they could not produce a correct result of reproduction. In order to deal with a problem regarding dominant-recessive relationship, students could not use the necessary logical deduction to identify a dominant trait from the information provided in the problem. It also implied that these students did not understand the concepts of dominant and recessive characteristics. Another theme of difficulty was about the movement of chromosomes during meiosis. In particular, students had difficulty of categorizing and duplicating of chromosomes during meiosis, separating of chromatids in meiosis I, and paring homologous chromosomes at synapsis.

In brief, it is clear that, from the literature, students encountered difficulty while solving genetic problems because they did not understand related concepts such as Mendel's laws, cell division, concepts of genes, alleles, chromosomes and chromatids. This hypothesis becomes clearer when considering that some students who were successful in solving problems failed to explain the basic ideas underlying the solutions. The root of this problem must be that that most biology texts treat meiosis in isolation from other genetic concepts. Thus, the students found it difficult to relate the two topics together.

Table 2.3 Students' alternative concepts of genetics found in the literature

Students' alternative concept of genetics	Reference indicators																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Cells only contains genetic information needed to carry out their function									+	+	+	+	+	+				+	+
Only some types of cells contain genetic information (especially gametes and brain cells)													+	+			+	+	
Sexual chromosomes are only in gametes														+				+	
Chromosomes or genetic material are found only inside some living organism (do not understand living thing)									+	+	+	+		+					
Alleles can be odd numbers																	+		
Do not understand concept of dominant and recessive genes				+	+														
Being unable to put correctly put symbol of alleles on chromosomes; put different alleles of a same gene on a same chromosome; put alleles of a same gene at different loci	+			+	+									+			+		
Confusion about definition, location and relationship between DNA, genes, alleles, chromatids and chromosomes	+	+							+	+	+	+	+	+	+	+			+
Alleles were each part of the chromosome joined by centromeres														+					

Table 2.3 (Continued)

Students' alternative concept of genetics	Reference indicators																		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Chromosomes do not relate to genetic information																		+	
A chromosome consists of a single double-strand DNA molecules are in haploid nuclei							+												
A chromosome consists of a two double-strand DNA molecules in diploid nuclei							+												
The two –DNA-molecules chromosomes in diploid nuclei are formed by joining of two single-DNA-molecule chromosomes at centromeres when gametes have fused together				+			+												
Chromosome number is related to age and health of a cell												+							
Sister-chromatids do not connect together					+		+												
All chromosomes have the same alleles														+					
Alleles are placed incorrectly on chromosomes during meiosis				+															
All chromosomes are either X or Y												+							
Chromosomes in a sperm are Y and in an egg are X												+							
Being unable to explain the connections between genes and DNA															+	+			

Table 2.3 (Continued)

Students' alternative concept of genetics	Reference indicators																		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Genetic information is transmitted from somatic cell to gametes or from cell to cell													+					+	
Sex-linkage can be indicated by the unequal number of phenotypes between male and females in a population						+													
A trait changes because a gene turns from recessive to dominant								+											
Only dominants can express								+											
A living organism with similar outlook had no gene												+		+					
Being unable to correctly transfer genotype to phenotype				+															
Crossing similar parents has to produce only parent-like offspring						+													
Genetic information is shared out at each cell division												+							
Being unable to identify events within cell division at the proper time	+			+	+		+					+							
Being unable to explain chromosomal processes during cell divisions			+	+															
Being unable to distinguish the differences between a product of mitosis and meiosis	+								+	+	+	+							

Table 2.3 (Continued)

Students' alternative concept of genetics	Reference indicators																		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Chromosomes split off and reunite to form a gamete, no replication				+	+														
Being able to properly connect meiosis to a process of heredity transmission		+	+		+														
Being unable to meaningfully use a Punnett square and algebraic method due to lack of basic understandings		+	+																
A sperm needs a greater number of chromosome than an egg												+							
Chromosomes from an egg and a sperm would cancel one set down into enable the other one to give genetic information												+							
Being unable to correctly combine gametes				+															
Mutation is response to environmental change								+										+	
Mutation takes place for survival								+										+	
Mutation is the cause of physical differences between offspring and their parents								+											

Note: A = Longden (1982); B = Stewart (1982); C = Tolman (1982); D = Moll, and Allen (1987); E = Stewart *et al.* (1990); F = Slack and Steward (1990); G = Kindfield (1994); H = Jimnez-Aleixander *et al.* (2000); I = Lewis *et al.* (2000a); J = Lewis *et al.* (2000b); K = Lewis *et al.* (2000c); L = Lewis and Wood-Robinson (2000); M = Wood-Robinson *et al.* (2000); N = Banet and Ayuso (2000); O = Marbach-Ad and Stavy (2000); P = Mardach-Ad (2001); Q = Johnson (2002); R = Banet and Ayuso (2003); S= Lewis (2004)

2. Nature of Difficulties in Learning Genetics

As cited several times in this study, genetics is a difficult topic in biology. To deal with problems related to learning genetics, it is useful to look at the natural basis of its difficulty. Genetics is perceived as a difficult topic for a number of reasons described in former studies. I will devote this section to reviewing the causes of the difficulty.

Tolman (1982) examined difficulties in the genetics problem solving of high school students. He found that one of the major difficulties encountered by students was misunderstanding in association of alleles, chromosomes and results from processes during meiosis. These errors led to another error regarding the production of a Punnett square. This finding implies that using a short cut-problem solving strategy without regard to basic understanding of the topic is a cause of difficulties. Another source of difficulty suggested by Tolman (1982) was the sequencing of the material being taught topic. He claimed that teaching meiosis in a separate chapter without making a connection to genetics could contribute to the confusion. For effective learning, Tolman (1982) suggested, cell division, especially meiosis, should be taught within the topics of genetics.

By using in-depth recorded interviews based on genetically oriented tasks, Langden (1982) found the major sources of learning difficulties in genetics among students. First, some students' alternative concepts were related to the nature of the concepts used in genetics. Most genetics concepts are abstract, so presenting them by means of a fixed, unanimated diagram causes confusion. The other source of difficulty is related to pedagogy. Evidence of this can be seen in the way that meiosis and genetics are taught separately and in the lack of practical supporting experience available to students. Longden (1982) further described that some students were confused about genetics concepts because of textbooks they were working with. Some textbooks are unclear and felt to identify important points such as timing of DNA replication in the pre-meiotic cell division. Frequently, the text diagram of meiosis shows the initial production of two strands instead of showing one chromatid chromosome at the beginning which is replicated into two stands later. That kind of diagram may lead to an assumption that there are two chromosomes each instead of a pair of chromatids. This situation, then, leads to confusions in later processes.

According to Moll and Allen (1987), problem solving is a very important activity for genetics learning. They studied the problem solving of college students. Their conclusions imply that students encountered difficulty in solving genetics problems because of their developmental stage; they had not reached the stage necessary to deal with the relatively complex relationships in genetics problems. Regarding genetics problem solving, Stewart (1982) conducted another study. Stewart (1982) found that even if students in the study were successfully solved problems by using short-cut method, such as a Punnett square or an algebraic method, they were unable to explain why they placed symbols (alleles) in their Punnett square in the way they did. Nor could they explain when performing the algebraic method. This situation points to teaching for product regardless of process or basic conceptual understanding, which results in poor understanding of students.

Bahar, Johnstone and Hansell (1999) used questionnaires to survey students' difficulties in learning biology. They found that genetics was the most difficulty topic for freshman university students. They explored the cause of difficulty further by interviewing a sub-sample of those students and they identified some of the sources of difficulty. Mainly, genetics was difficult because of language. Genetics requires a large and complex vocabulary. Terms such as "allele," "gene," and "homologous" are always interconnected. In addition, there are look-alike and sound-alike words. It is thus difficult for students to distinguish, use and understand them correctly. Some of the difficulty of genetics was due to its mathematics related content. Too much emphasis on this kind of content made students who have a problem with mathematics understanding dislike genetics and fail to understand it. Some students also mentioned about genetics symbols. They thought genetics involved a complex system of symbols. Inconsistent use of these symbols by a teacher and textbook was confusing. The attitude of students toward genetics also affected their ability to learn. Some students, at first, perceived genetics as difficult and boring topic but they became interested when they began to understand it. This point was not always negative but it could one of factors. Another main source of difficulty was similarity and difference among comparable topics taught side by side such as mitosis and meiosis. Bahar *et al.* (1999) and Ausubel, Novak, and Hanesian (1978) claimed that this might lead to confusion. Actually, this claim was proven by the fact that some students said that they confused mitosis with meiosis because their teacher taught these topic together and made a comparison between them. The last problem identified by both teachers and students was a time allowance. They were clear that not enough time was available to tackle this difficult area, and that what was needed was discussion and time for experimentation and digestion.

Kapteijin (1990) claimed that, within biology, there were three levels of organization. The macro level involves experience with phenomena at the organismal level; a direct observable level. Second, the micro level is a level of objects that are impossible to touch. Scientific equipment builds a bridge between human senses and this level. The molecular level is about biochemical phenomena in organisms. By means of open-ended questions, Marbach-Ad and Stavy (2002) probed high school students' understanding of genetic phenomena at these different levels. There were three different types of questions that required students to make a bridge between genetics concepts at different levels. They found that many students could not explain the interrelationships between those concepts. They, therefore, concluded that one of the reasons for the genetic learning difficulty was that genetic concepts and processes belonged to different levels of organization.

Knippels (2002) reviewed studies on genetics education and found that there were five main characteristics of genetics difficulties: a) the domain-specific vocabulary and terminology. b) the mathematical content of Mendelian genetics tasks c) the cytological processes d) the abstract nature of the subject in the biology curriculum e) the complex nature of genetics at macro-micro problem. Knippels, Waarlo and Boersma (2005) used a combination of research strategies to identify the main problems of learning and teaching genetics. They found that the problems were associated with the abstract and complex nature of genetics. The separation of genetics, reproduction and meiosis in the curriculum accounted for the abstract nature of genetics, while the different levels of biological organization contributed to its complex nature. Using content analysis, Knippels *et al.* (2005) found that textbooks were also a source of difficulty. In some textbooks, for instance, authors failed to organize content and bridge the differences at the genetics phenomenal level. In addition, not using contexts from everyday life or problems that have personal or societal relevance was added to the abstract nature of genetics and to a loss of motivation.

A combination of two notions uncovered another source of difficulty in genetics learning: context and the nature of the learning community. First, genetics concepts, like most other scientific concepts, are mainly studied in western countries; consequently, such concepts are often alien to students in other countries (Gellert, Jablonka and Keitel, 2001). Second, the context of learning shapes the interpretation and making-meaning process of students (Daniels, 2001; Jaramillo, 1996). When merging these two notions, students in Thailand who learn genetics mostly imported from western countries may encounter learning difficulty due to the differences between culture and context of Thailand and western country where genetics was originally studied. From these causes, we can conclude that genetics is difficult because of the nature and context of Thailand are not embedded in genetics teaching and learning.

Genetic difficulty due to context was supported by Santos and Bizzo (2005). Their study focused on Brazilian students' everyday understandings of inheritance. They found that students built their own everyday explanations to explain genetic phenomena in their families. The explanations were based on socially shared empirical evidence and grounded in social concepts of kinship that were sustained by everyday social activities and relationship. These concepts were also particularly resistant to change.

Science teachers are another source of genetics learning difficulty. As mentioned by Longden (1982), confidence and competence in genetics of science teachers are considered as a factor effecting genetics learning. In particular, if teachers are confident and understand genetics well, they are likely to help students overcome difficulties. As genetics is very interrelated with other topics in biology, teachers who perceive the relevance, coherence and association of genetics within the curriculum should be able to organize content in the way that helps students to connect each topic together and understand genetics more meaningfully. If, however, science teachers lack these components, students are likely to find that genetics is difficult.

In summary, the difficulty of genetics involves an emphasis on problem solving requires complex thinking, using many complex and unfamiliar words, and also involves the use of improper material such as textbooks with fragmented alignment of the topic. Moreover, if the way genetics is presented to students does not connect with their everyday lives, then it leads to learning difficulty. Main categories of difficulty are summarized in Table 2.4.

Table 2.4 The main categories of difficulty in genetics learning

Category (supported references)	Description
Abstract nature of concepts (Longden, 1982; Knippels, 2002; Knippels *et al*., 2005)	Alienation from real biological phenomena due to lack of connection between inheritance and sexual reproduction in general, and meiosis in particular
Complexity and Interrelation nature of concepts (Bahar *et al*, 1999; Marbach-Ad and Stavy, 2002; Knippels, 2002; Knippels *et al.*, 2005)	Inheritance has to do with all levels of biological organization and an adequate understanding of genetics requires 'to-and fro' thinking between molecular, cellular, organism, and population level. Complication of inheritance easily leads to conceptual problems. Contents at each level are dependent, but students fail to connect them together.
Mathematical content and probabilistic reasoning (Bahar *et al*., 1999; Knippels, 2002; Knippels *et al*., 2005)	Solving Mendelian problems requires mathematic understanding and process. Students who perform poorly in mathematics often also do so when solving genetic problems; see also difference between students
Terminology and symbolism (Bahar *et al.*, 1999; Knippels, 2002; Knippels *et al.*, 2005)	Genetics is rich in terminology, but not all terms are necessary for adequate understanding. These terms are unfamiliar for students. Some sound very similar. Students need to memorize these terms. Some sub-topics involve a complex system of symbols. Teachers and authors of textbooks do not use terms and symbols consistently or explicitly.

Table 2.4 (Continued)

Category (supported references)	Description
Problem-solving and problem solving methods (Stewart 1982; Tolman, 1982; Moll and Allen, 1987; Knippels *et al*., 2005)	Problem solving is a basic activity of genetics. Students need skill and developmental competence to achieve. Some problem solving methods are introduced to students. There is conceptual understanding that supports those methods but students use them without this understanding.
Examinations and time allocation (Bahar *et al*., 1999; Knippels, *et al*., 2005)	Genetics is just a small part of the final examination; consequently, not much time is allotted for this difficult topic
Image attitude, motivation and interest (Bahar *et al*., 1999; Knippels *et al*., 2005)	Inheritance may be perceived as a difficult topic in biology due to negative attitudes toward genetics as being uninteresting, and not useful or irrelevant to real life; resulting in poor motivation of a tendency to give up
Differences between students (Knippels *et al*., 2005)	Relevant prior knowledge and cognitive maturity is required for an adequate understanding of genetics. Students may differ in these respects. Furthermore, differences may also be related to opting for (or out of) chemistry and mathematics courses.
Curriculum structure and curriculum materials (Longden, 1982; Tolman, 1982; Kni; Knippels *et al*., 2005)	Inappropriate organization of concepts taught results in inadequate basic understandings of more complex concepts. In addition, timing interval and not relating topics outside and inside genetics lead to a gap in understanding. Some curriculum materials are inappropriate resulting in confusion.

Source: Adapted from Knippels, Waarlo and Boersma (2005)

3. Suggestions for Genetics Teaching and Learning from the Literature

Based on the nature of difficulty in genetics, scholars have made several suggestions for genetics teaching. This section will be dedicated to a review of these useful suggestions. Firstly, based on the result from a conference of leading researchers in the field of genetics, Smith and Simmons (1992) summarized the outcomes of the conference into four aspects. In the aspect of conceptual knowledge and understanding, students should be able to apply, predict, and explain genetics observations and phenomena, articulate their understanding of genetics observation and phenomena, and support their interpretations of these phenomena. In the aspect of reasoning tasks, being able to solve problems by using domain specific and general problem-solving techniques is an outcome. The nature of science and genetics is another outcome emphasized. Students should develop an understanding of the nature of science as exemplified in genetics. Students should, for example, understand the role of model building, problem posing, and the tentative and changing nature of knowledge. Desired student characteristics are to recognize and value individual differences and to be functionally literate in genetics, taking reasoned positions on social and ethical issues, and making reasonable decisions on policy issues (i.e., function as state citizens).

For achieving these four general outcomes, Smith and Simmons (1992) also posted specific recommendations for the classroom learning environment. The first main idea is to create a context that promotes meaningful learning of genetics through using alternative learning assessments, using open-ended problem solving, helping students to organize knowledge, and employing innovative teaching strategies and curricular topics. The classroom learning environment should function as a community of learners. In such classrooms, the main role of teachers is to help students and engage students in group learning. The teachers should create environments that help students attain insight into conceptual and procedural genetics knowledge and the nature of genetics through selecting and designing appropriate learning activities. The last specific recommendation is to engage students in meaningful problem solving by designing experiments which answer their own questions about genetics. That is having students take a dominant role in formulating questions and designing the procedure of experiments.

Some researchers have discussed the importance of sequencing of topics. According to Kapteijin (1990), within biology education, there are three levels of organization namely macro (organismal) level, micro (cellular) level, and molecular (biochemical) level. In this vein, Marbach-Ad and Stavy (2002) studied students' genetics understanding at these levels and found that one of the reasons for the difficulty of learning genetics was that genetic concepts and processes belonged to different levels of organization. To deal with this kind of difficulty, learning activities that integrate and do not separate of the different levels need to be more emphasized (Kapteijin, 1990). Moreover, Marbach-Ad and Stavy (2002) suggested that it was easier for students to learn from higher organisms, since they were more visible and similar to humans. Therefore, students should first learn genetic phenomena at the macro level in human beings or higher organisms. Then, when dealing with the micro level or when trying to connect the macro level (traits) with the micro level (genes or DNA), it would be better to deal with lower organisms. This is similar to the working practices of scientists who begin their investigations at the micro level from bacteria whose genetic system is simple.

This concept of teaching is in line with Knippels *et al.* (2005) who claimed that genetics education should start on the phenomenal level of the organism that students are familiar with, i.e. their family, and should gradually descend to the cellular. They further suggested that the relationship between meiosis and inheritance should be taught explicitly. In particular, they should be taught together. The relationships between them must be emphasized during classroom activities. Two main cell lines, the somatic line (mitosis) and the germ line (meiosis) should be distinguished in the setting of the life cycle. For the last one, students should actively explore the relationships between the levels of biological organization that are guided by the structure of the learning activities and/or by the teacher.

Lewis *et al.* (2000a) claimed that understanding the genetic relationship between cells within an individual was fundamental to an understanding of inheritance. Unfortunately, their study showed that children at high school-age lacked understanding of this point. According to their suggestion, in order to help students at this point, first the topics of cell division, life cycles, and inheritance should be taught together. At least, a teacher should try to recover students' understanding of the other topics before starting genetics and then link them together.

Suggestions about the organization of curriculum topics are also found in Tolman (1982). He studied genetics problem solving of high school students and found that sex determination seemed to be an inherently interesting topic for students. Alleles that were tied to the X chromosome are easily traced to the mother, in the case of boys, or to the mother and father (one from each) in the case of girls. Based on this finding, he claimed that if meiosis, sex determination by chromosomes, and sex-linked characteristics were taught back-to-back before other concepts, then students would be more proficient in tracing alleles back to parents. Activities of genes or alleles on the chromosome should also be identified especially during the first meiotic division. Segregation and random assortment should be treated concurrently with meiosis, using hypothetical alleles or genes on each chromosomes. Sex determination should follow logically form meiosis. The Punnett square should be introduced here in order to determine probabilities of having boy or girl children. After that, a teacher should introduce students with sex-linked traits and lead them to discuss this topic. The alleles should be traced through meiosis to the F_1 generation. At this point, students could deal with the concepts of dominant, recessive, homozygous, heterozygous, genotype, phenotype and so on by studying pea plants in Mendel's experiment. In addition, the human example should be used in order to analyze and explain Mendel's experimental results. The teaching sequence proposed by Tolman (1982) is shown in Table 2.5.

Table 2.5 Two contrasting genetics teaching sequences

Traditional Sequence	Tolman’ Proposed Sequence
1. Meiosis (without genes in diagrams, usually in a separate chapter, and little or no emphasis on chromosome behavior) 2. Mendel’s pea experiments - Genes - Dominances - Recessiveness - Segregation - Independent assortment - Genotype - Phenotype - Phenotype - Homozygous - Heterozygous - Alleles - Punnett squares 3. Monohybrid cross 4. Dihybrid cross 5. Incomplete dominance (Codominance) 6. Sex chromosomes 7. Sex determination 8. Sex-linked traits	1. Meiosis (include genes in diagrams and emphasize chromosome behavior during first meiosis division) 2. Sex chromosomes-Human (show genes in diagrams-trace back to meiosis) 3. Sex determination-Human (show genes on diagrams-trace back to meiosis) 4. Sex-linked traits-Human - Reemphasize genes on chromosomes-trace back to meiosis - Segregation - Random assortment - Dominance - Recessiveness - Genotype - Phenotype - Homozygous - Heterozygous - Alleles - Punnett squares 5. Monohybrid cross-Human 6. Dihybrid cross-Human 7. Codominance-Human 8. Mendel’s pea experiments-bring in history of development of terminology

Source: Tolman (1982: 527)

To deal with Mendelian genetics problem solving, Moll and Allen (1987) found that using a meiotic approach is successful to solve the problems and establish relationship between Mendelian genetics and cellular events in meiosis and fertilization. The best instructional procedure would be for students to first learn meiotic problem-solving methods with an emphasis on meiotic events. Then, students could learn to use algorithmic methods when they had to deal with complex problems.

Moll and Allen (1987) also found students' difficulty regarding placing alleles on a chromosome and movement of chromosome during cell division. They suggested that, to avoid such difficulties, extra emphasis on chromosome duplication and meiosis is necessary for understanding of this activity.

Based on some studies, it is clear that students do not clearly understand the definitions, functions, locations and relationships between basic genetic concepts (especially genes, alleles, DNA chromosomes and chromatids). In order to help students, teachers must ensure that the differences and interrelationships between different structures are explicitly taught (Lewis *et al*., 2000b; Stewart, 1982). Lewis *et al.* (2000a) identified the critical points that must be emphasized. These ideas include:

a) A recognition that chromosomes are, in effect, organizers of genetic information

b) A recognition that each gene has a specific location on a specific chromosome

c) A recognition that the replication of a chromosome during cell division mirrors the replication of the genetic information stored within that chromosome

d) A clear distinction between genes and genetic information, for example, recognition that there is a gene for eye color, but the genetic information within that gene may vary to specify blue or brown

e) A recognition that genes can be switched on and off according to need, for example, sunlight includes ultra violet light which is harmful; when fair skinned people are exposed to sunlight, the gene for melanin is switched on in their skin cells; their skin darkens; in the absence of sunlight the melanin gene is switched off and the suntan fades.

Lewis *et al.* (2000c) also gave further suggestions about genetic teaching. They claimed that students need a greater understanding of the relationship between the basic structure of genes and chromosomes in particular; this may help students to develop a clearer understanding of how the process of cell division and fertilization result in a continuity of genetic information within and between organisms. Moreover, they claimed that it might help students if

a) the basic structures and the relationship between related concepts are made explicit

b) the nature and purpose of chromosomes, in particular the physical relationship between genes and chromosomes, is emphasized

c) the similarities and differences between the two types of cell division are clearly identified in term of purpose, product, and process and

d) the link between chromosome behavior and the transfer of genetic information is re-enforced when discussing cell division and fertilization; and

e) the relationship between the three processes (mitosis, meiosis, and fertilization), the life cycle, and the continuity of genetic information is made explicit. Furthermore, technical terms must be used clearly and consistently when describing genetic phenomena to students

Longden (1982) made some suggestions to enhance effective genetic learning, especially about the cell cycle. The use of good visual material, film or video, on the dynamic dimension of meiosis may be sufficient to reduce the stereotyped reliance on stages. To use any diagram, a teacher should make sure that the symbols used make sense for students and should also emphasize explaining the points that may confuse them.

Santos and Bizzo (2005) found that social contexts and experiences exerted a powerful influence on students' understanding of genetic phenomena. Students' interactions with an adult in a family transfer some genetics understandings that might be either correct or incorrect. Direct experiences with phenomena in everyday life also contribute students' understandings. The combination of these kinds of experiences sets up everyday knowledge and a perspective of science education and its relation to their culture and beliefs. To deal with everyday knowledge, students should be considered as tourists in an unfamiliar culture and then teachers should act as a tour guides who present and guide students (Aikenhead, 1996). That is teachers should introduce students to genetics knowledge and guide them to use of related knowledge and technology in the context to students' everyday lives. Everyday knowledge may function as a scaffold or an obstacle to learning science (Santos and Bizzo, 2005). It may become obstacle to learning if scientific explanations cannot explain visible phenomena in students' everyday world. Picking an everyday situation in the classroom and discussing how science can explain it may turn everyday knowledge to be an accelerator of learning scientific knowledge. Knippels *et al.* (2005) suggested that it was often useful to mention students' direct experiences such as their family when they got stuck in their reasoning. Moreover, they also claimed that starting by presenting students with familiar examples could encourage genetics learning by motivating and helping students to ask meaningful questions.

In summary, there is common agreement on the topic sequence in the literature on teaching and learning genetics. First, cell division and genetics must be taught together because activities during meiosis are very connected and are fundamental to genetics phenomena. Second, students should begin learning genetics from less complex concepts in a familiar higher organism such as a mammal. This makes it more interesting and easier for students to learn genetics meaningfully.

During the process of teaching and learning, it is highly recommended that the definition, location, and function of genetic terminology must be taught explicitly. Moreover, the relationships between those terms must be emphasized. Finally, animated learning media and context-bounded examples facilitate genetic learning.

The Sociocultural Perspective

The theoretical or conceptual foundations for this study fall under what is called a sociocultural perspective. In this part, I reviewed the literature about the sociocultural perspective. First, I provided an overview of the sociocultural approach regarding the key concepts of this perspective. Then I discussed the nature of scientific knowledge and teaching, learning, and assessment according to a sociocultural perspective. The concepts from this review were regarded as fundamental to developing the instructional unit of the present study.

1. Fundamental Ideas in the Sociocultural Perspective

According to Daniels (2001: 2), the sociocultural perspective has its theoretical heritage in the ideas of the Russian psychologist, and pedagogical theorist Lev Vygotsky and his followers. Vygotsky's work was originally written in Russian and was translated into English many years after his death. There have been a range of interpretations and applications of his theory as most scholars have studied this perspective from those translated publications. However, there is agreement among those scholars regarding some common concepts. These concepts are the general law of development, the zone of proximal development (ZPD), and mediation. In this section I will review these fundamental concepts.

1.1 The General Law of Development

In Mind and Society (Vygotsky, 1978: 57), Vygotsky pointed out that

> Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals.

That is, learning is a process of the progressive transfer from external social activity to internal control, and in order to learn, students must engage in social activity and participate in scientific discourse. It has been called the general law of cultural development. It asserts the primacy of the social in development (Daniels, 2001: 56).

Similarly, John-Steiner and Mahn (1996) and Shepardson (1999) both observed that the general law of development points to the notion of social sources of development. That is, learning is a process of social interaction, and in order to learn students must engage in social activity and participate in scientific discourse. Through social (interpsychological) activity learners appropriate a framework or lens for seeing, talking, acting, and thinking about scientific concepts and phenomena which leads to the formation or restructuring of the intrapsychological plane. Even interpersonal activity is important to intra personal activity but it is not copying. On the contrary, interpersonal activity involves the formation and restructuring of intrapersonal activity (Wertsch, 1981).

1.2 The Zone of Proximal Development

The term zone of proximal of development is probably one of the most widely recognized and well-known ideas associated with Vygotsky's theory and is used in a wide range of disciplines such as writing, mathematics, science and second-language learning (Chaiklin, 2003). In *Mind and Society*, Vygotsky (1978: 86) defined the principle of the ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers."

According to Vygotsky (1978), the ZPD defines a relationship between the actual developmental level that has been already established and the potential development level that is not yet fully developed but is currently in an immature state. Actual development involves abilities that children can perform independently. The potential level of development is above their actual development but children can achieve it with the assistance of more skilled others. It is between these two levels that teaching and learning in school should be pitched. Learning occurs when children are interacting with people in their environment in cooperation with their peers. Many researchers have also argued that the ZPD is created in interaction between a child and an adult (Chaiklin, 2003). Brown *et al.* (1993: 191), however, proposed that not only humans but also artifacts, such as books, videos, wall displays, scientific equipment, and computers, that can be counted as the active agents in the ZPD. Therefore, social interaction between children and all the above contextual components are the sources of learning. From this viewpoint learning is not development but is a necessary process leading to development.

Chaiklin (2003: 42) added a more complete conception of the ZPD by mentioning that there were three aspects that, taken together, represent an "ideal type" of ZPD called the "common interpretation" of the zone of proximal development. The first aspects were named "generality assumption" implying applicability for all kinds of subject matter. That is the ZPD is not concerned with the development of skills for any particular task, but must be related to development. The second aspect named the "assistance assumption" suggests that learning is dependent on interventions by more competent others. In *Thinking and Speech*, Vygotsky considered that with collaboration, direction, or some other kind of help, the child is always able to perform more complex tasks (Chaiklin, 2003). The last aspect was named "potential assumption." It uncovered the point that a learner has potential and is ready to learn.

1.3 Mediation

The principle of mediation is another important aspect of Vygotsky's theories (Kozulin, 2003). For Vygotsky (1978), the ability to use tools enables human to see, interpret, talk about and manipulate phenomena. This ability distinguishes humans from other animals. Tools and signs mediate the formation of learners' cognitive activity. Vygotsky (1978: 7) brilliantly extended this concept of mediation in human-environment interaction to the use of signs as well as tools. Like tool systems, sign systems (language, writing, and number systems) have been created by societies over the course of human history and change with the form of society and the level of its cultural development. Vygotsky believed that the internalization of culturally produced sign systems brings about behavioral transformations and forms the bridge between empirical and theoretical forms of individual development.

The key concept "mediation" opens the way for the development of a non-deterministic account in which mediators serve as the means by which the individual acts upon and is acted upon by social, cultural and historical factors (Daniels, 2001: 14). The general concept of mediation within Vygotsky's theory is shown in Figure 2.1. From the figure, the subject/individual comes to learn about an object through the mediation of mediators including tools, artifacts, and adults, for example.

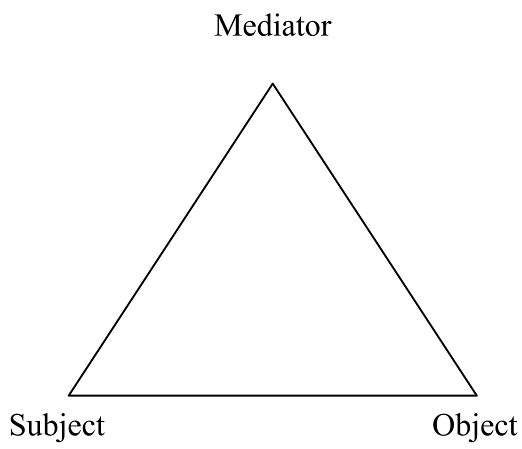


Figure 2.1 The basic triangular representation of mediation
Source: Adapted from Daniels (2001: 14)

Kozulin (2003) has distinguished mediations into two types. One is the human mediator and the other is symbolic mediators. Humans act as mediators by interacting with novices and guiding them into a new culture of community (Kozulin, 2003). There are three ways of mediation: apprenticeship, guided participation, and appropriation (Rogoff, 1995). Apprenticeship mediates learning by providing a model of community activity. Guided participation involves interactions in joint activities. Appropriation is changes resulting from participation in mediated activities inside an individual who participates in activities. Symbolic tools mediate learning by providing a means for an individual to see, talk, think, and interpret and so on about the world.

Shepardson (1999) further clarified the key word "tools" initiated by Vygotsky. Shepardson claimed that tools consisted of psychological tools (signs) and technical tools. Examples of psychological tools are language, words, systems of counting, mnemonic techniques algebraic symbol systems, works of art, writing, schemes, diagrams, maps, drawings, and all sorts of conventional signs (Wertsch, 1981: 136-137). They change nothing in the phenomenon but provide individuals a lens to look, talk, think and act about phenomena. In fact, if looking, talking, thinking and acting are the ways individuals try to make sense of something, then the way of knowing is a function of psychological tools. From the other perspective, the ways individuals perceive the world can be changed or expanded because of the appearance of tools, the so called "technical tools." Technical tools provide a new ability to look at phenomena from a different perspective. Examples of technical tools are magnifiers, computers, and books. Because technical tools can change individuals' ways of knowing, how to know is a function of technical tools. Both of them mediate the meaning-making process on the intrapersonal plane. In the process of learning science, learners must have the chance to use those tools in social activity. The individual in isolation does not invent tools. They are products of sociocultural activity to which individual has access by active participation in the social practices (John-Steiner and Mahn, 1996). As they are products of social activity, they are also called cultural tools (Arievitch and Haenen, 2005) in some publications.

It is clear that Vygotsky (Daniels, 2001: 15) was arguing that humans master themselves through external symbolic, cultural systems rather than being subjected by them. This emphasis on self-construction through and with the tools that are available brings two essential issues. The first issue is the perception of the individual as an active agent in development. The other issue is the importance of contextual affects, in that development takes place through the use of the tools that are available at that time at that place. Due to this particularity, the interpretations and perceptions of an individual can also vary according to particular time and place.

From those concepts, the major theme of the sociocultural perspective is that learning and cognitive development are the result of social interaction between an individual and the other individuals and between an individual and the cultural context (Jaramillo, 1996; Kozulin at el., 2003). The group is therefore important to the learning process for all learners who learn higher forms of cognitive activities through more knowledgeable peers and adults who jointly construct and transfer this activity primarily through language. In addition, the psychological tools including language, concepts, and symbols presented by adults or more competent peers mediate learning and development (Leach and Scott, 2003).

2. The Nature of Scientific Knowledge: Sociocultural Perspective

Any account of teaching and learning science needs to consider the nature of the knowledge to be taught (Driver *et al.,* 1994). Under the sociocultural view, Driver *et al.* (1994) and Leach and Scott (2003) claimed that scientific concepts are cultural. They are socially constructed and validated through the complex empirical and social processes of scientific institutions. To study and make understanding of any phenomenon, an individual needs to benefit from the cultural heritage, such as scientific instruments, previously studied theories or concepts. Moreover, knowledge must be proved in the scientific community through a social process. Through a process of challenge, debate, and revision, a new concept is validated, and when and how is should be used are determined. Consequently, it is unlikely that individuals can discover scientific concept through their own empirical enquiry. In short, scientific knowledge is not discovered but is symbolic in nature and also socially constructed between individuals and then it is communicated through the cultural and social institutions of science (Driver *et al.,* 1994). Scientific knowledge, then, should be learned through a social process (Leach and Scott, 2003).

Vygotsky separated children's concepts into two categories based on the way they are formed: everyday or spontaneous concepts and scientific concepts (John-Steiner and Mahn, 1996; Shepardson, 1999). Categorizing the different types of concepts provides a foundation for examining how children learn before they enter school and how this knowledge relates to concepts learned at school. Similarly, John-Steiner and Mahn (1996) and Shepardson (1999) explained that everyday concepts are formed through the interactions and experiences that occur outside the context of formal school settings. Mostly, these concepts are taken from adults unsystematically. This means that the sociocultural context shapes children's understanding of natural phenomena. On the other hand, scientific concepts are concepts that are formed through interaction and experienced within the formal school setting. They are explicitly and systematically introduced by a teacher in school. In learning science, everyday concepts move upward from everyday phenomena toward generalization according to scientific knowledge, and scientific concepts will move downward toward the phenomena. That is, everyday concepts shape scientific concepts (Shepardson, 1999). More simply, in formal learning everyday concepts will be restructured as scientific concepts, and then scientific concepts will replace everyday concepts about particular phenomena.

Based on the view of scientific concepts as socially constructed and on the relationship between everyday and scientific concepts, a group of sociocultural scholars (e.g. Driver *et al.,* 1994; John-Steiner and Mahn, 1996; Leach and Scott, 2003; Shepardson, 1999) pointed out similarly that scientific concepts are unlikely to be discovered by individuals through just their own empirical learning. Learning must involve being introduced to a symbolic world. Scientific concepts need to be introduced to children as a way of seeing phenomena. In this vein, scientific understandings can be formed when learners actively engage in social talk and activity about shared problems. Consequently, more knowledgeable members (e.g. teachers and more competent peers) play a significant role in the meaning-making process, which involves persons-in-conversation. Children should learn through being initiated into the concepts and practices of the scientific community. The role of science education is to mediate scientific knowledge for learners and help them to internalize the nature and process of that knowledge. Children need to be given access not only to physical experiences but also to the concepts and models of science. Accordingly, teachers must step into the process of learning by providing appropriate experiential evidence and making the cultural tools and conventions of the science community available to learners.

3. The Sociocultural View of Learning and Teaching

> [Y]ou cannot learn how to swim by standing at the seashore…to learn how to swim you have to, out of necessity, plunge right into the water even though you still don't know how to swim, so the only way to learn something, say, how to acquire knowledge, is by doing so, in other words, by acquiring knowledge (Vygotsky, 1997: 324).

From the above passage, we can see that Vygotsky basically perceived learning as a process of acquisition. Learning is an activity through which an individual tries to acquire a new skill that is above his/her current level of ability by doing the activity. Based on the sociocultural view of learning, Jaramillo (1996) reemphasizes that an individual does prefer to be actively involved in hands-on learning activities that interest him/her and are above his/her current level of ability. Vygotsky's concept of the zone of proximal development, illustrates a key difference between his beliefs and those of Piaget. Unlike Piaget who claimed that development leads learning, Vygotsky argued that learning leads development. In fact, Piaget believed that children can only learn what is possible for their given stage of development which originates from an innate program of developmental stages; on the contrary, Vygotsky proposed that being presented with challenges and assisted in overcoming these challenges induces the development of new abilities (Vygotsky, 1978).

Minick (1987: 28) described Vygotsky's thoughts about development as follows:

> He [Vygotsky] argued that when the infant cries and reaches for an object, the adult attributes meaning to that behavior. Though the infant has no communicative intent, these acts nonetheless function to communicate the infant's needs to his caretaker. Here, as in the adult's attempts to interact with the infant, the infant is included in communicative social activity before he has the capacity to use or respond adequately to communicative devices. Vygotsky argued that this provides the foundation for the transformation of the infant's behaviours into intentional indicative gestures.

According to Lerman (2001), learning, an activity on the mental plane, is constituted through the process of internalization. That is, learning is first about participating in communicative social activities and then transforming learned knowledge into cognition. In addition, learning, in this sense, is inseparable from teaching. Accordingly, Jaramillo (1996: 135) mentioned that, to learn a concept, the individual must have experience in those activities and socially negotiate their meaning in the authentic context of a complex learning environment. In the classroom setting, students learn through interacting with their teachers, peers, manipulatives, and their contextual setting. These interactions in social situations help individuals to critically consider their own thoughts, socially negotiate meaning, and finally construct their own meaning.

It is clear that learning is a social process happening in sociocultural activity. This can be illustrated by Rogoff (1990) who stated on the role of social activity in learning that:

> Cognitive development occurs in socioculturally organized activities in which children are active in learning and in managing their social partners, and their partners are active in structuring situations that provide children with access to observe and participate in culturally valued skills and perspectives. Social activity, in turn, constitutes and transforms cultural practices with each successive generation. The integration of individual and social activity is necessary for a balanced consideration of the role of individuals and their social partners, with the individuals actively participating in socioculturally structured collective activity.

Based on the initial ideas of Vygotsky, Hatano (1993) summarized key features of learners and learning. First, learning is actively achieved by interaction with others. When students work with others, whether they work with peers, teachers, parents, etc., their learning is affected by context of the situation created by those people. Communication with others helps the learner construct personal meaning through social interaction. Second, learners look for understanding from what they learn (Hatano, 1993). That is, they "construct" what is being taught to them. When learning takes place, students work to make personal meaning of what is being learned. How does the new information fit in with their existing understanding? Does what is being learned change previous understanding? Students take information and make it fit into their lives. Third, "learners' construction of knowledge is facilitated by horizontal as well as vertical interactions" (Hatano, 1993: 156). That is learners learn both from people of their own age such as their peers (horizontal interaction) and from someone or something that is more competent such as teachers, texts, and parents (vertical interaction). Both horizontal and vertical interactions result in learning. Finally, learning is enhanced when it comes from a variety of sources (i.e. teachers, peers and material).

As noted by Kozulin *et al.* (2003: 4), one of the new contributions Vygotsky made to learning was his idea that our sense of the world is shaped and mediated by tools acquired in the course of education and learning. For Vygotsky (1978), learning and cultural tools, especially language, are very important to human learning. That is because he emphasizes that the use of language separates us from lower animals. When an animal tries to solve a problem, it often relies on genetically determined responses or naturally forced responses. In contrast, humans use language either as inner speech or to communicate with the other humans to create strategies for solving the problem. Based on this observation, Shepardson (1999) remarked that social interaction in the science classroom is very important because it provides a way of seeing, acting, talking, and thinking about scientific concepts. To learn science, therefore, learners must be engaged in interactions with a more knowledgeable individual, using psychological tools (words) to mediate the formation of one's intrapsychological structure: first as a way of seeing and acting, then as a way of talking and thinking about scientific phenomena. In this way, language is a psychological tool for knowing. At the same time, interaction with learning technological tools enables learners to gain a different perspective of the phenomena. Therefore, the combination of the psychological and technological tools of science gives learners access to different ways of seeing, acting, talking, and thinking about the world. Finally, Leach and Scott (2003) and Shepardson (1999) concluded in the same way that within the sociocultural perspective the emphasis of science learning is on knowledge construction and the development of abilities to use and apply scientific explanations and techniques in understanding phenomena, solving problems, and creating products, and also in directing scientific inquiry, explorations, and activity.

According to Davydov (1990, cited in Karpov, 2003), a Vygotsky follower, there are two types of learning: namely empirical learning resulting in spontaneous concepts/everyday concepts and theoretical learning resulting in scientific concepts. Another goal of learning, then, is to change learners' spontaneous concepts into scientific concepts (Byrnes, 2001) by bridging the gap between empirical and theoretical learning (Westby and Torres-Velåsques, 2000). Empirical learning "is based on children's comparison of several different objects or events picking out their common salient characteristics, and formulating, on this basis, a "general concept" about this class of objects or events" (Karpov, 2003: 69). This situation always happens when children experience the natural world by themselves without any guidance and even in science classroom. Through empirical learning, children tend to collect just some visible-common characteristics of objects, but not reflect on the essential characteristics of scientific objects. Thus, empirical learning often leads to incomplete understandings.

Theoretical learning, however, is more akin to the learning that occurs in school settings. It is;

> based on students' acquisition of methods for scientific analysis of objects or events in different subject domains. Each of these methods is aimed at selecting the essential characteristics in the form of symbolic and graphic models. Teachers teach methods of scientific analysis, and students then master and internalize these methods in the course of using them. The methods then serve as cognitive tools that mediate the students' further problem solving (Karpov, 2003: 71).

This kind of learning leads to completeness of scientific concepts, a primary goal of formal schooling (Westby and Torres-Velåsques, 2000).

To meet theoretical learning, students should participate in a discovery activity that more knowledgeable others assist learning by providing verbally mediated experiences with taxonomic classifications and metalinguistic/metacognitive skills (Westby and Torres-Velåsques, 2000). Driver, *et al.* (1994: 11) commented that, from a teaching perspective, students' intervention and negotiation with more knowledgeable people such as teachers and peers is essential. The role of the teacher is to introduce new ideas or cultural tools where necessary and to provide the support and guidance children need to make sense of these ideas for themselves; the teacher should also listen to and diagnose the ways in which the instructional activities are being interpreted to inform future action.

Leach and Scott (2003) believed that introducing students to new science concepts is a subtle process that is enacted through teacher and students' talk, and takes place over an extended time period. The teacher might involve students in practical activities, each of which has a clear purpose in addressing aspects of the learning demands. The classroom discourse is guided by the teacher through different kinds of strategies. Actions that the teachers may take at different time may be to (a) develop key ideas relating to the new concepts being introduced, (b) introduce points relating to epistemological features of the new way of knowing, (c) promote shared meaning among all students in the class by making key ideas available to them (d) check student understanding of newly introduced concepts.

Introducing students to a new scientific concept also points to the view that teaching is providing a new way of thinking, seeing, talking, and acting about the phenomena (Leach and Scott (2003). This is in accordance with Driver *et al.* (1994) and Shepardson's (1999) beliefs. They proposed that learning science involves children entering into a different way of thinking, seeing, and explaining the natural world. However, this new way of actions is quite different from everyday style (Leach and Scott, 2003). Mature concepts occur when everyday versions and scientific versions of action have been merged (Daniels, 2001).

One criticism of Vygotsky by Lerman (2001) was that, as Vygotsky emphasized the presentation of scientific to students and opposed the idea that they need to rediscover the development of humankind for themselves, this style is very close to the transmission style of teaching. The important point is Vygotsky discouraged merely telling learners the knowledge. A central concern of Vygotsky was the mediation of cultural tools and metacognitive tools. Knowledge is constituted in historical and sociocultural settings, and cultural tools play a very important role in developing knowledge on the mental plane. Thus, cultural tools both transform the person and the world for that person and these cultural tools precede the individual. Words and symbols are mediators of thought and the word system creates the world of objects. Thus, it is cultural tools that will lead students to understanding of the world.

The concept of the ZPD has three implications for classroom activities (Moll, 1990: 8). The first is establishing the level of difficulty. This level, assumed to be the proximal level, must be a bit challenging for the learner but not too difficult. The second is providing assisted performance. The adult provides guided practice to the child with a clear sense of the goal or outcome of the child's performance. The last is evaluating independent performance. The most logical outcome of the zone of proximal development is the child performing independently.

Jaramillo (1996) described the connection between the ZPD and teaching in a similar way. Vygotsky's stress upon experiential learning was evident in the role of the teacher as a facilitator of learning phenomena. Based on the concept of the ZPD, teachers must foster learning among students that combines internal and external experiences. These experiences are the interplay of cognitive, emotional and external interactions. The role of teachers is to design this interplay in the students' zone. It is teachers and more competent peers who guide each student's social and cultural experiences. To do this, the teacher employs modeling and scaffolding techniques at a level that parallels the learner's ZPD. To prompt students to learn in the zone, teachers encourage them to learn by doing an activity. In the activity, students should firstly learn from concrete objects in a realistic-authentic context and then associate these objects with abstract concepts in a small group-cooperative learning setting and under the guidance of a teacher. During the process of teaching and learning, teacher and more competent peers use language and other tools to acculturate and communicate knowledge to learners. Language and tools, moreover, are use to inculcate a culture's social values and beliefs to children.

Smith, Teemant and Pinnegar (2004) claimed that under the sociocultural perspective, teaching consists of structuring goal-directed learning activities and assisting performance of learners during meaningful and productive social interactions. Teachers, as more knowledgeable others, provide assistance within the learner's ZPD. Effective learning activities provide opportunities for guided reinvention of knowledge that is valued by society in situations that are motivating for learners. Teachers assist students in making connections among situated experiences, and they guide the generalization of formal knowledge from these connections. Furthermore, teachers judge the quality of students' performances and explanations of thinking by comparing them to suitable standards, and teachers provide feedback that assists students' learning.

Vygotsky (Puntambekar and Hübscher, 2005) believed in the general law of development and emphasized the role of social interactions as a crucial factor of learning. Therefore, according to his theory, an individual must learn under assistance from an adult or a more skillful peer within an individual's ZPD. In order to enable an individual to move from one level to another in ZPD, providing learners with supports and introducing them to knowledge are a key of teaching. This practical notion is in accordance with Driver *et al.* (1994: 7) who mentioned that more experienced members of a culture can support a less experienced member by structuring tasks, making it possible for the less experienced person to perform them and to internalize the process, that is, to convert them into tools for conscious control.

To assist learners' learning within the ZPD, the term "scaffolding" has been used to describe the way adults and more knowledgeable peers provide help for the learners to bridge a gap in their ZPD (Byrnes, 2001). While Vygotsky (Puntambekar and Hübscher, 2005) did not talk about scaffolding, in his conception of teaching and learning scaffolding is essential. According to Vygotsky' s conception of the ZPD, learners would be unable to develop full scientific understanding of science without scaffolding from teachers or peers (Byrnes, 2001). However, the emphasis of intervention and support by adults is not on the transference but on the collaborative use of tools and sign systems, wherein teachers and children engage in exploratory talk and activity that assist them in the appropriation of skills, words, and knowledge as tools for reorganizing and understanding their experiences (Moll, 1990).

Puntambekar and Hübscher (2005) noted that the key features of scaffoldings are shared understanding of a common goal that provides motivation to students to engage in the task; providing appropriate support of adults and more advanced peers; and fading out the support in order to let students to take control their own learning. Inter-subjectivity or shared understanding of the activity is attained when the adult and child collaboratively redefine the task so that there is combined ownership of the task and the child shares an understanding of the goal that he or she needs to accomplish. The role of the teacher or more knowledgeable others is to ascertain that the learners are invested in the task and to help sustain the motivation. Another key feature of scaffolding is that the more knowledgeable individuals provide appropriate support. Thorough knowledge of the task and its components and also knowledge of students' capabilities are crucial for performing this key element. The last key element of scaffolding is fading out the support. While being supported, students are learning on the interpersonal plane. After that, cognitive processes move to the intrapersonal plane in which teachers can withdraw support for a particular activity.

In the same vein, from the viewpoint of Moll and Whitmore (1993), the roles of adults in the sociocultural approach can be succinctly described as follows:

1. Guide and supporter: the teacher is crucial for helping learners take risks, focus their questions and ideas, and translate them into manageable activities, ensuring that each child find academic success.

2. Active participant in learning: researching theme topics along with the children, combining his or her own content question with demonstrations of the research process.

3. Evaluator of their development.

4. Facilitator: planning environment, curriculum, and materials (Moll and Whitmore, 1993).

Moll and Whitmore (1993) also remarked that the goal of mediated assistance is to make children aware of how they are manipulating materials and ideas and applying knowledge. For them, the essential factors contributing to success of this classroom based on Vygotskian theory is that children have control over all aspects of their own learning experience. They select group, reading materials, writing topics, theme topics, and language to use for each activity. Teachers trust learners and let learners share responsibility for generating the learning task. This kind of learning environment invites the learners to participate in a process of negotiation and co-construction of knowledge in a shared problem space.

More knowledgeable persons contribute to knowledge growth by providing assisting performance within a learner's ZPD (Tharp, 1993). Based on the concept of the ZPD, Tharp (1993) summarized seven means of assisting performance and facilitating learning that should be used in the classroom to facilitate learners' learning in the ZPD:

1. Modeling: offering information and a memorable image at the beginning for the learner, to later serve as performance standard.

2. Feedback: providing information on how a performance compares to a standard. Ensuring feedback is the most common and single most effective form of self-assessment.

3. Contingency management: application of the principles of reinforcement and punishment to behavior.

4. Instructing: requesting specific action. It assists learners by selecting correct responses and by providing clarity, information, and decision making.

5. Questioning: a request for a verbal response.

6. Cognitive structuring: "explanation". It assists learning by providing explanatory and belief structures that organize and justify new learning and perceptions, and allow the creation of new or modified schemata and,

7. Task structuring: chunking, segregating, sequencing, or otherwise structuring a task into or from components. It assists the learners by modifying the

task itself, so that units presented to the learners fit into the ZPD when the entire structured task is beyond that zone.

Although Vygotsky stressed the guiding role of adults, he also perceived the important role served by peers on students' meaning construction (Jaramillo, 1996). According to Jaramillo (1996), Vygotsky acknowledged that children come to learn adult meanings and actions through peer collaboration. More knowledgeable peers can facilitate learning of less knowledgeable ones by prompting, modeling, explaining, asking questions, discussing ideas, providing encouragement, and keeping attention on the task in the contexts of peer tutoring, cooperative learning, and sibling relationships (Carter and Jones, 1994; and Jones and Carter, 1994). Pairing or grouping students with different competencies can become a social context that promotes sustained achievement for less competent students (Jaramillo, 1996).

4. Context and Science Learning

Another theme of sociocultural theory is the notion that learning is affected by the cultural context in which it is developed (Kozulin *et al.,* 2003). According to Vygotsky (Jaramillo, 1996), social experience shapes our ways of thinking and interpreting the world; cognitive development and social situation, thus, cannot be separated. A number of studies have confirmed this point. Akatugba and Wallace (1999), for instance, investigated the various meanings, actions, and interpretations with which students use proportional reasoning when solving physics tasks. The results clearly indicated that there is an association between sociocultural context (consisting of cultural heritage, students' worldviews, societal expectations, authoritarianism, upbringing, customs and traditions, language, everyday life) and students' use of proportional reasoning in physics. Even in the area of learning assessment, Solano-Flores and Nelson-Barber (2001) strongly confirmed that sociocultural factors including the values, beliefs, experiences, communication patterns, teaching and learning styles, and epistemologies inherent in the students' cultural backgrounds, as well as the socioeconomic conditions prevailing in their cultural groups, influenced the ways in which students made sense of scientific items and the ways in which they solve them.

Through their experiences in the context of society, individuals develops their self-identity, desires, goals, needs, belief, values, expectations, and ways of thinking and interpreting the world (Lerman, 2001; Minick, Strone and Forman,1993). Lerman, (2001) also claimed that, in everyday situations of children's lives, individuals learn how to be, in gendered, ethnic, class, and other historical, sociocultural identities. One can conclude that these mental properties and identities are shaped and constructed by the contexts they confront in the everyday life. It is these mental properties and identities that motivate learning and interaction in the classroom (Lerman, 2001; Minick, Strone and Forman, 1993). In addition, sociocultural context provides not only individuality, but also a commonsense way of describing and explaining the world as Driver *et al.* (1994) argued that a commonsense view of childhood evolves as a result of experience and socialization. This kind of sense is constructed, communicated, and validated within the culture of the community and it differs from the scientific view in both epistemological and ontological aspects. Thus, humans as individuals within sociocultural contexts construct their own ways of interpreting and knowing the world in the light of their prior experiences, mental structures, and beliefs, rather than accepting a universally imposed scheme (Jaramillo, 1996). Learning and interactions with the others in the classroom, therefore, are shaped by self-identity, desires, goals, needs, belief, values, expectations, ways of thinking and interpreting the world, and prior knowledge about concepts and natural phenomena, and social and cultural context shapes these factors as well.

Culture is often referred to as a component of context that shapes learning and understanding making. According to Van der Aalsvoort, Van Tol and Karemaker (2004), culture within sociocultural theory is described as the created environment of people. It contains views, meanings, and ways of collaborating, rules and values as well as visible "products," for example, signs and symbols in the material world. Consistent with Phelan, Davidson and Cao (1991: 228) suggested that culture be conceptualized as the “norms, values, beliefs, expectations, and conventional actions” of a group. Geertz (1973: 5) further defined culture as “an ordered system of meanings and symbols, in terms of which social interaction takes place.” This definition is similar to that of Elmesky and Tobin (2005) who conceptualized culture as a system of symbols, associated meanings, and practices. Therefore, culture is the created environment that contains norms, values, rule, beliefs, expectations, and their products such as signs and symbols. Culture is associated with practice and meaning-making in a particular setting. In order to learn, children need to interact with this created environment (Van der Aalsvoort, Van Tol and Karemaker, 2004).

Unfortunately, the social and cultural context of the community often differs from that of the scientific community resulting in differences between the culture of the real word and the scientific world due to different of the methods for generation knowledge and different standards and processes for assessing the knowledge (Hogan and Corey, 2001). Scientific knowledge can be unfamiliar for students. The difference between everyday culture and scientific culture is clearer in non-western countries. It is clear that importing knowledge, curricula, textbooks, techniques, and tests of science and mathematics leads to the culturally alienating effect of science and mathematics education in schools of these countries often involves a break in cultural identity that can generate ambiguity in an individual’s sense of self (Gellert, Jablonka and Keitel, 2001) especially in non-western countries. Due to fundamental differences between the cultures of western science and indigenous cultures of non-western country (Aikenhead, 1997), students in these countries feel that school science is like a foreign culture to them (Maddock, 1981). Consequently, "learning science in the classroom involves children entering a new community of discourse, a new culture" (Driver *et al.,* 1994: 11). In learning science, children are “crossing cultural borders from their life-world subcultures (associated with, for example, family, peers, school, and media) to the subcultures of science and school science” (Aikenhead, 1996). That is scientific instruction that merely delivers scientific concepts, processes, and tasks which are quite often foreign to students in non-western settings will not be meaningful to the students. Students find it difficult to believe things that do not make sense to them. What they learn and do in science should be meaningful and have some relevance to their everyday lives (Akatugba and Wallace, 1999). In addition, if a scientific representation of a particular phenomenon is very different from its representation in the everyday world, students may find it difficult to learn science in the classroom (Driver *et al.,* 1994) eventually resulting in rote learning (Reif and Larkin, 1991).

From this claim, Hawkins and Pea (1987) and Wolcott (1991) claimed that when the culture of science generally harmonizes with a student's life-world culture, science instruction will tend to support the students' view of the world. Gellert, Jablonka and Keitel (2001) proposed that the basis of teaching science and mathematics in schools, thus, should be a teaching regarding problems and contexts that are familiar and meaningful in the cultural environment of the learners. To promote scientific literacy, therefore, school activities should be directed toward creating a willingness on the part of children to approach problems by scientific means as well as fostering the ability to critique scientific applications and the use to which science is put in society. This learning goal can be achieved by a) asking and informing other children or people about relevant findings; b) convincing others of the usefulness and feasibility of certain changes by means of personal examples, public hearings, or involving the local media; and c) developing hand-on activities that may give support and acceptance from outside schools to continue this kind of learning experience.

Furthermore, emphasizing the importance of sociocultural forces in shaping the situation of a child's development and learning points to the crucial role played by parents, teachers, peers and communities in defining the type of interaction occurring between children and their environment (Kozulin *et al.,* 2003: 2). Jaramillo (1996) also explained that in the sociocultural approach the term "social" is instrumental in understanding and learning. It consists of the rules and norms of society that adults and more competent peers teach learners, the way students learn to-be-learned knowledge, and the social and cultural context that is created. In the school setting, for example, students learn what society deems as appropriate behaviors via un-educative and educative experiences. That means the created learning environment is another context that strongly influences understanding. Classrooms and activities must be organized in a way that encourages students to participate. For example, a teacher may assign students to sit in groups to enhance cooperative learning.

5. Sociocultural View of Assessment

In the sociocultural perspective on teaching and learning, classroom assessment is also seen as a social process and social product (Gipps, 2000). Methods of assessment are simply practices that develop patterns of participation, which subsequently contribute to students' identities as learners and knower. Students should have an active role in assessment as people who can "negotiate, shape and reflect on their participation and non-participation" (Boaler, 2000). This view of assessment somehow agrees with the remark of Greeno (1997) who mentioned that students should take initiative and responsibility for their learning and assessment and function actively in the negotiation of the curriculum and the formulation of the goals and criteria for success (Greeno, 1997).

Smith, Teemant and Pinnegar (2004) developed a collection of assessment practices based on the sociocultural perspective. These sociocultural assessment practices consist of the following:

a) Focus on quality: Assess the quality of students' performances on complex authentic tasks. Anticipate the types and quality of understanding and performances desired at the end of the learning experiences. Teachers must act as experts to determine the quality of students' performance on authentic tasks. Teachers must also help learners to set learning goals and to analyze the differences between their current thinking and work and exemplars of high quality thinking and work.

b) Attend to language, culture, and content: Assess language and literacy use in comprehension and expression of cultural understandings and socially shared meaning. Make accommodations when language development or culture interferes with displays of content understanding and competence.

c) Sample many situations with appropriate methods: Use appropriate methods to gather samples of evidence from assisted, unassisted, individual, and group performance in familiar and unfamiliar contexts on several occasions for each important content topic and authentic performance. The selection of assessment methods, tasks, and formats should be matched with the type of information about learning that is needed. Teachers should ask learners to compare their current understandings and performances to their learning goals for each of these situations, contexts, content topics and authentic tasks.

d) Provide encouraging feedback: Making revisions and improvements is part of the learning process. Attend to the needs of each student by providing helpful feedback and encouragement for improving quality and monitoring progress toward high expectations. Provide feedback that is specific enough to assist revisions and improve the quality of each student's thinking and work. Help students learn when and how to seek the assistance they need it in various individual and group situations.

6. General Remarks

According to the basic ideas of the sociocultural perspective, learning is social in origin and occurs through internalization of social activities. Learners are active meaning-makers. They construct knowledge by cooperative interaction and negotiation of shared activities in a social context. More knowledgeable people and cultural tools both play a crucial role in assisting learning. However, learning is also an individual process as the individual must internalize knowledge and experiences through a social process into his/her conceptual understanding. Cultural tools enable learners to see, talk, think, and act about the phenomena being learned. More knowledgeable people play role of introducing learners to knowledge and relevant tools, and assisting learners to achieve their learning goals. Learning is the process of attempting to work beyond one's current level of ability. Learning occurs when learners can use and apply scientific explanations and techniques in explaining phenomena, solving problems, and creating products, and also in directing scientific inquiry, explorations, and activity. Instruction has to be organized in such a way that learners really can become subjects of their own activity (instead of being more or less passive objects of educational arrangements and teachers' actions). In other words, learners must consciously understand the goals, course, and results of the activity and be actively engaged with the learning material, analyzing that material, solving problems in that context, drawing their own conclusions—not under pressure but through their own initiative.

The literature reviewed in this section points to teaching as an assisting activity. Teachers, adults and more knowledgeable peers should provide assistance for the learners in their ZPD. That also means that learning activities must be in learners' ZPD. That is they should be a bit challenging for the learner but not too difficult. To design an effective learning activity, teachers should provide opportunities for learners to share understanding of a procedure and a common goal of the task and then let learners cooperatively learn by engaging in the task. To decrease a tension between social identities and make science meaningful, knowledge, cognitive tools and artifacts presented to students must involve problems and contexts that are familiar and meaningful in the cultural environment of the learners. The main role of the teacher is to provide structure, resources and activities, to guide learners, to actively participate in activities with learners, and to assess learners' understanding. Teaching strategies used in the classroom should include modeling, explaining, asking questions, discussing ideas, and providing encouragement and feedback.

In order to assess learning, students should take initiative and responsibility for their learning, and assessment by functioning actively in the negotiation of the curriculum and the formulation of the goals and criteria for success. Students must have chances to use appropriate methods to gather samples of evidence from assisted, unassisted, individual, and group performance in familiar and unfamiliar contexts on several occasions for each important content topic and authentic performance. Teachers should ask learners to compare their current understandings and performances to their learning goals for each of these situations: contexts, content topics and authentic tasks.

Theoretical Framework of the Study

To design genetics curriculum, learning contents should be included the structure and function of genetic material, the process of heredity transmission, genetic variation and mutation, breed selection and improvement, biological technologies and their application and impacts of them on society, human and environment. Organization of learning activities shall be based on the principle that all learners are most importance and are capable of learning and self-development. Learning shall aim for development of learner in all aspects at their maximum potentials. Learning activities therefore shall be in accordance with learners' interests, differences, and the context of the community. Besides understanding of genetic content, learners should be developed process and skill of critical thinking, questioning, and researching and scientific mind. Moreover, the nature of science and technology must be integrated into all lessons. Teachers should act as facilitator, organize and prepare learning resources for students. During the process of learning, teachers should use various assessment methods to assess students' learning. Assessment should be regarded as part of learning process.

The sociocultural perspective emphasizes research on co-participation, cooperative learning, and joint discovery; teachers bring existing knowledge to students by co-constructing it with them. From the sociocultural perspective, interaction with more knowledgeable members enables children to learn properly. Cooperative learning has been suggested by IPST as an effective approach for learning science (IPST, 2003). Sociocultural perspective is match with Thai science education.

To deal with problems related to learning genetics, it is useful to look at the natural basis of its difficulty. Genetics is perceived as a difficult topic for a number of reasons described in former studies. The difficulty of genetics involves an emphasis on problem solving; requires complex thinking; using many complex and unfamiliar words; and also involves the use of improper material such as textbooks with fragmented alignment of the topic. Moreover, if the way genetics is presented to students does not connect with their everyday lives, then it leads to learning difficulty.

Given the difficulties of genetic learning and sociocultural perspective, it is possible that the sociocultural approach may be able to remedy those difficulties. In learning, students face problems understanding genetics and solving genetics problems and this is possibly because their ability at their current developmental level is inadequate to do these tasks alone. Under the sociocultural approach, what is being learned must be interesting and also above their current level of individual performance but it should be within their ability to learn with the assistance of knowledgeable person. To learn concepts or new abilities, the students must experience them and socially negotiate their meaning in the authentic contexts for complex learning environment. In the other words, the students must learn cooperatively in joint social activities. They need well organized contexts and the support of more knowledgeable adults or peers to overcome the difficulties.

Sociocultural perspective is like to solve problem about technical complexity of genetic terms and concepts. Under this perspective scientific concepts are treated as culture. Scientific concepts are socially constructed and validated through the complex empirical and social processes of scientific institutions. Genetics concepts, then, should be learned through social process. As a social process, concepts must be learned through interaction with others and their meaning should be socially negotiated in social situations. By interacting with more knowledgeable people and resources, the students will gain access to the language of scientific community and be guided in appropriate ways to use the concepts. In addition, as it is difficult for students, as new members of a scientific culture, to make sense of and be able to use scientific concepts appropriately, adults and more competent peers should introduce the new scientific language needed to the students. Teachers and more knowledgeable peers can use the communication system of language to explain how to direct lessons that will facilitate students' understanding of new concepts.

According to Vygotsky's sociocultural perspective, teaching and learning materials (i.e. signs, symbols, writing, formulae, and graphic organizers) are cultural tools, and they shape and mediate the formation of understandings. Unfortunately, after learning alternative concepts may be found because the students may use those materials inappropriately. Then assistance from more knowledgeable members is required to guide them because it is important to keep in mind that, especially for a teacher, one cannot take it for granted that children will fully detect relations and meanings underlying all of those tools, no matter how obvious they appear to adults. The acquisition of concepts represented by tools requires guided experience; it does not appear spontaneously. By offering a variety of cultural tools, it will contribute to scientific understanding because it provides students opportunities to access the concepts from different perspectives. However, even rich educational materials may still remain ineffective if there is no human mediator to facilitate their appropriation by the learner. In this line, this perspective is clue for problem of using improper materials such as textbooks.

Also, genetics is difficult for students because it is abstract and complex. Knippels *et al.* (2005) proposed several criteria for learning and teaching strategies in order to cope with the abstract and complex nature of genetics; these criteria are compatible with the sociocultural perspective of teaching and learning. First, to adequately sequence the subject matter, genetics education should start with the phenomenal level of the organism that students are familiar with, i.e. their family, and should gradually descend to the cellular. Furthermore, students should actively explore the relationships between the levels of biological organization themselves, guided by the structure of the learning activities and/or by the teacher.

Children form genetic understandings from direct experience with phenomena in everyday life while acting under a system of cultures and beliefs: these understandings may be either correct or incorrect. A presentation of genetics that is unconnected to everyday life, then, leads to learning difficulty. In the context of Thailand, an additional cause is the difference between culture and context of Thailand, as a non-western country, and western countries where genetics was originally studied. The difference of culture and context turn to the difference of learning and understanding. To deal with this situation, students shall be considered as tourists in an unfamiliar culture and require a high degree of guidance ("bus tours") from a tour guide teacher to take them to some of the principal sites and to coach them on what science to look at and how to use unfamiliar knowledge and techniques in a familiar context. This, in part, reflects the aspect of sociocultural theory that learning is shaped by context and teachers or more knowledgeable others must introduce genetic concepts to students and provide them with assistance and opportunities for interaction.

From the given characteristics of the curriculum, the sociocultural approach is likely to be appropriate for Thai science education. That is because the sociocultural view of learning also argues that learners are active meaning-makers through interaction and cooperation; availability of multiple sources of information enhances knowledge construction; and adults, peers and communities play important roles in learning. In addition, due to the notions that modes of thinking evolve as integral systems of motives, goals, values, and beliefs that are closely tied to concrete forms of social practices, student prior knowledge is justified by familiarity and intuition according to empirical experiences in community. Furthermore, using learning media and resources that are a familiar part of learners' context and everyday life can bring about effective learning. This is seemed to be in line with Thai science education framework which encourages using local media and resources.

CHAPTER III

METHODOLOGY

Introduction

The main purpose of this study was to investigate whether or not sociocultural approach-genetics instructional unit promoted high school students' understandings of genetics in Thailand and how. The genetics instructional unit taught on the basis of sociocultural perspective was developed. After the instructional unit was developed and implemented, the effectiveness of the sociocultural approach-genetics instructional unit was explored. In fact, this study involved a three-part process: (1) designing an extended course of instruction referred to as a sociocultural approach-genetics instructional unit; (2) teaching the instructional unit and examining teacher participants' adaptation and implementation of the instructional unit; and (3) examining the participants' experiences resulting from teaching and learning in the genetics instructional unit constructed on a basis of the sociocultural perspective, involving students' accomplishments as a result from learning genetics through the instructional unit, and teacher and students participants' reflections on the unit. The researcher would like to provide a thick description of students' understanding of genetics and to assess the effectiveness of the unit using words, images, and descriptions; thus, this study was a qualitative research in nature.

This chapter presents the methodological framework of the study through discussion of the following sections: review of research methodology, research design, and then data collection, and data analysis. Dealing with ethical concern and strategies for ensuring trustworthiness of the study were discussed at the end of this chapter.

Review of Research Methodology

1. Research Paradigm: Interpretive Paradigm

Interpretive research which is the research methodology of this study is based on naturalistic paradigm. Interpretive paradigm is a way to understand real situations which happen in the real world (Merriam, 1998). It is a way to understand and interpret how people create and maintain their social world (Namjampa, 2003: 76). Under interpretive umbrella, researcher should aim to understand situation from the participants' point-of-view. Interpretive research is naturalist in nature. Interpretive research thus should carry out research in natural setting without manipulation or control of the research setting (Lincoln and Guba, 1985) because the research setting is subject to change (Patton, 2002). As participant embedded in dynamic research setting, it is not reasonable to isolate participant from their contexts such as classroom, school, and community and so on (Lincoln and Guba, 1985).

Interpretive researcher elects qualitative over quantitative methods to investigate reality because such methods can deal with the multiple realities and value patterns adaptively and sensitively (Lincoln and Guba, 1985). The way to collect data is based on descriptive write-up rather than using of numerical data. According to Merriam (1998), in a process of research, researchers are looked as a research instrument. According to Lincoln and Guba (1985), this is because "nonhuman instruments" have a limit to evaluate and reveal the meaning from complex and dynamic setting. As research instrument, researchers can get close to data resources and actively interact with them within context; the result is deeper information and better understanding on participants in context. Therefore, the interpretive researchers normally have personal involvement with participants during the studies. In addition, interpretive researchers should collect data from multiple aspects and resources in the setting under study. This provides a comprehensive and complete picture of a study.

To analyze data, interpretative researchers usually use inductive data analysis. They generate or inductively develop a theory or pattern of meaning in naturalistic setting rather than confirm or test the existing theory. They use their own background and point of view for interpretation. This kind of analysis helps the researcher develop fully understanding of setting so that transferability, qualitative external validity, to other settings more accurately. Additionally, inductive analysis produces explicit, recognizable, and accountable interaction between the researcher and participants (Lincoln and Guba, 1985). This kind of research also produces negotiated outcomes: the researcher discusses his or her interpretations with the human sources from which the data have primarily been drawn. The participants in that context can best assess specific working hypotheses critically and understand and interpret the influence of local value patterns (Lincoln and Guba, 1985). The interpretation of an interpretative study is reported in a case study mode since it can efficiently illustrate the influential local particulars such as the particular investigator-respondent interaction, the contextual factors, the local mutually shaping factors, and the local and investigator values (Lincoln and Guba, 1985). The report provides a thick description for transferability to other sites. However, transferring findings of one context to another needs to be considered carefully because realities of different contexts and interactions within each context could be very different (Lincoln and Guba, 1985).

2. Research Design: Case Study

In selecting the interpretive paradigm as the methodology, the research design under this methodology must be evolving, flexible and provide an in depth and thick description of the phenomenon. Case study was picked as a research method because this method involves gaining in-depth understandings and insights into educational practice and its meaning of situation and context and because the study "seeks to understand a larger phenomenon through close examination of a specific case and therefore focus on the particular" (Rossman and Rallis, 1998: 70). Through case study, the manifest interaction of significant characteristics of the case can be covered, but the researcher is also able to capture various patterns, and more latent elements that other research methods may overlook (Berg, 2004). Case study can also establish cause and effect in real contexts. Further, contexts are unique and dynamic; it is a case study that can deal with the complex dynamic in order to investigate the interactions of events (Cohen, Manion and Morrison, 2000). In summary, a case design provides in depth understandings of a phenomenon within a complex dynamic context; and it has flexibility for the different context and purposes of the study. Therefore, the research uses case study as an appropriate method for investigation of the events in a complex setting such as a science classroom.

Yin (1984) described four benefits of case study approach; (1) to explain complex causal links in real-life intervention; (2) to describe the real-life context in which the intervention has occurred; (3) to describe the intervention itself; and (4) to explore those situations in which the intervention being evaluated has no clear set of outcomes. These four benefits strongly relate to the nature of the present study. The purpose of the present study is about to design the instructional unit, implement it, and then investigate and describe the processes, actions and outcomes occurring during the study. The researcher, thus, sees case study as an appropriate design for the present study.

According to Berg (2004), a case study method involves systematically collecting an amount of information about a particular person, social setting, event, or group to permit the researcher to fully understand how the subject operates or functions and may also utilize a variety of data collecting methods. The best common process of a case study is best compared with a funnel. At the beginning, the study is the wide end at which the researchers investigate for possible places, subjects and sources of data. After that, the more specific process will be conducted. They identify for the specific site and participants, plan for the methods and then begin to collect data. During the study, the researchers may modify the design and procedure to best possibly fit with the nature and context of the study when they become more familiar with the study.

According to Merriam (1998), case study research involves rich, intensive, and thick description of the case, and the interpretation of the meanings of the phenomena in the case being studied with extensive knowledge and information that are gathered in the process. However, thick description does not mean a mere simplistic description of everything. The researchers shall focus on the focus of the study within periphery (Wolcott, 1994). Hitchcock and Hughes (1995) mentioned that a case study is concerned with a rich and vivid description of events relevant to the case which provides a chronological narrative of events relevant to the case. Furthermore, a case study focuses on perceptions of events perceived by individual actor or group of actors, and highlights specific events that are relevant to the case. Researchers have the responsibility to be selective in answering what is being studied, including the full and literal description but realistic range of the study. As Merriam (1998) indicates, the case study is holistic and lifelike.

According to Best and Kahn (2003), a case study may utilize a wide range of methods including; (1) observation of physical characteristics, social qualities, or behavior; (2) interviews with the subjects and other people involving to the subjects; (3) questionnaires or tests; and (4) recorded data with different kinds of forms and from different kinds of sources. Because the researcher believes that using multi-sources of data will provide a complete understanding of the case, different methods are used in the present study.

3. Research Quality: Trustworthiness

By mean of qualitative research, the quality of the study is talked in term of "trustworthiness". Trustworthiness of the study involves the concepts of credibility, transferability, dependability and confirmability (Lincoln and Guba, 1986).

3.1 Credibility

Credibility as an analog to internal validity deals with the issue of compatibility between the researcher's constructions and informants' reality (Lincoln and Guba, 1985). Credibility can be defined as the scope to which variations in an outcome can be ascribed to controlled variation and independent variation (Lincoln and Guba, 1985). Instead of focusing on a presumed "real" reality, "out there", creditability establishes the match between the constructed realities of respondents (or stakeholders) and those realities as interpreted by a researcher and attributed to various stakeholders.

To increase the credibility, Licoln and Guba (1985 cited Denzin, 1978) suggested to use “triangulation”. There are different types of triangulations.

1. Data triangulation involves time, space, and persons of data collection

2. Investigator triangulation involves the use of multiple, rather than single observers

3. Theory triangulation involves using more than one theoretical scheme in the interpretation of the phenomenon

4. Methodological triangulation involves using multi-method of data collection on the same subjects

Other techniques for increasing creditability are prolonged engagement, persistent observation, peer debriefing and member checks. Prolonged engagement at the site of the inquiry helps prevent misinformation and distortion. In addition, it establishes rapport with the stakeholders and assists the researchers immersing in and understanding the culture of that context. Persistent observation reveals the characteristics and elements in the situation that are most relevant to the problem or issue. Peer debriefing provides a chance for researchers to get reflections on their own posture and values and their role in the inquiry, facilitates testing working hypotheses outside the context. The last one, member checking provides chances for the stakeholders from where the original data were collected to correct error of facts or errors of interpretation and give additional information leading to further illuminate a given construction.

3.2 Transferability

Transferability as an analog to external validity is an issue about the degree to which a study's findings can be applied in other contexts, setting, time or with other participants. Lincoln and Guba (1985) used this term in place of external validity. Threats of transferability are selection effects, setting effects, history effects and construct effects. Selection effects refer to the fact that constructs being tested are specific to a single group. Setting effects refer to the fact that the results may be a function of the context. History effects refer to the fact that may militate against comparisons from historical experiences. Construct effects refer to the fact that the constructs studied may be irregular to the studied group. Rather by the researchers, transferability is judged by others who may wish to apply the study for their own situation. To increase transferability, the researcher should give detail in thick description, provides an extensive and careful description of the time, the place, the context, the culture in the setting.

3.3 Dependability

In place of reliability, dependability is used for qualitative study (Lincoln and Guba, 1985). In qualitative view, reliability means the consistency of what is collected as data and what is being studied (Cohen *et al.,* 2000). To establish reliability, researchers should assure that every repetition of the same instruments to the same phenomena will yield similar measurements. This is unacceptable in naturalistic inquiry whose the phenomena are central to change; growth and refinement of construction. Therefore, dependability is used in place. Dependability does not concern on methodological change and shift in construction. Instead, it views these changes as a part of increasing sophisticated constructions in an emergent design. However, such changes need to both tracked and publicity inspectable so the outside reviewer can understand what factors in the context led the researchers to the decisions and interpretations made during the process.

To ensure dependability, Merriam (1998) suggested three techniques including the investigator's position, audit trial, and triangulation. The investigator's position means that the researcher should explain the assumptions and theory behind the study, the group being studied, the basis for selecting participants and a description of them, and the social context from where data were collected. The researcher is responsible for describing the change that occur in the setting and how these change altered the way the researcher approached the study (William, 2002). Audit trial requires the researcher to give detail how data were collected, how categories were formed, and how decisions were made. Triangulation is about using different types of data sources, instruments or framework as described in credibility.

3.4 Confirmability

Confirmability is concerned with the extent to which a study's findings are the result of the inquiry with minimum biases, values and prejudice of the researcher (Cohen *et al.,* 2000). This term is similar to objectivity. The criterion for objectivity is inter-subjectivity agreement. To establish objectivity, the researcher should employ not only inter-subjective agreement but also the methodology and its set of methods that render the inquiry impermeable to human bias and distortion such as experimentation. Explicitly, objectivity reflects the positivist epistemological positions that subject/object dualism is possible. In naturalistic paradigm, confirmability is the parallel criterion to objectivity. It asserts that interaction is inevitable. Rather than focusing on the assurances of objectivity in method, confirmability embraces the assurances of integrity of the findings that are rooted from data themselves. This means that constructions, assertions and facts can be tracked to their source and the logic used to compress the interpretations into structurally coherent and corroborating wholes in a case study are available to be inspected and confirmed by outside reviewer. According to Lincoln and Guba (1985), using electronically recorded materials, written field note, unobtrusive measures, to enhance confirmability, and survey results are the ways to collect, reduce and analyze data which have concerned confirmability.

Design of Current Research

1. Overview of the Research

The study reported here was an interpretive study. A design of the study was a case study because the researcher aimed to gain an in-depth understanding of the study. There were three goals of investigation including: 1) to investigate the way the teacher participant adapted and implemented the genetics instructional unit, 2) to investigate the effectiveness of the genetics instructional unit and 3) to investigate participants' reflection toward the SA-GIU. This study involved two main processes. The first one was to develop the genetics instructional unit taught on a basis of sociocultural perspective. Later in the first semester of academic year 2007-2008, the instructional unit was implemented in a classroom by the teacher participant who was willing to participate in this study. During this part, a set of data gathering methods was employed to collect data. Summary of research method was shown in Table 3.1.

To complete this study, the researcher designed the genetics instructional unit taught on the basis of a sociocultural approach called sociocultural approach-genetics instructional or SA-GIU. The purpose of this part was to characterize and design the genetics instructional unit that was in agreement with Thai science education framework and sociocultural perspective of learning. During this process, relevant documents were reviewed including the national education act; IPST's science curriculum standard; literatures regarding sociocultural perspective; and research regarding genetics teaching.

One the SA-GIU was complete before the implementation in a classroom, the teacher participant participated in the orientation session called "pre-teaching meeting". This session aimed to introduce the teacher participant to the sociocultural approach and the sociocultural approach-genetics instructional unit. Then, the teacher participant was asked to review the lesson plans and then negotiated about the way they would like to implement the unit. This session was held during the semester break. After that the SA-GIU was implemented in a school in Suphan Buri in the first semester of academic year 2007-2008. During the period of the instructional unit implementation, the teacher participant and the researcher had meetings at least once a week in order to discuss and exchange experiences from implementation from the past week and to make a plan or preparation for the upcoming week. It was called "supporting meeting".

While the SA-GIU was being implemented, the researcher investigated: ways the teacher participant adapted and implemented the unit; effectiveness of the SA-GIU; and the participants' reflections toward SA-GIU. To investigate the way the teacher participant adapted and implemented the unit, three methods were used: discussion during pre-teaching and supporting meetings, classroom observations and teacher's journals. This would draw a picture for the readers how the teacher participant used the SA-GIU in the classroom.

To evaluate the effectiveness of the SA-GIU, the researcher explored students' genetics concepts and another skills or abilities which students have gained from learning in SA-GIU. Genetics concepts and gained abilities were named as students' accomplishments. Factors that contributed those accomplishments were also investigated. A number of data sources were used to collect data in this part. These included written concept survey regarding genetics concepts, classroom observation and semi-structured group interview were used. Genetics concept survey was analyzed for students' genetics concepts. To reveal another accomplishment, classroom observation and semi-structured group interview were used.

In aspect of participants' reflection, there are two types of participant; teacher participant and student participant. To investigate the teacher participants' reflections, journals and semi-structured interviews during pre-teaching and supporting meetings were employed. For student participants, they were asked to journal and were interviewed by means of a semi-structured group interview. In this part of the study, participants got a chance to express their opinion about the benefits or weaknesses of genetics teaching and learning on the basis of the sociocultural perspective.

Table 3.1 Data collection of the study

Research Question	Subjects	Data	Instruments	Data collection
How does the teacher participant adapt and implement a sociocultural approach-genetic instructional unit?	The teacher participant	-Documentation of the instructional unit adaptation - Documentation of the instructional unit implementation	- Discussion in pre-teaching meeting - Discussion in supporting meetings - Teacher' journals - Classroom observations	- Before unit implementation - Weekly during implementation - Once a week - Every period
What student accomplishments can be identified as a result of their learning genetics through a curriculum unit created from a sociocultural perspective?	16 student participants	Students' accomplishments	- Classroom observations - Semi-structured group interviews - Genetics concept survey	- Every period - After unit implementation - Pre and Post instruction

Table 3.1 (Continued)

Research Question	Subjects	Data	Instruments	Data collection
What are the teacher participant's reflections on the sociocultural approach-genetics instructional unit?	The teacher participant	Teacher's reflections on the sociocultural approach-genetics instructional unit	- Semi-structured interview in pre-teaching meetings - Semi-structured interview in supporting meetings - Teacher's journal	- Before unit implementation - Weekly during implementation - Once a week
What are the student participants' reflections on the sociocultural approach-genetics instructional unit?	16 student participants	Students' reflections on the sociocultural approach-genetics instructional unit	- Semi-structured group interviews - Student journals	- After unit implementation - Once a week

2. Participants of the Study

The research school in the present study was located in Suphan Buri. There were two different groups of participants involving the present study; the teacher participants and student participants. The teacher became the participant of the study through a criterion-based sampling method. The criteria used for selection of participant teachers of this study were: a) the teacher was teaching genetics at high school level; b) the teachers in this study were willing to participate in the research procedures and c) the teacher showed her belief in a sociocultural perspective of learning.

The instructional unite implemented classrooms were selected by the teacher participant. Therefore, the student participants were high school students who were in a classroom the teacher participant decided to implement the instructional. In this study, the teacher participants decided to implement the instructional unit. These students must agree to participate in the study. In this study, the teacher participant decided to implement the genetics instructional unit in a grade 12 classroom. There were sixteen students in this classroom. Thirteen students were girls and the remainders were boys.

3. Data Collection Methods

The researcher used multi-methods to gather the data. The researcher emphasized the use of documents, group meetings, interviews, observations, journals and concept survey. These methods were suggested by experts (e.g. Berg, 2004; Best and Kahn, 2003) as effective methods for a case study. In the following section, data collection and data analysis was described.

3.1 Sociocultural Approach-Genetic Instructional Unit

The intervention of this study was called Sociocultural Approach-Genetics Instructional Unit or SA-GIU. It was 13 genetic lesson plans and required 36 periods of 50-minute periods. It was part of advance biology course for grade 12. In order to design the SA-GIU, related documents including the literature reviews on the sociocultural approach, the National Education Act 1999, the IPST's Science Curriculum Standards, and research regarding genetics teaching and understanding were reviewed. The literature about sociocultural perspective was reviewed for a framework of sociocultural teaching and learning. The other documents provided a framework to design the unit in the aspects of national education framework; science expected learning outcomes, scope of genetics to-be-taught contents, genetics topics ordering and common difficulties of genetics concepts. The researcher also used other documents such as newspaper, magazines or local documents to find the persons, places, issues that can be used as genetics teaching and learning resources.

SA-GIU was designed to be a package ready for use. Lesson plans, student manual and instructional materials were prepared. Each lesson plan contained the information about the contents, learning outcomes, learning activities, assessment, instructional materials, and worksheets. Before and during unit implementation the participant science teacher had opportunities to adapt the lesson to meet student need, classroom culture and context, instructional setting and resource.

Through the unit, students were perceived as active learners. They were encouraged to actively participate in learning activities in order to construct their own meaning of particular events or situations. To contribute to learning, students must engage in social interaction with more knowledgeable people and artifacts such as textbooks, CDs and computers. A variety of learning media and resources were provided. In addition, the unit encourages the use of teaching and learning resources and interesting issues that are available in the community or familiar to students in order to contribute to effective learning. The role of the teacher (and also of other adults and more knowledgeable peers in the community) is to introduce scientific ideas and tools to students where necessary, and to provide learning circumstances, support and guidance for students to make sense of the concepts taught themselves. For assessment, teachers and learners will work together to set goals and procedures, and will use a wide range of assessment methods. The guiding principle, the process of instructional unit development, the content and activities of SA-GIU were discussed in full details in Chapter 4.

3.2 Pre-Teaching Meeting and Supporting Meeting

The participant with this research instrument was the teacher participant who used the SA-GIU. There were two kinds of meeting involving this study, pre-teaching and supporting meeting. These meetings were instrument for research question 1; adaptation and implementation of the instructional unit and research question 3.1; teacher's reflection toward SA-GIU. The meetings also gave the teacher participant chances to get involved in the development of the SA-GIU.

During the semester break before the unit implementation, the researcher set an orientation session, which was called pre-teaching meeting, for the teacher participant. This meeting was aimed; 1) to introduce the teacher to the philosophy of the sociocultural perspective, 2) to demonstrate how to implement the lessons and material in classroom and 3) to get the teacher participant involve in the development of the unit by making comment and adaptation. A week before the meeting, the participant teacher was asked to review lesson plans and curriculum materials. As overviewed in Table 3.2, the pre-teaching began with the teacher reflecting on her current practice of genetics teaching, difficulties, problems and of genetics teaching. Based on the situation of current teaching and the requirement of science education reform, the intervention was subsequently introduced to the teacher as an alternative way to teach genetics. Then sociocultural perspective of learning was reviewed and discussed. Next, each lesson and its activities were demonstrated and the teachers were asked to make comments on the lessons. At this time, the teacher participant could call for adaptation of lessons and material. At the end of the meeting, roles of the researcher, teacher's responsibilities, and students' responsibilities were discussed.

To provide continuous support for the teacher during the genetics instructional unit implementation in the academic year 2007, the teacher participant and the researcher had meetings with the participant teacher every week after finish genetics lessons of that week. This meeting was called “supporting meeting”. The main purposes of the meetings were; 1) for the teacher participant to reflect and negotiate for unit adaptation, 2) for the researcher to give the teacher feedbacks, and further describe and demonstrate the next lessons. The flow of supporting was shown in Table 3.2. First, the teacher reflected on her teaching in the last week in aspect of how SA-GIU could be benefit or difficulty for teaching and learning and what change the teacher would suggest for those lessons, activities and materials. Then the teacher participant described response of students on the lessons. Next, the teacher participant described changes that she made for the unit and the reason behind changes. Finally, lessons for the next week were prepared. The researcher and the participant teacher made plan for an upcoming week. If necessary, the researcher further described and demonstrated the lessons of the next week again.

Table 3.2 Overview of meetings during the study

Topics of Discussion	
A pre-teaching meeting (Before the implementation)	**Supporting meetings** (during the implementation)
- Teacher’s reflection on current teaching genetics - The research project overview - The Sociocultural perspective overview a) introducing basic ideas b) reading and studying an example of teaching under sociocultural perspective c) discussing about roles of a teacher and students from the example	- Teacher’s reflection on teaching in the last week a) teacher’s satisfaction on teaching b) benefit of teaching c) problem of teaching d) teacher’s suggestion for the lesson - Response of students - Teacher’s adaptation of the unit - Preparation for the next lesson a) teacher plan for a next week

Table 3.2 (Continued)

Topics of Discussion	
A pre-teaching meeting (Before the implementation)	**Supporting meetings** (During the implementation)
- Lesson plans and materials review - Demonstration of lesson plans - Teacher's reflection and adaptation on the lesson plans - Description on roles of the researcher, teacher's responsibilities, and students responsibilities	b) researcher further describe and demonstrate the lessons

All conversations during meetings were audio recorded and the researcher also made filed notes of conservations. Teachers' conversation during meetings demonstrated two interests of the study; teacher's adaptations and implementation of the instructional unit. This data was used together with teachers' journals and classroom observation.

3.3 Semi-Structured Interview in Pre-Teaching and Supporting Meeting

During pre-teaching meeting and supporting meeting, the teacher participant was interviewed. The purpose of these interviews was to investigate the reflections of the teacher participant on the SA-GIU (see Appendix B). Therefore, it was to answer research question 3.1; teacher's reflection toward SA-GIU. The topics of the interviews were the problems or limitation about SA-GIU implementation, effectiveness of the SA-GIU for teaching genetics and suggestion for adjustments. The format of the interview was semi-structured interview. After the teacher participant was asked with these initial questions, the researcher noted the interesting and unclear points and asked probing questions to fulfill the completeness to the data.

All interviews were recorded. To analyze the data, the transcripts were read coded. Codes then were categorized for findings. The findings then were compared to findings from teacher's journals.

3.4 Teacher' Journal

Once a week, the teacher participant was asked to write journal. The teacher's journal consisted two parts including adaptation of the lessons; interest of research question 1 and reflection on the lessons; interest of research question 3.2.

For the first part, the researcher believed that in school the teacher participant might adjust the instructional unit at any time depending on the context of school, the researcher therefore asked the teacher participant to write journals to record the adjustments and the reasons once a week. The topics of writing were descriptions of changes and reasons for changes. The teacher participant should describe how she changed the lessons and explained why she changed them. To analyze data, the researcher read and made codes of data. Coding was categorized to form findings. With discussion during meeting, this research instrument revealed teacher's adaptations and implementation of the instructional unit.

In the second part, the researcher asked the teacher participant to write journals to record her reflection on SA-GIU once a week. The topics of writing were about how the teacher liked lessons in SA-GIU and why, how the lessons supported or obstructed teaching genetics, how the lessons supported or obstructed students learning genetics. At the end, the teacher participant could make comments or suggestions for the lessons. To analyze data, the researcher read and made codes of data. Coding was categorized to form findings. The findings were teacher's reflections on the sociocultural approach-genetics instructional unit
The findings were compared with findings from teacher's semi-structured interviews in meetings.

3.5 Classroom Observation

During the unit implementation, the researcher observed all teaching of the teacher participant. The main purpose of the observations was to document the ways that the teacher participant practically implemented the sociocultural approach-genetics instructional unit in the classrooms and the teaching strategies the teacher participant used while teaching the unit. This could triangulate with teacher's journal and interview. Moreover, it provided data of; how students learned, and what talent and ability they developed during learning in this SA-GIU.

To observe, the researcher acted as participant observer by which the researchers "actually participate in the situation or setting they are observing" (Fraenkel and Wallen, 2000: 536). The researcher believed that sharing experiences in the context of the study would give deeper understanding of the situation. During the observation, the researcher was known as a researcher to the group, and had less extensive contact with the group (Cohen, Manion and Marrison, 2000: 310). The researcher sat at behind a classroom and made field notes regarding behaviors, events, and the contexts surrounding the events and behaviors. Thus, the researcher emphasized an observing role than a participating role. The researcher did not act as a teacher but provided the participant science teacher some helps when was asked. During whole-class discussion, the researcher observed the discussion as a member of the class and sometime shared idea when he was asked. During group work, the researcher jointed a group and observed what was happening within a group.

Because the researcher believed that it was not possible to observe all events happening in the classrooms, all lessons were also video recorded because video recordings would provide more details and some aspects that the researcher had missed by observations alone. Field notes and video tapes were used together to ensure trustworthiness of the study. In addition, voice recorders were used to record conversations of two groups of students. Purposefully, these groups were selected because there was agreement among the teacher participant and the researcher that they were active groups; they usually involved classroom activities and there were lots of conversations among group members.

To analyze data, the transcripts were coded and categorized. In the coding and categorizing process, the researcher developed a set of categories that provide a reasonable reconstruction of the data collected. The researcher refined the categories, explores the relationships and patterns across the categories for the understanding of the people and setting being studied. After the process of data gathering, the researcher asked the teacher participants to review the transcriptions and tentative interpretations to check for the accuracy and plausibility of the data. Findings from this data were teacher's adaptation and implementation of SA-GIU and students' accomplishments. Therefore, this research instrument was for research question 1 and research question 2.

3.6 Semi-Structured Group Interview

After finishing the genetics instructional unit implemented in the first semester of academic year 2007-2008, all students were interviewed by mean of group interview. The purposes of these interviews were to investigate students' accomplishment and student participants' reflections on SA-GIU. Thus data from semi-structured interview could was part of research question 2, and 3.2. Liamputtong and Ezzy (2005) suggested that it was very useful to use group interviews when the researcher wishes to explore the perspectives and experiences of the participants from various backgrounds on the particular interest in a variety of aspects. Group interview was useful at this point because it created a setting where the participants felt comfortable to discuss a specific issue (Liamputtong and Ezzy, 2005). Moreover, group interview was used for this purpose because the researcher was aware that an individual might not be able to recall all aspects or events evolving from the classroom. According to the summary of Cohen, Manion and Marrison (2000), group interview could add depth of data because it could generate a wider range of responses regarding the discussed point than in individual interviews. In fact, it could bring together people with varied opinions, or as representatives of different collectivities.

In the process of interview, there were four students in each group. These groups were the same groups of students which they were and worked together during genetics lessons. At the beginning of the interview, the researcher informed students the purposes, process and strategy of the interview and dealing with research ethical concern. The topics of interviewing were students' background, teaching and learning science before and after SA-GIU implementation, how students learned during SA-GIU implementation, students' accomplishments resulting from learning in SA-GIU, problems of learning in SA-GIU, reflection toward SA-GIU, and suggestions. In the interview, the research asked initial questions, any students might respond the question. Another student might add, support or argue what one previously responded. The researcher asked probing question regarding students' responses. To ensure that every student got involved in interview, the researcher kept calling students' names if they less participated in interview process. Each interview took about 50 minutes and was audio taped.

To analyze data, the transcripts were coded and categorized. In the coding and categorizing process, the researcher developed a set of categories that provide a reasonable reconstruction of the data collected. The researcher refined the categories, explores the relationships and patterns across the categories for the understanding of the people and setting being studied. Transcriptions and tentative interpretations were sent to the interviewee to check for the accuracy and plausibility of the data.

3.7 Genetics Concept Survey

In the present study, genetics concept test was used to investigate students' genetics concepts. This research instrument was used to answer the researcher question 2. By this instrument, the student participants were presented with a set of open-ended questions regarding genetics concepts. To respond to the questions, the student participants were required to write narrative explanations or draw pictures to support their answers. The scope of the questions concerned genetic trait, dominance, law of segregation, law of independent assortment, gene, allele, genetic material, chromosome, DNA, nucleotide, DNA replication, transcription, translation and genetic engineering. Some items were created to investigate students' understanding of a single concept and some items were designed to investigate relationships between related concepts.

The genetics concept survey composed of seventeen main items with nineteen questions totally. The genetic concept survey consists of two types of questions; two-tier multiple choice questions and open-ended questions. There were seven items of two-tier multiple choice questions and eleven items of open-ended questions. Allowed time to complete a survey was 2 hours. All sixteen student participants were asked to complete the open-ended concept survey before and after learning in the SA-GIU.

To analyze data, the researcher read students' responses and made codes from responses. After that, students' responses were categorized into one of five categories including scientific concept (SC), incomplete concept (IC), incomplete concept with alternative concept (ICA), alternative concept (AC) and no conception or on response (NC) (Table 3.3). Scientific concepts were responses that were in the same manner with scientific accepted concepts. Incomplete concepts were responses that all parts were in the same line with some part or aspect of scientific concept. Alternative concepts were responses that were similar to scientific concepts with some misunderstanding about the concepts. No conception meant no understanding about concept. No respond or responses that were not relevant to the question were categorized into this category.

Table 3.3 Categories of students' understandings of genetics

Categories	Characteristic of response
Scientific concept (SC)	Both answer and explanation are correct as in accepted scientific explanations
Incomplete concept (IC)	Answer is correct and entire explanation is correct but not cover all points of accepted scientific explanations
Incomplete concept with alternative concept (ICA)	Answer is correct and (any) - entire or part of explanation differs from scientifically accepted conception - no reason Answer is incorrect and (any) - entire explanation is accepted - explanation contains both correct and alternative information
Alternative concept (AC)	An answer is wrong and entire explanation differs from scientific concept
No conception (NC)	- No response at all - An answer is wrong with no explanation - An answer does not relevant to the question or question repeated

3.8 Students' Journal

In order to monitor the student participants' reflections and opinions toward the SA-GIU, all 16-student was asked to write journals once a week during a period of unit implementation. The students were asked to write about their opinions or feelings toward a genetics instructional unit, and benefit, problems or difficulties of learning genetics using the sociocultural perspective as a reference. The journal was in a structured format in which the topics of the reflection are provided. However, some space was left for the students to make the free comments.

To analyze data from this instrument, the researcher read and made codes emerged from data. Categories were developed from coding. The findings were students' reflections on the SA-GIU. The findings from this instrument were compared with findings from students' semi-structured group interviews to form research findings of the research question 3.2.

Data Analysis

There are many techniques used in data analysis. Different techniques are different but also interconnected, overlapped and complementary (Punch, 1998). The general process of data analysis is segmenting, coding and categorizing. The selection of data analysis technique depends on the purpose of the study and nature of data (Punch, 1998). Most data in this study was qualitative data, to analyze data in this study; two techniques were used to analyze data. These techniques were content analysis and thematic analysis. In this section, concepts of content analysis and thematic analysis were discussed.

1. Content Analysis

Content analysis is one of the most common analysis techniques of qualitative data (Ezzy, 2002; Merriam, 1998). Content analysis assumes that the researcher knows what the important categories will be prior to the analysis (Ezzy, 2002). It begins with predefined categories, then defines the units of analysis and the categories into which real data will be placed. The final stage of content analysis is the interpretation of results. It is useful way for confirming or testing a pre-existing theory. In this study, content analysis strategy was used to analysis students' concepts of genetics. By this mean, categories of conceptions were developed first, then students' responses were categorized into these predetermined categories.

2. Thematic Analysis

Thematic analysis requires the researcher to use a various types of information in systematic manner to interpret and increase understanding of information (Boyatzis, 1998). It focuses on identifiable themes and patterns of people, events, situations, and organizations. If is emphasized that thematic analysis is a kind of inductive analysis in which the categories into which themes will be sorted are not decided prior to coding the data (Ezzy, 2002: 8). According to Aronson (1994), there are four steps of thematic analysis as followed.

1. List the conversation transcripts, patterns of experiences, which can come from direct quotes or paraphrasing common ideas.

2. Relate and identify all data that relate to each intellectual scheme or idea.

3. Combine and catalogue related patterns into themes. Themes emerge from the informants' stories as they are pieced together to form a comprehensive picture of their collective experience.

4. Build a valid argument for choosing the themes. This is done by reviewing related literature and then referring back to the literature.

Ethical Concerns

Concerning ethical issue, informed consent, confidentiality, and the safety and welfare of participants were notified to the participants in an ongoing manner. Before implementation of the instructional unit, the school principal and the participant science teacher were firstly informed about the aims of the investigation; the procedure and possible disturbances in such activities which may result from the conduct of the research and they were willing to take part in this study. Also, the students were informed about this information. Before testing and interviewing, the students were informed about the aims, the procedure and implication of the interviewing. They were guaranteed that their identity would be out of reach of the public and their answers would not have any effects to their grades. In addition, if audio or VDO recording is applied, the students were informed and asked for permission. To maintain anonymity of teacher, students and schools, pseudonyms were used in the research report. At the end of the study, the researcher shared the findings to the participant teacher, and the school principal.

Strategies for Ensuring Trustworthiness

By mean of qualitative research, the quality of the study is talked in term of “trustworthiness”. Trustworthiness of the study involves the concepts of credibility, transferability, dependability and confirmability (Lincoln and Guba, 1986). Credibility as an analog to internal validity deals with the issue of compatibility between the researcher’s constructions and informants’ reality. To increase the credibility, methodological triangulation involving multi-method of data collection on the same subjects (Cohen and Manion, 1989) is used in this study (as used by Lee, 2003; Park, 2005). The researcher collects data by multiple sources of data through multiple methods. Moreover, member check and peer review is an additional technique used in this study to assure the credibility (as used by Park, 2005). The participants are asked to read the transcripts and tentative interpretations of data in order to check for accuracy and plausibility. The peer review is used to solicit feedback and suggestions from the researcher’s committee members regarding changes or data analysis.

Transferability as an analog to external validity is an issue about the degree to which a study’s findings can be applied in other contexts or with other participants. Due to this study is qualitative case study in nature which is interested in deep understandings about the phenomenon being studied, it is difficult to generalize with many situations. However, rich and as thick as much as possible of this study is used as a mean to enhance transferability. The rich and thick description makes it possible for readers to consider whether the findings can apply to their own situations.

Dependability is the possibility to which a study's findings would be repeated if the same study with the same subjects in the same setting is replicated. This is an analog of reliability in quantitative research. In terms of dependability, this study provides data-based evidence to support interpretations based on the paradigm assumptions and theories that undergird the study. Any changes during the instructional unit implementation were reported so the readers can understand what factors in the context directed the researcher interpret data in that way.

For the last term, confirmability is concerned with the extent to which a study's findings are the result of the inquiry with minimum biases of the researcher. In order to enhance confirmability, different techniques are used in this study. These techniques consist of triangulation of data sources and using journal written by the participants. The research tries to assure that the facts and findings are rooted from data themselves. Therefore assertions and facts presented in this study can be tracked to their source.

CHAPTER IV

DEVELOPMENT OF THE SOCIOCULTURAL APPROACH - GENETICS INSTRUCTIONAL UNIT

This chapter discusses the design and development of the Sociocultural Approach - Genetics Instructional Unit (SA-GIU), which aims to promote the students' understanding of genetics as well as improve both the teaching and learning of genetics. This part of the study was conducted from May to August in 2007. The chapter begins with a discussion on the main guidelines of the SA-GIU. The next part discusses the process of intervention design and development. At the end of the chapter, the structure and outline of the instructional unit are illustrated.

Principles of Sociocultural Approach - Genetics Instructional Unit

1. The Sociocultural Perspective of Learning

From the literature review, there are three significant components of the sociocultural perspective that greatly influence teaching and learning. These key components are the zone of proximal development (ZPD), the general law of cultural development, and the role of signs and tools (cultural tools). As shown in Figure 4.1, these key components imply that there are important characteristics of the SA-GIU. ZPD implies three aspects of the SA-GIU; human mediation, cooperative learning and style of evaluation. To overcome the gaps in the ZPD, students need so called human mediation; assistances and supports from a teacher or more knowledgeable peers. Therefore cooperative learning is an effective method for learning. By working cooperatively with peers, different levels of development and ability can bridge the gaps in the ZPD and it provides context which students can get guidance and supports. Finally, the ZPD implies a need to design ways to evaluate students' performance while they are engaged in activities.

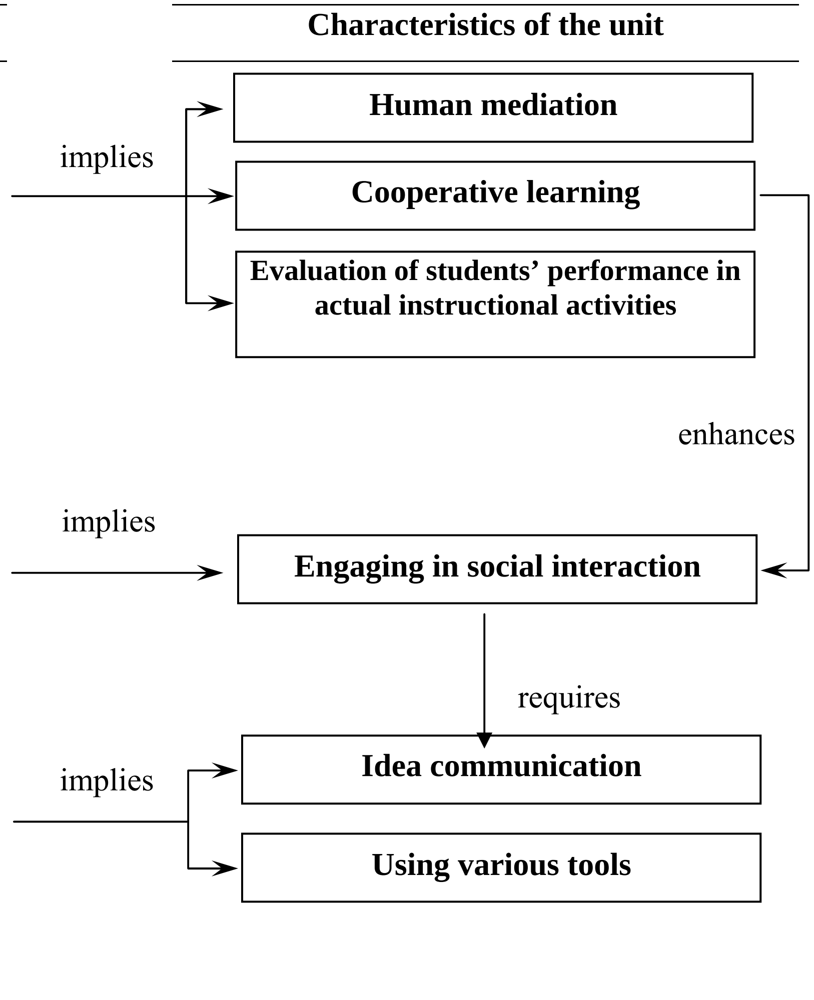
The general law of cultural development implies that interaction is crucial for learning. That is because without interaction, development at a social level would not exist. Therefore, in order to learn, students must engage in social interaction and then cooperative learning could promote the level of social interaction. This is because while working cooperatively in the classroom, it is good chances that students would interact and communicate with each other. In the opposite direction, social interaction would increase the possibility of cooperative activities.

Cultural tools imply two characteristics. First, cultural tools mediate concept formation; therefore students should have opportunities to use cultural tools to communicate their ideas. Second, cultural tools can act as media for learning, teaching and communication; therefore, using a wide range of tools could promote better understanding. Moreover, cultural tools are required for effective social interaction.

According to the fundamental ideas of the sociocultural perspective, learning is social in origin and occurs through the internalization of social activities. Learners are active meaning makers. They construct knowledge through cooperative interaction and negotiation of shared activities in a social context. More knowledgeable people and cultural tools both play a crucial role in assisting learning. Cultural tools enable learners to see, talk, think, and act about the phenomena being learned. More knowledgeable people play the role of introducing learners to knowledge and relevant tools, as well as assisting them to achieve their learning goals. To design an effective learning activity, teachers should provide opportunities for learners to share their understanding of a procedure, set a common goal for the task, and then let the learners cooperatively learn by engaging in the task. Teaching strategies used in the classroom should include modeling, explaining, asking questions, discussing ideas, and providing encouragement and feedback.

Figure 4.1 Key components of the sociocultural perspective and conceptual characteristics of the SA-GIU

Key concepts	Explanation
Zone of Proximal Development (ZPD)	The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky, 1978)
Law of general development	Every function in the child's development appears twice: first, on the social level (interpsychological), and then inside the child (intrapsychological). (Vygotsky, 1978)
Cultural tools	- Psychological tools change nothing in the phenomena and represent the means to talk, think, and explain about phenomena (Shepardson, 1999) - Technical tools provide alternative ways to see phenomena (Shepardson, 1999)



2. Recommendations for Genetics Teaching from Literature

Based on the suggestions for genetics teaching and learning from the literature in chapter 2, some suggestions were brought into the SA-GIU. First, in respect to content, the genetics topics began with the less complex concepts in familiar higher-level organisms and progressed to the more complex concepts at the molecular level in microorganisms. Therefore, the SA-GIU started with human genetic traits, genetic material, genetic dogma, and then genetic technologies. Second, cell division was taught together with genetics because the activities during meiosis are extremely related and fundamental to most genetics phenomena.

In respect to strategy, definition, location, function and the relationships between genetic terminologies such as DNA, gene, allele and chromosome were all taught explicitly. Since genetics and similar technologies have been increasing their role in society, students should be gaining the ability to hold well-reasoned positions on social and ethical issues, and make reasonable decisions on policy issues. Researching and debating about genetic engineering and GMOs was set as a learning activity in the SA-GIU. Another suggestion was that the students should develop an understanding of the nature of science as exemplified in genetics. To understand the roles, limitations, and fundamental basis of model building, these topics were discussed when the students used or built models. The tentative and perpetually changing nature of genetic knowledge was discussed at certain points such as the development of studying of heredity and genetic materials discovery.

When talking about learning materials and resources, media such as VDO and animations, models, and context-bounded examples were also emphasized in the SA-GIU. Motion pictures of cell division, the DNA structure, chromosomes, DNA replication, transcription, and translation were developed. Chromosome models, DNA models, and models showing DNA replication, transcription, translation, and genetic engineering were used in the SA-GIU. Many genetics topics relevant to Thai contexts were brought into the SA-GIU. Some of these topics included the mutation and trait improvements of the Butsarana plant, sex determination and the proportion of Suphan Buri population, and genetically modified papaya.

3. Common Alternative Concepts of Genetics

From the literature, students encountered difficulties while solving genetic algebra problems because they did not understand several basic concepts such as Mendel's laws, genes, alleles, chromosomes, and chromatids. Therefore, these concepts were taught first. When solving genetic algebra problems, Mendel's laws were used as the fundamental basis underpinning Punnett's square. It was found that the students who could not complete genetics problem solving could not correctly place alleles on a chromosome. To solve this problem, when learning about chromosomes and cell division, alleles were also placed on in order to demonstrate allele movement during the process. Also, the relationship between concepts such as chromosomes, genes, alleles, and DNA was always difficult for students. Relationships among them were explicitly taught and a cassette-tape chromosomes activity was developed to enhance understanding of this topic. In addition, sometimes students did not understand genetic concepts at the micro level because they were rather abstract; therefore, models and animations were utilized to illustrate these points.

Framework of Lessons in the Sociocultural Approach - Genetics Instructional Unit

Based on the above key components and literatures regarding sociocultural teaching and learning, a sociocultural perspective framework for learning was established (Table 4.1). Genetics lessons in the SA-GIU were designed in agreement with the framework. Each lesson was took into consideration the following items:

1. The teacher explored students' prior knowledge about the soon to be learned concepts by asking questions or mentioning everyday events. Students were encouraged to share their understanding and pose their own questions.

2. The teacher asked questions or assigned cooperative tasks. To complete the task, students were assigned to work with a partner or in a small heterogeneous group. The students designed procedures to answer the question or complete the assignment with their partner or group members. During this phase, students were required to research, share, and discuss with fellow group members. The teacher gives guidance and supports in manner to help students to finish tasks. Mean while, the teacher monitor and evaluate students' performances.

3. Within group, the students share and discuss about results from previous stage and develop a group's conclusion. The teacher aided students to communicate their thinking by prodding with questions that attempted to get students to clarify their thinking and further evaluate the value of their thoughts. Also, the teacher might assist students by means of modeling, giving reinforcement, instructing, explaining, or guiding. This stage of learning may happen at the same time with a previous stage.

4. Each group shared its findings with the class. The teacher and the other groups gave feedback. The students interpreted the results of their own findings by comparing with the others' findings. After whole-class discussions, the students were able to better compare their own solutions and strategies. With the teacher's assistance, the students negotiated the establishment of a common agreement in the classroom. To demonstrate their conclusions, students were encouraged to use drawing, acting, writing, and any other method or tool that would aid them.

5. The students demonstrated the final product of their understanding. This was the time for students to demonstrate their full grasp of the meanings (concepts) by using signs and tools. Not everyone's understanding was identical, but they shared similar and important key ideas.

Table 4.1 Conceptual framework of lessons used in the Sociocultural Approach-Genetics Instructional Unit

Process	Objectives	Activities	Teacher's role	Students' role
Initiation	- Motivate students - Elicit ideas - Explain objectives	- Asking questions or discuss real-life events - Discussion - Using instruments such as quizzes or concept maps	- Stimulate students' interest - Ask and answer questions - Connect students' prior knowledge to the content - Encourage students to participate and discuss	- Answer questions and share ideas - Joint discussion
Doing the task	- Create circumstances for student to learn - Challenge students' current ideas	- Giving students a problem or task - Giving orientation - Completing the hands-on activity or practical work in pairs or groups	- Create an appropriate problem or situation - Give guidelines and explain what students are expected to do - Monitor students' performance and give supports	- Consider and gain an understanding of the problem or task - Cooperatively work with partners or group members to complete tasks - Ask for help if needed

Table 4.1 (Continued)

Process	Objectives	Activities	Teacher's role	Students' role
Making a group agreement	- Clarify and exchange ideas with partners and group members - Communicate ideas by using signs and tools	- Researching, sharing and discussing ideas within pairs or groups to come to some conclusions - Teacher assisting	- Encourage students to research, share and discuss their ideas - Help students consider and clarify their thinking - Assist and support students learning - Monitor students' performance	- Research, share and discuss ideas with partners or group members - Use their knowledge and abilities to complete the task -
Sharing and negotiation	- Clarify and exchange ideas with classmates - Review ineffective ideas - Making 'taken-as-shared' meaning	- Sharing and discussing group findings with classmates - Giving feedback	- Encourage students to share ideas - Encourage students to use signs and tools for idea communication	- Present group findings - Give feedback to the other classmates - Reconsider findings according to feedback

Table 4.1 (Continued)

Process	Objectives	Activities	Teacher's role	Students' role
Sharing and negotiation (continued)	- Communicate ideas by using signs and tools	- Comparing, discussing and negotiating with group members and other classmates to create a common understanding Teacher assisting	- Encourage students to share ideas and give feedback to the other groups - Help students consider and clarify their thinking - Assist students by means of modeling, reinforcement, instructing, explaining, feedback, or guiding	- Reconsider findings according to feedback Make their own understanding
Making the product of understanding	- Communicate understanding by using signs and tools - Make students aware of changes in their understanding	- Making conclusions of the learning - Assigning additional exercises or homework	- Select or design exercises or homework - Direct students to conclude the lesson	- Establish a conclusion - Use newly learned concepts to complete exercises or homework - Compare their previous and current thinking

Unit Design and Development Process

The development of the Sociocultural Approach - Genetic Instructional Unit followed these steps (Figure 4.2).

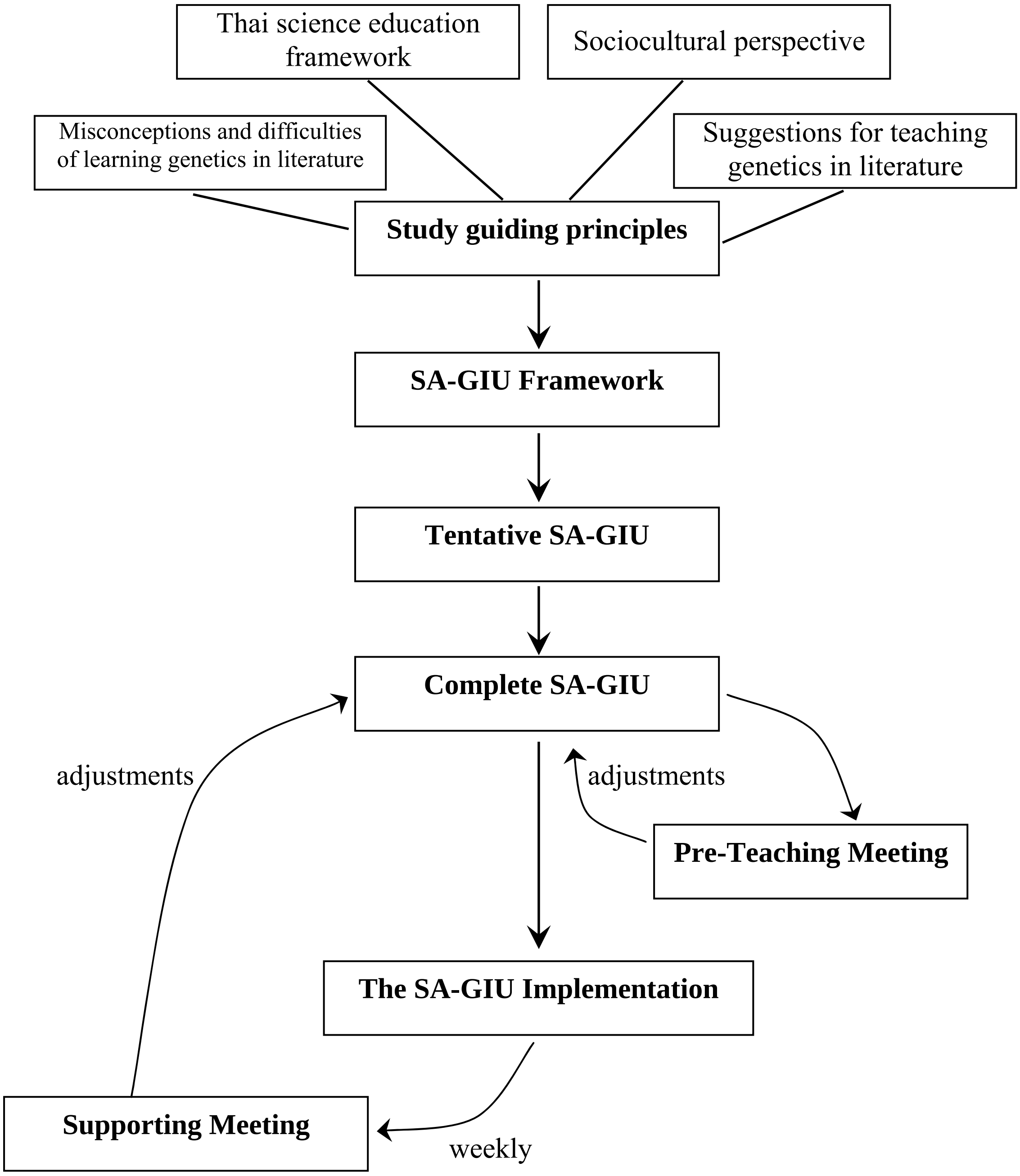


Figure 4.2 Development of the Sociocultural Approach - Genetics Instructional Unit

1. Developing the SA-GIU Framework

The aim of this step was to develop a framework of the SA-GIU that was in agreement with both the national and general science education frameworks. Firstly, the researcher studied documents regarding the principle guidelines for the SA-GIU. These documents included the National Education Act of 1999 (ONEC, 2003), the National Science Curriculum Standard (IPST, 2002), teacher's and student's basic and advanced science content handbooks (IPST, 2006), as well as literature regarding the sociocultural perspective, genetics alternative concepts, and genetics teaching and learning techniques. Then the researcher developed a conceptual framework of the SA-GIU in terms of learning and learning guidelines, the scope of genetics content, expected learning outcomes, and an assessment guideline. The outcomes of this step were basic characteristics of the SA-GIU and a conceptual framework of lessons used in sociocultural perspective-oriented genetics. The framework was proposed to committee members for them to approve and revise.

2. Developing a Tentative SA-GIU

The purpose of this step was to develop a tentative outline of each lesson. Firstly, the researcher looked at the science curriculum of the studied school to determine the time allotment for genetics and the various topics. Next, tentative lessons were developed. These lessons consisted of the expected learning outcomes, genetics contents, outline of activities, instructional materials, and assessment outline. After that the researcher proposed the tentative lessons to the committee for checking their validity and giving feedback. The committee was composed of three experts: a lecturer from the faculty of science who specialized in the content of genetics and two lecturers from the faculty of education who had expertise in curriculum planning and design, pedagogy, and assessment and evaluation. The researcher then revised the lessons based on their feedback. The unit ended up being composed of 13 lessons.

3. Developing the SA-GIU and Curriculum Material

In this step, the rigid SA-GIU was completed. Specific learning outcomes were finalized for each content area and instructional strategies for each learning objective were developed. Once the rigid SA-GIU was completed, curriculum materials including lesson plans, learning media, worksheets and a teacher's manual were developed to guide students towards successfully meeting the expected outcomes. The researcher proposed the rigid SA-GIU to committee members for checking its validity and giving feedback. The same as those who checked the tentative SA-GIU, the committee was composed of three experts: a lecturer from the faculty of science who specialized in the content of genetics and two lecturers from the faculty of education who had expertise in curriculum planning and design, pedagogy, and assessment and evaluation. The researcher adjusted the tentative unit based on their suggestions.

4. The SA-GIU Orientation: Pre-Teaching Meeting

The aim of this step was to give the teacher participant an overview of the SA-GIU, explain each lesson, and demonstrate how to use the lessons and materials. First, the researcher gave the SA-GIU to the teacher participant to read and review. A week later, the orientation meeting took place. It began with the teacher reflecting on her current method of genetics teaching, difficulties she encountered, and problems that occurred. The newly planned unit was subsequently introduced to the teacher as an alternative way to teach genetics. Then, the sociocultural perspective of learning was reviewed and discussed. Next, the researcher reviewed and demonstrated how to use the lessons and materials. After that, the teacher participant was given a chance to respond with any feedback or suggestions for the adaptation of contents, teaching strategies, materials and lesson durations. At the end of the meeting, roles of the researcher, teacher's responsibilities, and students' responsibilities were discussed. This orientation was set up during the semester break just before the SA-GIU implementation.

5. On-Site Adaptation: Supporting Meeting

While the teacher participant was implementing the SA-GIU, the researcher set up meetings with the teacher participant once a week. In the meetings, the teacher participant and the researcher discussed any problems of the implementation or teaching strategies and then adjusted as needed. Therefore, the SA-GIU was adjusted as its implementation progressed and the situation changed.

Content of the Sociocultural Approach - Genetics Instructional Unit

In this study, genetics was part of an advanced biology course for grade 12. The SA-GIU consisted of thirteen lessons. The content of the SA-GIU covered the contents described in the Basic and Advanced Science Content Handbook: Biology 5 (IPST, 2006). The sequence of genetics topics in the SA-GIU are compared with that of the IPST's handbook in Table 4.2

The lessons in the SA-GIU began with the introduction of genetics. In this lesson, students learned about genetic traits and the various traits found in humans; mostly concrete and observable concepts. At the very least, this illustrated to the students how genetics might be useful to them. In the second lesson, Mendel's work, Mendel's laws and related concepts were learned. The third lesson was when students learned about cell division and how the roles it played in genetic inheritance. In this lesson, genes were located on chromosomes to demonstrate the activity of genes during cell division. This might help students imagine where genes were and how they got separated and aggregated during gamete formation. After students had learned Mendel's laws and cell division, they learned about sex determination and all types of characteristic controls in the fourth lesson. In the fifth lesson, to help illustrate the nature of science, students studied the development of ideas about heredity. The sixth lesson covered the discovery and definition of genetic material; DNA and RNA were also the topics of this lesson. After that, the chemical components and structure of DNA was taught in lesson seven. In lesson eight, the relationship among the learned concepts—DNA, genes, alleles, and chromosomes—

was demonstrated and expanded on. Processes of DNA replication, transcription, and translation were main topics of the ninth, tenth, and eleventh lessons. In the twelfth lesson, the topic was mutation. Students studied about different types and causes of mutation. In the final lesson, genetic engineering technology, its possible applications, and concerns regarding GMOs were discussed.

As shown in Table 4.2, the ordering of topics was reordered and some extra topics were added to the SA-GIU. Based on the literature, the researcher regarded cell division as a topic very related to genetics and a basic topic for understanding genetics. Therefore, cell division was added into the unit. The researcher also believed that the nature of science must be taught explicitly, so the fifth lesson was designed in a manner to be very specific about the nature of scientific knowledge. Furthermore, lesson eight was a specific lesson that explicitly taught the relationship between DNA, genes, alleles and chromosomes. It was not found in the IPST textbook (IPST, 2006).

Table 4.2 Comparison of genetics topic organization between the Basic and Advanced versions of the Science Content Handbook: Biology 5 and the SA-GIU

Organization in the Basic and Advanced Science Content Handbook: Biology 5	**Organization in the SA-GIU**
Part 1: Genetic traits ▪ Mendel's work ▪ Probability and the law of independent assortment ▪ Law of aggregation ▪ Test cross ▪ Heredity beyond Mendel's laws - Incomplete dominance - Co-dominance	Lesson 1: Why we are unique - Genetic characteristics - Genetic variation - Discontinuous variation of traits - Continuous variation of traits Lesson 2: Heredity follows laws - Law of independent assortment - Law of aggregation - Basic genetics concepts

Table 4.2 (Continued)

Organization in the Basic and Advanced Science Content Handbook: Biology 5	**Organization in the SA-GIU**
- Multiple alleles - Polygenes - Sex-linked genes - Linkage genes - Sex influenced traits - Sex limited traits Part 2: Genes and Chromosomes ▪ Gene transfer and chromosomes ▪ Discovery of genetic material ▪ Chromosomes - Shape and number of chromosomes - Structure of chromosomes ▪ Chemical components of DNA ▪ DNA structure ▪ DNA property - DNA synthesis - How DNA controls genetic traits - DNA and protein synthesis ▪ Mutation Part 3: Genetics and DNA Technology ▪ Genetic engineering - Restriction enzyme - DNA ligase	Lesson 3: Cell division and genetic inheritances - Mitosis - Meiosis - Crossover - Linkage - Diploid - Haploid Lesson 4: He in Humans - Sex determination - Complete dominance - Incomplete dominance - Co-dominance - Multiple alleles - Multiple genes/polygenes - Sex-linked genes - Sex influenced traits - Sex limited traits Lesson 5: Genetics before Mendel's era Lesson 6: Genetic material - Discovery of genetic material - Definition of Genetic material, DNA, and RNA

Table 4.2 (Continued)

Organization in the Basic and Advanced Science Content Handbook: Biology 5	Organization in the SA-GIU
▪ Cloning - Gene cloning in plasmid - Gene cloning by PCR technique ▪ DNA analysis and genome study - DNA analysis - Genome study ▪ Applications of DNA technology - Medical applications - Forensic applications - Agricultural applications - Applications for gene location and gene function - Environmental applications ▪ Safety of DNA technology and social and ethical issues	Lesson 7: DNA: A magical spiral - Chemical components of DNA - Structure of DNA Lesson 8: Chromosomes, DNA, genes and alleles—are they related? - Chromosomes, DNA, genes, alleles and their relationships Lesson 9: DNA replication - Process of DNA replication Lesson 10: How genes control characteristics (part 1) - Process of transcription Lesson 11: How genes control characteristics (part 2) - Process of translation Lesson 12: Mutation - Types, causes, and applications of mutation Lesson 13: Genetic engineering Genetic engineering, GMOs and their effects

Learning Assessment in the Sociocultural Approach – Genetics Instructional Unit

The learning assessment used here was a mixture of ideas from the assessment guideline in the NEA 1999 (ONEC, 2003), the science curriculum standard (IPST, 2003), and the sociocultural perspective view of assessment. To assess learning, a variety of methods were used, specifically focusing on performance assessment and authentic assessment. This is in accordance with the sociocultural perspective which believed that any teacher should evaluate students' performance while they are engaged in actual instructional activities. Therefore, in the SA-GIU the teacher assessed students' learning by observing the students doing activities, discussions, and collecting the students' work. In addition, the sociocultural view of assessment points that making revisions and improvements is part of the learning process, thus feedback that was specific enough to assist revisions and improve the quality of each student's thinking and work was immediately given to the students in classroom or written on their worksheets. Students should have an active role in assessment as people who can negotiate, shape, and reflect on their works (Boaler 2000) and should take initiative and responsibility for their learning and assessment (Greeno, 1997). Therefore, it was possible in this instructional unit that students occasionally evaluated their friends and themselves or set up their own criteria for tasks.

Outline of the Sociocultural Approach - Genetics Instructional Unit

In this study, genetics was part of an advanced biology course for grade 12. The SA-GIU consisted of thirteen lessons and took thirty six periods of fifty minutes each; overall, about three months with only three periods a week on the schedule. The activities of in the SA-GIU were developed to be in accordance with the educational framework and sociocultural perspective of learning. Therefore, the emphasized activities were cooperative work, social interaction, and using various media. The common teaching strategies employed in the SA-GIU were group or pair tasks, doing hands-on activities, presentation of ideas, and discussion. The descriptions of the activities in each lesson are briefly outlined below (Table 4.3).

Table 4.3 Outline of lessons in the Sociocultural Approach - Genetic Instructional Unit

Lessons	Concepts	Activities	Assessment	Time*
1) Why we are unique	Genetic characteristics, genetic variation, discontinuous variation of traits, continuous variation of traits	- Discuss how each person is different. - Discuss what genetic traits are - Investigate the characteristics of classmates. - Present and discuss the results of the investigation. - Discuss different types of genetic traits. - Give examples of genetic traits in other living things and discuss about words used in the community that may imply genetics or genetic traits. - Make a genetic trait-tree and discuss why each one is unique. - Investigate the genetic traits of family members.	- Observe the students' performance during the discussion and while answering questions - Worksheets and notebooks - Participation in the classroom activity - Lesson conclusion	2

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
2) Heredity follows laws	Mendel's experiment, law of independent assortment, law of aggregation, basic genetics concepts (genes, alleles, loci, dominant alleles, recessive alleles, dominant traits, recessive traits, genotypes, and phenotypes)	- Use chromosome models to study, demonstrate, and discuss basic genetics concepts. - Research Mendel's experiment and Mendel's laws, then present and exchange the newly acquired information. - Study and discuss Punnett's square and use it to explain the results from Mendel's experiment - Design strategies to test genotypes (test cross).	- Observe the students' performance during the discussion and while answering questions - Worksheets and notebooks - Participation in classroom activity - Lesson conclusion	4

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
3) Cell division and heridity	Mitosis, meiosis, crossover, linkage genes, diploid cells, haploid cells	- Read and discuss cell division and genetic inheritance. - Discuss basic knowledge about cells. - Research information about cell division and match pictures with descriptions of the stages of cell division. Then, order the stages in the proper sequence and present and discuss the results. - Watch a cell division video while the students explain each stage. - Watch a video and discuss the concepts of crossing over and linkage. - Demonstrate cell division and investigate movement of chromosomes and gene by using a pipe-cleaner DNA model. Discuss the differences of mitosis and meiosis.	- Observe the students' performance during the discussion and while answering questions - Students' presentations - Worksheets and notebooks - Lesson conclusion	2

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
4) Heredity in Humans	Sex determination, complete dominance, incomplete dominance, co-dominance, multiple alleles, multiple genes/polygenes, sex-linked genes, sex-influenced traits, sex-limited traits	- Read and mark the main ideas about types of heredity; discuss and exchange the results. - Examine a picture of male and female karyotypes and discuss how they are different, then discuss the definition of autosomes and sex chromosomes. Conclude this part with sex determination in humans. - Compute, present, and discuss the probability of giving birth to a boy or girl. - Apply knowledge about sex-determination and probability to explain the demographics of the local community; discuss and share ideas. - Discuss and give examples of sex-influenced traits and sex-limited traits.	- Observe the students' performance during the discussion and while answering questions - Worksheets and notebooks - Lesson conclusion	4

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
4) Heredity in Humans (continued)		- Discuss the definitions of complete dominance, incomplete dominance, co-dominance, multiple alleles, multiple genes/polygenes, and sex-linked genes, then match them up with examples of traits; present and discuss the results.Compute, discuss, and explain sex-linked traits and chances of them being expressed in each sex; discuss and share ideas. - Discuss and practice the drawing and reading of pedigree charts. - Draw a pedigree chart of one's family. - Apply pedigree to solve problems.		1

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
5) Genetics before Mendel's Era	Nature of science	- Discuss how genetic traits are passed. - Read and research the evolution of thoughts related to heredity. - Discuss the nature of scientific knowledge, specifically in the field of genetics.	- Observation during the activity, discussion, and asking/ answering questions - Conclusion of the lesson	1
6) Genetic material	Discovery and definition of genetic material, DNA and RNA	- By means of a jigsaw technique, research and share information about the discovery of genetic material. Then, discuss, answer questions, and share those answers with the class. - Write a message or discuss ideas about genetic material on an electronic public web board.	- Observation during the activity, discussion, and posting/answerin g questions on the web	2

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
6) Genetic material (Cont.)		-	- Worksheets and notebooks - Lesson Conclusion - Self-assessment form	
7) DNA: A magical spiral	DNA components and structure	- Extract, observe and draw DNA based on local plants. - Observe and record the structure and components of DNA from a paper model, 3D animation, and picture; share and discuss conclusions from the information. - Answer questions about DNA, then share and discuss the answers. - Apply the newly acquired knowledge to play the "DNA domino game."	- Observation during the activities, discussions, experiment, questions, and answers - Record of learning - DNA model or animation clip	4

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
7) DNA: A magical spiral (Cont.)		- Study the evolution of the DNA structure and play another game. - Discuss the discovery of DNA models and the nature of science. - Design and make DNA models using local materials or design and make a DNA movie clip.	- Worksheets and notebooks - Group work assessment form - Lesson conclusion	
8) Chromosomes, DNA, genes, and alleles—are they related?	Chromosomes, DNA, genes, alleles and their relationships	- Compute the length of DNA and create a hypothesis of how DNA fits in a nucleus. - Watch an animation of chromosome formation then answer and discuss questions about the chromosome's structure and components. Afterwards, share and discuss these answers.	- Observation during the activity, discussion, and asking/answerin g questions - Worksheets and notebooks - Lesson conclusion	2

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
8) Chromosomes, DNA, genes, and alleles—are they related? (Cont.)		- Discuss and share thoughts on the number of chromosomes in different organisms and the relationship with the complexity of the organism. - Analogize chromosomes, DNA, genes, and alleles with a cassette tape. Discuss and identify the relationship between chromosomes, DNA, genes, alleles by using the analogy.	-	
9) DNA replication	Process of DNA replication	- Discuss prior knowledge on DNA replication. - Watch an animation of DNA replication, then answer and discuss a set of questions. - Use a paper model to demonstrate DNA replication.	- Observation during the activity, discussion, and asking/answerin g questions	3

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
9) DNA replication (Cont.)		-	- Demonstration of DNA replication - Worksheets and notebooks - Lesson conclusion	
10) How genes control characteristics (part 1)	Process of transcription	- Discuss prior knowledge about gene expression. - Study a diagram of "central dogma" and discuss how genes control characteristics; present and discuss related ideas. - Play a game to identify the difference between DNA and RNA. - Watch an animation and look at a diagram of transcription, then answer questions; present and discuss the answers with the class.	- Observation during the activity, discussion, and asking/answering questions - Playing games - Worksheets and notebooks	3

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
10) How genes control characteristics (part 1) (Cont.)		- Study a table of genetic codes. Discuss the structure of the genetic codes and attempt to translate the genetic codes to mRNA. - Apply knowledge of the genetic codes to play "genetic code bingo."	-Lesson conclusion	
11) How genes control characteristics (part 2)	Process of translation	- Discuss prior knowledge of translation. - Research translation and then present and discuss the required units for translation. - Perform further research and discussion on the process of translation. Match diagrams with descriptions and order the stages of translation, then present and discuss the results. - Discuss the outcome of translation.	- Observation during the activity, discussion, and asking/answering questions - Worksheets and notebooks - Lesson conclusion	3

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
12) Mutation	Types and causes of mutation	- Read a news article about a mutant plant (butsarana), then identify the causes and results of the mutation. - By means of a jigsaw puzzle, study the cause, types, and importance of mutation; present and discuss conclusions. - Research and write a report about mutation and genetic disorders.	- Observe the students' performance during the activity, discussion, and while answering questions - Concept map - Report - Worksheets and notebooks - Lesson conclusion	2

Table 4.3 (Continued)

Lessons	Concepts	Activities	Assessment	Time*
13) Genetic engineering	Genetic engineering, GMOs and their impact on humans and the environment	Day 1 - Read articles from the news involving genetic engineering. Discuss and explain the definition and characteristics of genetic engineering. Present and discuss related ideas. - Research and demonstrate the process of genetic engineering. Day 2 - Do a mini-government activity: research and debate the applications, risks, and ethical issues of genetic engineering.	- Observe the students' performance during the activity, discussion, and while answering questions - Role-play - Worksheets and notebooks - Lesson conclusion	3

Note

* = 50-minute period

Chapter Summary

This chapter discussed the process used for the design and development of the Sociocultural Approach - Genetics Instructional Unit, from the principle guidelines that framed the unit all the way through to the specific genetics content and activities of each lesson. In this study, genetics was part of an advanced biology course for twelfth graders who were studying in a science and mathematics program. The main ideas were based on both the basic and advanced versions of the *Science Content Handbook: Biology 5* (IPST, 2006). However, the topics were reordered and other content was added. In the next chapter, the SA-GIU was implemented at a school in Suphanburi, Thailand and the results of the study will be reported. At the beginning of the chapter, the context of the study will be described. After that, the results will be illustrated in terms of the instructional unit adaptation and implementation, students' accomplishments, and the participants' reflections on the effectiveness of the SA-GIU.

CHAPTER V

INSTRUCTIONAL UNIT
IMPLEMENTATION AND EVULATION

Introduction

This chapter discusses the implementation, effectiveness and reflections of participants toward the SA-GIU. At the beginning of the chapter, the research illustrated the context of this study; it included school background, teacher background, students' background, and classroom setting. Also in this section, the situation of genetics teaching was described to give a picture of how the teacher participant had taught genetics before the SA-GIU was implemented. The next section was about how the teacher participant adapted and implemented the unit during the first semester of the academic year of 2007-2008. In the students' accomplishments section, an effectiveness of the SA-GIU in terms of students' genetics concepts and the skills and abilities they gained were reported. Next, reflections from the teacher and students on the genetics instructional unit were investigated. To gather this data, a number of methods of data collection were employed, including comprising concept surveys, interviews, classroom observations, teacher journals, student journals, and work from students.

Context of the Study

1. School background

The school involved in the study was a public school located in Suphan Buri province and belonged to Office of the Basic Education Commission. The school was classified as a medium size school surrounded by rich fields and a pond. The school operated from grades 7 to 12. There were two main learning buildings in this school. The first one, a four-floor building, was general classrooms and a school office. The other one was a two-floor science building, where all science courses were taught. Each room was used as both lecture room and laboratory room. On the first floor of the science building, there was a library and computer room. The computer room was run by the local administration office of this community. There were 20 computers in this room. It was a free service open to all local people in the community. However, not many people came to visit during a school day and students could access this room any time. The school used this room to teach computer courses and students used it as a learning resource.

In the first semester of the academic year of 2007-2008, when the SA-GIU was implemented, there were 506 students in the school. Most students were from low or moderate income families, employed in agricultural based businesses. Some students came to this school because it was near their house, while others could not pass the examination for the bigger famous schools. They then returned to this school, which was near their house. The structure of students at each grade is shown in Table 5.1. On average, there were about 41 students in a classroom in grade level 3 and about 22 students in grade level 4.

Table 5.1 Structure of student number in the school

Grade level	**Grade**	**Classroom number**	**Student number**		**Total**
			male	**Female**	
	7	3	55	76	131
Level 3	8	3	60	68	128
	9	3	56	62	118
	10	2	17	32	49
Level 4	11	2	16	29	45
	12	2	12	23	35
Total		15	216	290	506

Total, there were 23 teachers in this school. There were 4 teachers responsible for science teaching and the teacher participant was the only science teacher who was responsible for teaching biology at grade level 4.

2. Teacher background

To find the teacher participant, the researcher proposed the outline of the genetics instructional unit to many biology teachers in Suphan Buri and asked if they wanted to participate in the study. Several biology teachers accepted the proposal. The researcher then went to observe their teaching about once a week for a semester before the implementation of the SA-GIU. There were two purposes for going to observe, to get familiar with the teacher and students and also to investigate how this teacher taught science. After a semester-observation, some teachers withdrew from the study. However, this teacher still volunteered to take part in the study.

Another reason the researcher selected this teacher was that she showed a belief in using a sociocultural perspective of learning. Before the pre-teaching meeting, the researcher asked the teacher participant about effective science learning. On an informal interview transcript, she stated that she believed that to learn science, students should have a chance to do hands on activities, analyze, and answer questions. Among these strategies, she believed that doing hands on activities and then having discussions was the best ways to learn science. In other words, she perceived language (cultural tool) as a key factor of learning, even though she did not mention the word language. The researcher also observed her science class and her teaching also reflected her belief in using sociocultural perspective. In the science class, she always asked questions and let students have discussions, even though students did not always give answers or responses. She explained that by doing this, she hoped students would discuss and share ideas. In conclusion, this teacher implicitly held a belief in using the sociocultural perspective and was willing to use the SA-GIU in her classroom; therefore, she was picked as the teacher participant for this study.

This teacher was a 42 year-old woman and had 17 years of experience teaching biology. Her highest degree was Master's Degree in Science Teaching (Biology). She had 17 years of experience in science teaching and 15 years of experience teaching genetics. Her work load was 19 periods a week. She was responsible for teaching science at grade level 3 and grade level 4. In addition, she was the head of the public relations department and the head of the school health unit and gave assistance to the academic department. Also, she was the homeroom teacher for the class that was studied.

She sometimes participated in professional development programs. In the past two years, she participated in professional development programs regarding project based teaching for enhancing thinking processes, integrated teaching, organizing activities to enhance thinking skills, classroom research, scientific problem solving processes, and constructing CAI. Recently, she went to a professional program on teaching genetics for the 5-Es model for secondary levels.

3. Student background

The teacher participant decided to implement the SA-GIU in a grade 12 classroom. This classroom was in the science and mathematics program. There were 16 students in this classroom consisting of three boys and thirteen girls. Their age ranged between sixteen to seventeen years. All of them had been studying in this school since they were in grade 10 and some since grade 7, thus, they had been learning with the teacher participant for at least three years. To explore their background, the researcher surveyed them by using questionnaires. The information was as follows: all of them were Buddhists and most of their parents (eleven students) were agricultural workers, while the others were government officers or laborers. They were from low to average income families, earning about 6000 baht a month on average.

In terms of academic achievement, their G.P.A's ranged between 2.5 to 3.8, mostly 3.0 to 3.5. As for biology, their achievements ranged from C to A's, but most of them got higher than B's. All of them liked to learn biology. They gave similar reasons why, such as biology was very close and useful to their lives. As for their goals, all of them wanted to go to university for different professions, such as engineering, nursing, and science.

As stated in the questionnaires, all of them liked to learn biology. The reason was that biology was very close to their lives and it was applicable to real life. However, it was found from the semi-structured group interviews that five of them preferred learning physics more than biology. The reasons were based on their previous experience in biology. They thought learning biology was boring with no activities to do, and there were lots of facts and contents they could not remember.

In terms of their genetics background, they had learned basic genetic concepts in a basic biology course, when they were grade 10 students. According to the teacher participant, in the Basic Biology Course the students learned about genetic characteristics, genetic material, DNA, genes, chromosomes, applications of genetics, and cell division. However, they had only learned the surface concepts, such as definitions and how they looked, but nothing in-depth.

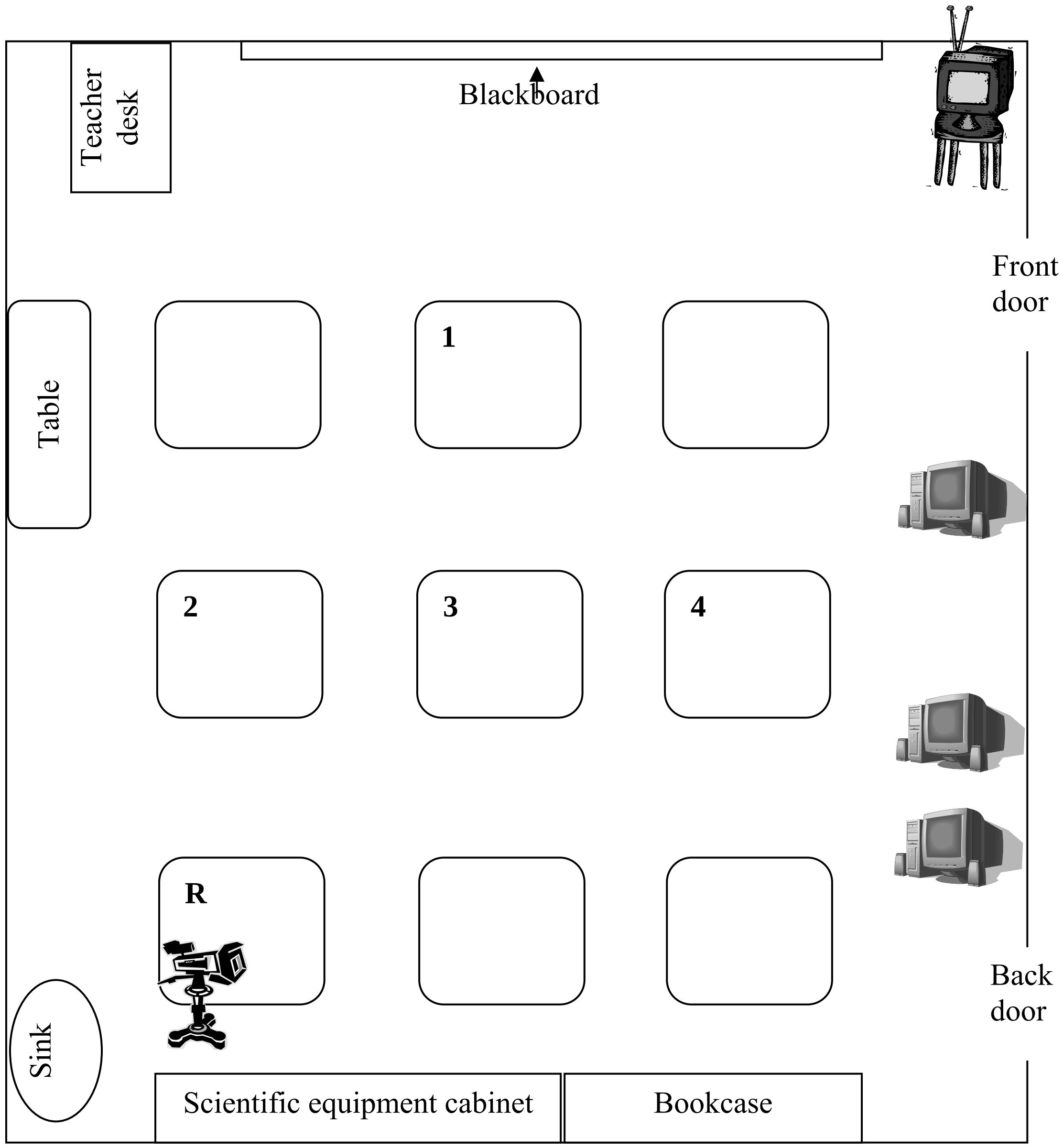
4. Classroom Setting

The classroom studied was a room with electrical fans, and it was used specifically for biology. As illustrated in the Figure 5.1, there were nine tables put in a 3x3 row format. Students were asked to sit in groups around these tables. There were about five to six chairs around each table. The maximum number of students was about 50. In this study, four groups of four students sat at tables with marked numbers. These groups were assigned by the teacher on purpose to form heterogeneous groups, which were of mixed sexes and achievement levels. Groups 1, 2, and 4 were composed of 3 girls and a boy. Only group 3 was all girls. All groups sat at the same tables and all students sat in the same positions through the study.

The facilities in this room were a blackboard, a television set with DVD player, three computers, a scientific equipment cabinet, a bookcase, and several bulletin boards hanging on the wall. Two computers could be used to access the internet, but during this study the internet service kept going out of order. In the cabinet, there was basic scientific equipment, such as a microscope, flashes, beakers, test tubes, droppers, forceps, funnels, alcohol lamps, and some basic chemical substances used in biology experiments. On the bookcase, there were several Thai language-biology textbooks, including IPST textbooks, some from other publishers, and other supplementary books. The researcher also donated Thai-language genetics textbook and an English genetics textbook, for students to use as a resource. On the bulletin boards, there were information and charts regarding genetics, such as DNA, GMOs, and cell division. While teaching, the teacher participant always used a microphone and a loudspeaker.

Normally during the study, the researcher sat at a table in the left corner at the back of the classroom (a table with an R label). A video camera was put beside the researcher's table.

Figure 5.1 Outline of the studied classroom



5. Situation of Genetics Teaching

In order to give an illustration of how the teacher participant normally taught genetics, the research interviewed the teacher participant and asked her to do a questionnaire. To triangulate the data, the researcher used a complete observer technique to observe her science teaching five times in a semester, before the unit implementation. She was teaching another biology course in the same classroom that was part of the subject of this study. Also, the researcher asked the students to explain the teacher participant's science teaching methods before starting the study.

The genetic topics normally taught in the advanced biology course before this study is shown in Table 5.2. It took thirty six periods. This course was given three periods a week and took about three months to finish. The sequence of topics followed the IPST's textbook (IPST, 2006).

Table 5.2 Sequence of genetic topics and the amount of time the teacher participant taught them

No.	**Topics**	**Time (50-minute periods)**
1	Genetic traits	3
2	Mendel's work	2
3	Probability and Mendel's laws	3
4	Test cross	1
5	Inheritance beyond Mendel's laws	6
6	Gene and chromosome	1
7	Discovery of genetic material	2
8	Chromosome	1
9	Chemical structure of DNA	2
10	Structure of DNA	3
11	Properties of DNA	5
12	Mutation	2
13	Genetic engineering and gene cloning	3
14	Application of DNA technologies; safety of DNA technologies; social and ethical concerns	2
	Total	36

To teach those topics, the teacher participant said that she began by giving examples or asking questions or revising previous learning. Then, she mainly lectured and explained concepts. She often asked questions and had students answer and discuss them. She sometimes assigned students to do experiments that were suggested in IPST's textbook. It was similar with what was found from classroom observations. This was also in accordance with the student participants, who had 3 years of experience in a science class with this teacher participant. As shown by interview transcripts in Table 5.3, their teacher always used lecture techniques, and they always sat and listened to their teacher. Beside lecture, there were a few activities for them to do. Unfortunately, some student participants agreed that such a way of learning was boring and that they always fell asleep in biology class.

The teacher participant always assigned students to do exercises at the end of each chapter as provided in the IPST's textbook as homework. Again, some student participants mentioned this in the interview (Table 5.3). Students did a lot of exercises they were assigned, but that did not help them understand science much. They always paraphrased the textbook. They did not really understand the concepts.

From the classroom observations, it was found that when the teacher participant asked questions, only a few students would answer her questions. She often gave students too short a time to answer, not giving students enough time to think. Accordingly, some student participants mentioned this situation. The researcher asked them for reasons why they did not answer questions. They said:

G1S1: She does not specifically ask me. I am at the back of the class.
G1S4: Normally, she does not ask me either.
R: Why?
G1S4: Well, it seemed like she did not ask me. Also, I did not understand. Sometimes, she asks the whole class and someone else answers.
G1S1: Or she asks the others who are interested in learning.

This interview transcript implies that the teacher participant did not ask the questions for the whole class, but only for students who were judged as smart. She did not try to encourage students to answer questions. Some students said that they did not answer because lecturing was boring and they did not pay attention to biology. Consequently, they did not catch what the teacher was teaching and did not know what to answer. Some students said that the teacher asked smart students but they were not smart so they did not have to answer.

In terms of classroom organization, the researcher observed and found that students always sat in groups of 4-5. But in the interview, the student participants said that did not make them a group. They never talked or discussed what they were learning with other group members. They were mostly assigned individual tasks. If there was an experiment, they cooperated with friends in order to do the experiment and present the results. However, they rarely talked or discussed an experiment and the results.

As for learning materials and resources, the teacher participant used the IPST's textbook as a main resource. Each student needed to have this textbook. The teacher participant also used textbooks from private publishers as references; some of these textbooks were available in the school's library. The other materials she used were transparencies, worksheets, PowerPoint presentations, pictures, diagrams and drawings. From classroom observations it appeared that, all students had the IPST's text book and personal biology notebook. The teacher always taught according to the topics in the textbook. The students turned to the page as their teacher was talking. When they were asked questions, they read what was written in the textbook. Along with the textbook, the teacher participant used transparencies, wrote technical terms with their definitions, and sometimes drew on the blackboard. Students copied what their teacher wrote or drew into their notebooks.

To assess students' learning in terms of formative assessment, she observed the students' behaviors while answering questions and examined students' work. In terms of summative assessment, she had a mid-term examination and a final examination. These examinations were paper and pencil based tests. The formats of these tests were multiple choice and short answer

Table 5.3 Transcripts of a semi-structured group interview about the teacher participant's science teaching before the SA-GIU was implemented

Group 1	Group 2	Group 3	Group 4
G1S1: Sat and listened to her. G1S2: Opened a textbook and followed along with her. G1S3: She asked questions G1S4: She wrote on the blackboard. R: Did you answer questions? G1S4: Followed what was in the textbook. G1S2: there were answers in the textbook. G1S1: During learning [science], we were not eager.	G2S4: We had to do exercises for homework G2S1: But mostly not any other activities, just lecture. G2S2: And writing on the blackboard. G2S1: We took lots of notes in our notebooks G2S3: Also, it is filled with exercises G2S2: But we did not understand R: Why? G2S2: Well, [we] copied from the textbook.	G3S3: It makes me sleepy. R: Could you give me details? G3S3: Mostly lecture. G3S2: We opened a textbook along with her. G3S3: We did experiments if there were any in the textbook. G3S2: Did it carelessly. G3S3: Did not care, just did it. …..	G4S1: Previously, we just learned what was in the book. Just… (G4S4: Reading separately) …read individually, then the teacher explained and assigned post-unit exercises. No worksheets or VDO. About workgroup, we… (G4S3: Did separately) did not do anything with group members, did it individually. G4S3: Moreover, less activities, classroom discussions, and experiments.

Table 5.3 (Continued)

Group 1	Group 2	Group 3	Group 4
G1S2: Sometimes, [we] wrote reports. G2S3: Just finished and submitted it (to the teacher). ….. G2S2: There were experiments, but just a few. G2S3: [We] followed the directions in a textbook. G2S1: Just a textbook, nothing else.	G2S1: We were able to do exercises because we used a textbook. Without it, we wouldn’t [be able to do]. ….. G2 S1: Just sat and listened, when it was time for biology class, I fell asleep because I was just sitting for two periods. G2 S3: Yes, just sitting. G2S4: Did not even think. G2S2: What I think about biology, it’s not interesting. It’s boring.	G3S1: [The teacher] lectured, we opened a textbook. G3S2: Almost no experiments. G3S1: Maybe once in a long time. G3S4: About once a semester.	

Implementation of the Sociocultural Approach-Genetics Instructional Unit

1. Over View of the SA-GIU Implementation

In this study, three 50-minute periods were allowed for genetics every week. Two periods were on Tuesday and another one was on Wednesday. The teacher participant implemented the SA-GIU from late May to Mid August, 2007. Some weeks, genetic class was cancelled, due to national holidays and extra-curricular school programs. Fortunately, in this semester, the teacher participant was also responsible for a guidance subject, so she was able to donate some of these periods for the genetics course. Total, it took fifty-one periods to finish the SA-GIU.

2. Teaching in Practice

The discussion in this section will be focused on the teacher participant's implementation of the SA-GLU in a genetics class. This section will describe her teaching practices, including teaching strategies, the use of instructional media and material, the assessment techniques she employed, and her interaction with students in the class. Her teaching practice were discussed following the process of initiation, assigning the problem or task, making a group finding, sharing the findings, making an agreement on the meaning, and making the product of understanding. This was examined by taking multiple sources of data into consideration, like classroom observations, the teacher's journal, discussions, and interviews during the meetings.

2.1 Teaching Stage of Initiation

The main objectives of this stage were to investigate students' prior and basic knowledge and to motivate students' interests. She always used the activities, media, and questions provided in the SA-GIU manual. The activities in this stage could be, asking questions, doing short pretests, watching videos, or reading documents such as news paper or knowledge sheet, followed by discussion. It was found during classroom observations that the teacher participant always used questions suggested in the SA-GIU manual as a starting question and then continued ongoing discussions by creating new questions. Sometimes, because she knew the students' backgrounds, she asked questions relating to students' backgrounds or real life. After asking questions, she waited until someone had a response. Sometimes, she requested each group to express ideas. The student participants also noticed this. They found it was different from a previous biology course.

> R: Considering your other teacher's previous role in the classroom, was it different?
>
> G3S3: Quite.
>
> G3S2: I think she was more focused on our answers before. She wanted us to answer questions.
>
> G3S3: Oh…before it would be fine if we did not answer, but now if we do not, she waits till there is an answer.

As described early in the section on the situation of genetics teaching, before participating in this study, the teacher participant often asked students questions, but she did not wait for an answer or even encourage students to think. That has changed during this study.

She often spent more time in this stage than expected. This was because if she judged that students did not understand the basic knowledge, then she spent more time reviewing those basic topics. For instance, during lesson 3: cell divisions and inheritance, the main objective was to investigate activities and movements of chromosomes and genes during the processes of cell division. Because the students already learned the processes of cell divisions, the initiation stage of this lesson was designed to review types and stages of cell divisions by mean of a quiz (matching and short answering), but students could not finish it. The teacher participant suggested they study from the textbooks and internet. Ten minutes later, most students had almost finished the quiz; she moved on by beginning a classroom discussion. She asked students to share their answers and discussed the right answers. It took about thirty minutes to finish this activity. It was clear here that the teacher participant decided not to use just simple lecturing, but also to encourage students to research and discuss the topic.

2.2 Teaching Stage of Doing the Task

The main goal of this stage was to create circumstances that challenge and enable students to think and learn. Activities suggested in this stage were completing worksheets, doing experiments, doing demonstrations by using models, researching for conclusions, playing games, and so on.

In this stage, the teacher participant also used activities and media provided in the SA-GIU manual. However, she did do something different from the intended lesson plans. When starting tasks, the teacher participant often just told students to do activities, but she did not allow time for students to review purposes and procedures of activities or asked questions if they were not sure about activities. It seemed the students were not sure of what they were doing. As a result, students did hands-on activities without understanding them.

However, it was found from classroom observations that she showed a sign of change in the last lesson. Before doing the activity “Genetic engineering: How do they do it,” she advised students not to start and to read the instructions carefully. A minute later, she described what they had and what they needed to do. She also did something similar for later activities.

When students were doing activities, the teacher participant walked around the classroom and observed activities in each group. When she observed that students had problems or had done something wrong, she gave support and guidance, mostly by asking questions first, but, if needed, she gave students a more directed support, such as pointing, demonstrating, or giving directions.

Most tasks in the SA-GIU were group tasks. In order to set groups up, the teacher participant assigned her students into the groups. She explained that she mixed students' achievements and abilities. She was able to use this strategy because she had taught these students for at least two years; it seemed she knew her students well. Apparently, she assigned three boys into different groups and in every group there was someone who had a leadership role. It can be concluded that the teacher participant intended to form heterogeneous groups, and she used her judgment to assign the students into groups.

2.3 Teaching Stage of Making a Group Agreement

The purpose of this stage was for each group to exchange ideas with partners or group members by using signs and tools and, finally, developing a group conclusion. In this stage, the teacher participant visited all groups, observed ongoing group activities, and gave students support if needed. She supported students' learning in several ways. For instance, the teacher assigned each group to read, research, and answer questions about cell divisions and heredity. She gave three questions and let students discuss within the groups. While the students were reading, she walked around the classroom and stopped at groups.

T: If you wish, when you read you may want to underline or mark important sentences, circle, draw pictures, or whatever. It will help when you look for answers or read it later.

(Students kept continuing on their work and 2 minutes later, the teacher came back)

T: Does your friend understand?

G3S3: Yes.

T: You already discussed it or just told her the answers? (She turned to tell the whole class) Group readers, you should often ask your members what they think and understand.

G3S3: Understand? Where is the first answer? (Teasing with friends)

T: No, do not just say that. You should make agreements on what your group answer is.

(The teacher participant walked to another group. Students in group 4 turned back to their friends and started sharing ideas. Two minutes later, the teacher came back.)

T: What did you get? What processes would involve heredity?

G3S3: Chromosomes.

T: But what would be the process?

G3S3: Oh, cell division.

T: How are chromosomes involved in heredity?

G3S2: They transfer genes from parent to a child.

T: What is on a chromosome, then?

G3S2 and G3S3: Genes, there are genes.

As showed in this situation, the teacher participant supported students learning in several ways. She advised them of reading techniques and gave motivation; she advised students to discuss and share ideas. She also asked guiding and challenging questions to accommodate students' understanding. In another situation, when the students had questions, she would not give answers directly but gave guidance first and moved to explanation if that did not work.

She acted similarly at each group until she was sure that most of them understood. Therefore, she spent most of her time on each lesson in this stage. However, it was found that she appreciated spending that amount of time on this stage, as she wrote, "using the sociocultural approach is good because students develop an understanding; not just learning by rote memorization, but a teacher must motivate and guide each group, which took time," (week 3). In addition, during supporting meeting, when the researcher asked her how she valued spending that amount of time in the classroom, she said, "I think it is necessary because it helps student learn better."

From classroom observations, it is apparent that the teacher participant never gave answers or concluded any task unless students researched or discussed it first. For instance, in lesson four, she assigned students to read the story "Ken needs a concubine" and answer questions about sex determination. Apparently, a few students finished the assignment. She could have wrapped it up, but she let students share ideas and discuss it in groups first, then, moved on to the next step, a whole class discussion on the topic. Also, it was found from classroom observations that the teacher participant often encouraged students to use various sources of information as references, by reminding students to search for information from sources such as the internet or textbooks in the bookcase or library.

2.4 Teaching Stage of Sharing and Negotiation

The purpose of this stage is to let students share group conclusions and discuss and negotiate them for classroom conclusions. After this stage, students should hold similar understandings of a particular topic of study.

During this stage, the teacher participant either requested a volunteer or randomly picked some groups to share their thoughts. Sometimes, she had groups share responsibilities. Then, all group had a chance to take part in the classroom activities. She let students share their ideas first, then, gave chances for other groups to discuss and reflect. Then, it became an open discussion. The teacher participant listened to students' talks and challenged students' thoughts by asking questions, if alternative concepts were found or there was something missing in students' answers. She also acted as facilitator of idea sharing and negotiation. For instance, she helped to clarify students' questions by rearranging questions or asking more related questions to get a complete answer.

When presenting and sharing ideas, the teacher participant often encouraged students to draw pictures or use diagrams and models to get a better understanding. For instance, while learning about interrelationships of chromosomes, DNA, genes, and alleles, the representatives of group 2 was explaining about the relative size of those concepts. They thought that genes were smaller than DNA, but some classmates argued the opposite. The teacher participant asked the representatives to explain their reasons, but they could not. The teacher participant then advised them to draw a diagram of DNA and genes on a black board. They drew a long curved line representing DNA with short bold part representing a gene. Finally, everyone agreed that genes were smaller than DNA.

In this stage, it was found many times that students had different ideas or they were not sure about their thoughts. Instead of telling students the answer, the teacher participant advised students to search for information from the internet or books. For instance, during lesson four: genetic material, all students agreed that the s-strain of Streptococcus causes pneumonia, but they were not sure why. The teacher participant asked a student from group 4 to search for information from the internet. Finally, they understood that a capsule coat protects it from white blood cells.

2.5 Teaching Stage of Making the Product of Understanding

The objective of this step was for students to apply their learned knowledge to create an outcome from their understanding and for the teacher to evaluate students' understanding. Suggested techniques in this step of the SA-GIU emphasized using language. These techniques examined by using verbal answers, written paragraphs or reports, concept maps, models, animation, and so on.

Normally in this stage, the teacher participant helped students to conclude each concept or topic by answering questions, such as what can we conclude or what is the conclusion? For instance, after finishing idea sharing and discussions about genetic engineering, the teacher participant finished this stage with the following:

T: So, if we ask about genetic engineering, can we conclude what is genetic engineering?

S: Manipulating genetics material. (many students at the same time)

T: How? In what way can we use genetic engineering?

S: Bringing genes from a living thing and mix it with genes from another living thing.

T: Mix? In what way?

S: …cut and…
T: Yes, cut.
S: and inserting it into the DNA of the other organism.
T: So what do we call that?
S: Genetic engineering.

A good thing was that the teacher participant did not just ask students to conclude answers at the end of each lesson, but she always used this technique to go along with the learning process. This made it a good chance for her to monitor students' understandings. However, it was found that the participating teacher sometimes omitted this step or concluded the lesson by her.

3. Adaptation of the Sociocultural Approach-Genetics Instructional Unit

At the beginning of the study, the teacher participant used activities and always followed the steps and questions provided in the SA-GIU. She kept lesson plans in front of her. She sometimes stopped and looked at the lesson plans. But after the first two weeks, she seemed to be more relaxed. The teacher participant showed that she used her professional judgment to adjust and adapt the SA-GIU for use with her class.

Normally, during the SA-GIU implementation, the teacher participant requested a volunteer to present or share ideas, but at the beginning of the SA-GIU implementation, it was found that sometimes no one volunteered or just a few groups shared their ideas. In order to manage this problem, she used random strategies to pick a group; she made a ticket for each group and randomly picked one. It seemed successful for these students as one said during group interviews, "we had to think and be prepared, in case the teacher asked us to share ideas." Later, she used this strategy less. That was because students were willing to share ideas.

In addition, it was also found early in the week of implementation that some students tried to complete assignments from other subjects while learning genetics, therefore, they were less active in discussions and interactions with their groups. Most students also arrived to genetics class very late, about ten to twenty minutes late. She explained that students did other assignments in genetics class because they needed a good grade. The teacher participant felt that students could do better in the genetics class. After talking with the researcher, she agreed that, by nature, scoring could be a good motivation for her students. Therefore, we decided to give a weekly score for each group. The teacher participant and the researcher developed a criterion for scoring. The Amount of the scores was based on students' performance and participation in activities during that week. The researcher made small chromosome models to represent scores of each group and put them on a bulletin board in front of the classroom. Apparently, after that, all students arrived to genetics class earlier, within ten minutes of the alarm. Many times, each group raced to be the first members in the classroom. They rarely brought other assignments into the genetics classroom or they would stop it before the teacher participant started teaching. Consequently, they paid more attention and got involved in group discussions.

Several times during the SA-GIU implementation, many students in this class had to skip genetics because they went to attend extra-curricular activities. For instance, at week 4, ten students left the genetics class for an extra-curricular activity, then, the teacher participant adapted the lesson. She had six remaining students to do the activity, and she asked these students to be experts and help the others do the activity in the following week. She used this technique several times during the SA-GIU implementation.

Time management was a major problem of the SA-GIU implementation. In order to deal with time, the teacher participant skipped activity 2.2 in lesson 2: Inheritance follows laws. For activity 2.2., students in a group of three would study the results from Mendel's experiment by randomly picking color beads, representing alleles, from a bucket and observe the ratio of outcomes. She explained in her journal that she gave time for students to do activity 2.4, researching about Mendel's study. In activity 2.4, students researched from several textbooks and the internet; then, they presented and discussed Mendel's experiments and findings. Therefore, even though she skipped an activity, students still learned similar concepts from other activities provided in the SA-GIU. During a supporting meeting, she explained that she would omit some activities, if remaining activities were sufficient for students to understand a lesson. By doing this, she gave more time to main activities. In class, she gave a lot of time for students to complete tasks in groups.

For some activities, such as the activity "Ken needs a concubine" in lesson 4, she assigned students to do some activities as homework, then, had them bring them to share and discuss in the classroom. Another technique she used was omitting an activity in class but letting students do it after class and not bring it back for classroom discussion later. She used this technique in lesson 7. In this lesson, students would have applied their understandings to play a DNA domino game in the classroom, after they had already learned about the components and structures of DNA in other activities, but the teacher participant saved time by letting students play after class.

Students Accomplishments

1. Genetics Concepts

To investigate development of students' understanding of genetics concepts, a genetics concepts survey (see Appendix A) was administered to all student participants a week before and a week after the implementation of the SA-GIU. The genetic concept survey consists of 17 items and 19 questions. There are two types of questions in this survey; two-tier multiple choice questions and open-ended questions. Main concepts of investigation were genetic trait, dominant, Mendel's laws, gene, allele, genetic material, chromosome, DNA, nucleotide, DNA replication, transcription, translation and genetic engineering. To analyze data, students' responses were categorized into five categories (see Table 3.3). Frequencies of students in each category before and after the SA-GIU implementation were compared (Table 5.4).

Table 5.4 The frequencies of the student participants' genetics concepts in each category by concepts

Concepts	Categories of conceptions	Before implementation	After implementation
		Frequency N=16	Frequency N=16
Genetic trait			
Question 1	SC	5	**14**
	IC	**6**	1
	ICA	2	-
	AC	3	1
	NC	-	-
Dominant and recessive trait			
Question 4	SC	-	**12**
	IC	2	-
	ICA	1	4
	AC	**8**	-
	NC	5	-
Law of segregation			
Question 5.2	SC	-	2
	IC	1	-
	ICA	-	-
	AC		**13**
	NC	**15**	1

Table 5.4 (Continued)

Concepts	Categories of conceptions	Before implementation	After implementation
		Frequency N=16	**Frequency N=16**
Law of independent assortment			
Question 5.3	SC	-	-
	IC	-	3
	ICA	-	-
	AC	**13**	**11**
	NC	3	2
Gene			
Question 2	SC	1	**15**
	IC	-	-
	ICA	1	1
	AC	**11**	-
	NC	3	-
Question 3	SC	-	-
	IC	-	-
	ICA	-	**13**
	AC	**13**	2
	NC	3	1
Question 9	SC	-	-
	IC	-	-
	ICA	-	**14**
	AC	1	-
	NC	**15**	2

Table 5.4 (Continued)

Concepts	Categories of conceptions	Before implementation	After implementation
		Frequency N=16	Frequency N=16
Allele			
Question 5.1	SC	1	5
	IC	-	-
	ICA	-	-
	AC	7	**10**
	NC	**8**	-
Question 9	SC	-	-
	IC	-	-
	ICA	-	**14**
	AC	1	-
	NC	**15**	2
Genetic material			
Question 6	SC	-	4
	IC	-	**6**
	ICA	-	-
	AC	6	3
	NC	**10**	3
Chromosome			
Question 7	SC	-	-
	IC	-	**11**
	ICA	1	-
	AC	6	5
	NC	**9**	-

Table 5.4 (Continued)

Concepts	Categories of conceptions	Before implementation Frequency N=16	After implementation Frequency N=16
Chromosome (continued)			
Question 8	SC	-	-
	IC	5	-
	ICA	-	**15**
	AC	**7**	-
	NC	4	1
Question 9	SC	1	**14**
	IC	-	-
	ICA	-	-
	AC	-	-
	NC	**15**	2
DNA			
Question 10	SC	-	**6**
	IC	6	5
	ICA	-	-
	AC	1	-
	NC	**9**	5
Question 11	SC	-	**13**
	IC	**11**	1
	ICA	2	-
	AC	3	2
	NC	-	-

Table 5.4 (Continued)

Concepts	Categories of conceptions	Before implementation Frequency N=16	After implementation Frequency N=16
DNA (continued)			
Question 13	SC	-	**7**
	IC	2	4
	ICA	-	4
	AC	-	1
	NC	**14**	-
Nucleotide			
Question 12	SC	-	**9**
	IC	-	-
	ICA	-	3
	AC	1	5
	NC	**15**	-
DNA replication			
Question 14	SC	-	4
	IC	-	-
	ICA	1	**12**
	AC	3	-
	NC	**12**	-
Transcription			
Question 15	SC	-	-
	IC	-	**14**
	ICA	4	2
	AC	2	-
	NC	**10**	-

Table 5.4 (Continued)

Concepts	**Categories of conceptions**	**Before implementation** Frequency N=16	**After implementation** Frequency N=16
Translation			
Question 16	SC	-	**7**
	IC	-	4
	ICA	-	3
	AC	4	2
	NC	**12**	-
Genetic engineering			
Question 17	SC	-	**7**
	IC	-	4
	ICA	3	3
	AC	**8**	2
	NC	5	-

Note: SC = scientific concept, IC = Incomplete concept, ICA = Incomplete concept with alternative concept, AC = Alternative concept, NC = No conception

From Table 5.4, the before the SA-GIU implementation highest frequencies of the student participants were mostly in no understanding category or possessed some alternative concepts in their conceptions. In all questions, the student participants have developed from lower categories to higher categories. In another words, the student participants held less alternative genetic concepts after learning in the SA-GIU. Details of students' genetics conceptions in each concept were as follows.

1.1 Genetic Trait

The scientific conception of genetic trait is that traits can be transmitted from a generation to next generation; in other words from parents to offspring. The student participants were asked to choose characteristics which they think could be found in a first-born child born from a couple. Then they were asked to give explanation best describe their answers.

In pre-implementation survey, there were 5 students who held complete concept and another 5 had partial understanding. For the student who held partial conception, most of them they chose all right choices but they just explained that a child should look alike parents. They were different aspects of alternative conceptions regarding genetic traits found in this study. Firstly, some students could not identify genetic traits and non-genetic traits; one thought eye lids-pattern was not a genetic trait and another thought skills such as tennis playing and reading was genetic trait. Another form of alternative conception was genetic traits were transmitted either from father or mother (from one of them). Next form of alternative conception was that traits were controlled by amount of transmitted factor which they used a term "heredity" received from parents.

Considering post-implementation survey, most of the student participants, 14 students, held complete scientific concept. A student could correctly identify genetic trait but did not clearly explain about transmission between generations. Only a student still held alternative concept. This student could not completely identify genetic trait; hair pattern was not genetic trait.

In conclusion, this result showed that students had made big progress in understanding concept of genetic traits. It was found from classroom observation that the student participants took large amount of time for this lesson. They widely discussed about their own traits and family members. In addition they had leant this concept once in a basic biology course. Then they found it easy to understand.

1.2 Dominant Traits

The scientific conception of dominant traits is that traits which can express even there is a single copy of allele in genotype and can depress expression of another trait; recessive trait. The recessive traits are traits that can express only when two copy of alleles are existed in genotype. The student participants were asked to explain why all kittens born from black cat and white cat from litter to litter were black (Question 4).

In pre-implementation survey, most student participants held alternative concepts or had no understanding this concept. There were two students had incomplete concept; black hair is dominant trait which depress white hair characteristic. The alternative concepts students held before the SA-GIU implementation were follows.

a. Firstly, Dominant or recessive traits were not controlled by alleles but rather were determined by amount of genes, cells, or heredity which they thought controls traits. For instance, all kittens were black because they had got greater amount of cells and heredity from a black cat.

b. Some students thought that dominant was determined by sex as one wrote that genes of male cat were more dominant than genes of female cat. Another similar line of alternative conception about dominant and recessive relating sex was that only received genes from either a male or female cat.

c. A student participant who had incomplete concept with alternative concepts used a word “gene” as synonym of “allele” in manner to explain genetic backup of dominant trait. This was in accordance with Mungsing (1993) and Ratanaroutai (2006) who found alternative conception between the terms of “gene” and “allele” in Thai students.

Considering post-implementation survey, most of the student participants (12 students) had developed complete scientific concept. They could identify that black hair was a dominant trait and were able to write genotypes of trait. However, the others (4 students) still had incomplete concept with alternative conception. They were able to point out that black hair was dominant to white hair but three of them used a term “gene” as synonym of “allele” in order to explain genetic backup of trait. Another student treated this trait as sex-linked trait and it was found that she thought both X^DX^d and X^dY cats had black hairs.

1.3 Law of Segregation

The scientific conception of law of segregation is that during gamete formation each member of the allelic pair separates from the other member to form the genetic constitution of the gamete. Therefore, in normal situation there should no a gamete containing two alleles of the same gene. To explore this concept, the student participants were asked to explain why there is no a gamete containing same two alphabets (alleles) (Question 5.2).

In pre-implementation survey, most students had no understanding about law of segregation. However, there was a student had partial conception; this student drew a diagram to illustrate how alleles of two genes separated and formed different forms of gametes. Considering post-implementation survey, number of students with scientific concept became two. However, most of the student participants (13 students) had completely alternative conception. The other one did not show understanding in this concept.

1.4 Law of Independent Assortment

The scientific concept of law of independent assort is that during gamete formation the segregation of the alleles of one allelic pair is independent of the segregation of the alleles of another allelic pair. The student participants were asked to explain why there are various types of reproductive cells produced from a single mother cell (Question 5.3).

In pre-implementation survey, none of the student participants used law of independent assortment to explain this question. The most found explanation was that each types of cell produced its own reproductive cell then there were various forms of gametes. In similar thought, reproductive cells were from by fusion of cells; mixing different types of cells produced various forms of alleles in gametes. Sex and difference of reproductive system was also perceived as cause of this event.

Considering post-implementation survey, only three student participants realized that this involved Mendel's law and meiosis cell division but they could not identify it was law of independent assortment. Most student participants (11 students) still had alternative concepts. Some alternative concepts about cause of various forms of gametes involved cell division including; a) there were many steps of cell division during gamete formation, b) different gametes passed different types of cell divisions, c) there was cross over during mitosis cell division, and d) number of chromosomes was decreased during meiosis cell division. Another line of alternative concept was it was because each gamete was formed by mixing different gametes or alleles from parents then there were many forms of gametes in an individual. Another student participants explained that there were many genes then there were many forms of gametes. There was a student who thought that it was law of segregation which underpinned different forms of gametes.

1.5 Gene

The scientific concept of gene is that genes are control units of genetic traits. Genes are short part of DNA containing genetic codes and are in chromosomes. There were three questions were asked in different aspect of gene concept. For the first one, the student participants were asked to explain what controls existence of dimple and explain their thoughts (Question 2). This question was to investigate conception about function of genes. For the second question, Question 3, the student participants were asked to choose places or structures they thought the thing controls dimple could be found. For the last question, Question 9, the student participants were asked to explain the interrelationships among chromosomes, cell, genes, nucleus, alleles, and DNA. These two questions were to investigate conception about location of gene.

In respect of gene function, before implementation of the SA-GIU, there was a student held scientific conception of gene; the others had alternative concepts or did not understand this concept. The most found alternative concept was that the student participants thought heredity or genetic trait. It was possible that they used theses terms as synonym of gene. More interesting, some student participants thought that trait was controlled by amount of control unit as they used heredity or genetic trait transmitted from parents. For instance, dimple would express if there is greater amount of heredity of dimple. Another alternative concept in this context was that environment affected dimple as a student wrote that often smile could make dimple. Considering post-implementation survey in aspect of gene function, most of the student participants moved up to scientific concept category. The only students still used term genetic trait instead of gene.

In aspect of gene structure and location, in pre-implementation survey, thirteen students had alternative concepts; the others had no understanding. They did not use “gene” to represent a control unit of trait but they rather used another terms such as chromosomes or cheek cells. Therefore, all of them thought that control units of traits were found only in particular cells this implied that each cell contained different control unit of trait. Some of them thought that control units of dimple were only found in cheek cells; gene would be found in cells that involved that trait. Some of them thought that control units were only found in chromosomes because chromosomes controls trait, that implied these students held alternative concept about function of chromosome. There was a student thought that control units of traits were found only in gametes because gametes were very important cells. Considering post-implementation survey, it was found both in Question 3 and 9 that most student participants were aware that genes were on chromosomes which were in nucleus of cells but they did not realize that similar genes were found in all cells in an organism. Also most students thought that alleles were components or parts of a gene. However, most of them used term “gene” as control unit of trait. This implied they have developed more scientific conception of gene concept

1.6 Allele

The scientific concept of allele is that alleles are different forms of a gene. Normally, alleles of a gene in cell are in pair. Dominant alleles of genes are represented by capital letters and recessive alleles of similar genes are represented by minor letters.

There were three questions were used to investigate allele conception. In the Question 5.1, the student participants were asked to identify what the letters A, a, B and b appearing in gametes represented for. The last one, Question 9, the student participants were asked to explain the interrelationships among chromosomes, cell, genes, nucleus, alleles, and DNA. This question was to investigate conception about definition of allele.

By pre-implementation survey, most students showed that they had no understanding in allele. Only student could tell that capital and minor letters were symbols of alleles. In respect to structure of allele, fifteen students had no understanding. Alternative concept regarding allele found here were that a single capital or minor letters represented genes or trait and genes were part of alleles.

Considering result of post-implementation survey, most of the student participants similarly thought that a single capital or minor letters represented something else; not alleles. However, five students gained understanding in this aspect of allele. Regarding location of alleles in cell, they have changed from the beginning. They thought that alleles were component of gene or on gene. However, they did be aware that alleles were in cell, in nucleus, and on chromosomes.

1.7 Genetic Material

Scientifically, genetic material is molecular material which contains genetic information of organisms and can be transmitted from a generation to a next one. To investigate the student participants' conceptions of this concept, they were asked to read a story “in experiments, scientists found that within specie of bacteria, there were some cells of bacteria could produce insulin but some of the same specie could not. These scientists extracted a material from a cell with ability to produce insulin and then injected this extract into a cell of bacteria that could not produce insulin. They found that a bacteria cell that before could not produce insulin was be able to produce insulin. The scientists cultured this cell and found that later generation of this cell still could produce insulin.” Finally they were asked to identify what the scientists extracted from a bacteria cell and explain their reason.

The result from pre-implementation survey was found that most of them (10 students) had no understanding in this concept. For the others, they thought that the cell extract was insulin or substance functioning as activator of co-factor of insulin production. Considering result of post-implementation survey, four of the student participants held scientific concept and another six students held partial understanding in this concept. However, some alternative concepts found here were revealed. Two of them thought that a substance was mutated gene. The other thought it was a precursor of insulin. The other three student participants had no understanding.

1.8 Chromosomes

In respect to the scientific concept, a chromosome is composite of DNA and proteins found in nucleus of cells. As DNA is a component of DNA, genes are on chromosomes. A number of chromosome in a reproductive cell is half that of in a somatic cell due to a process of meiosis cell division.

Under a concept of chromosome, three different questions were asked regarding different aspects of chromosome conception. Question 7; components of chromosomes, the student participants were asked to identify components of DNA. Question 8, number of chromosome in a reproductive cell, the student participant were asked whether number of chromosome in a somatic cell and a reproductive cell is equal or not and explain why. The last question, Question 9, the student participants were asked to explain the interrelationships among chromosomes, cell, genes, nucleus, alleles, and DNA. This was to investigate students' conceptions about location and what found in chromosome.

The result from pre-implementation survey showed that the before learning in the SA-GIU, most of student participants did not understand concept of chromosome or held some alternative concept about chromosomes. The alternative concepts regarding concept of chromosome were follows.

a. Chromosomes composed of cell, gene, nucleus, allele and DNA; cell and nucleus; dominant and recessive gene; gene; and chromosome X and chromosome Y.

b. Chromosome number in reproductive cell was similar as in somatic cells because equal number of chromosome in both kinds of cells was needed to maintain a functional body.

c. Chromosome number was determined by size of cell; bigger cell had a greater amount of chromosome.

d. It depends on individual. Someone might have chromosomes in somatic cells more than in reproductive cells. Another one might have chromosomes in somatic cells less than in reproductive cells.

Considering the result of post-implementation survey, most of the student participants have developed better understanding in concept of chromosome. They were able to tell component of and interrelationship of chromosomes with cell, nucleus, DNA, gene and allele correctly. However, they still held many alternative conceptions in chromosome regarding number of chromosomes in reproductive cells and somatic cells. The alternative concepts regarding concept of chromosome were that chromosomes were composed of genes, DNA and alleles; or only genes. In another way, almost students realized that there were different number of chromosomes in somatic cells and reproductive cells but there were forty four chromosomes in each somatic cell and there were just two chromosomes in reproductive. Moreover, all students were not aware about role of protein in chromosome structure.

1.9 DNA

The scientific concept of DNA or deoxyribonucleic acid is that a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms. It is composted of nucleotides which are two strands in double helix form. The DNA of individual is unique, a half of DNA (genetic material) is from father and the rest is from mother.

In order to explore different aspect of DNA conception, three questions were asked. For the first one, Question 11, the student participants were asked to give definition and explain the importance of DNA. Question 10, the student participants were asked to explain why DNA finger print would be used to identify individual. The last one, Question 13, the student participants were asked to draw a line around an area on a picture they thought it was a DNA. These questions were to investigate definition and function of DNA, transmission of DNA, and components and structure of DNA, respectively.

The result from pre-implementation survey showed that, before learning in the SA-GIU, it seemed that the student participant had well prior knowledge about definition of DNA. By different questions, they perceived that DNA was something inherited from their parents (11 students) and each individual possessed unique DNA (6 students). However, most of them did not understand how DNA was inherited from their parents and how DNA looked like. Two students could correctly identify DNA components on diagrams but they could not explain. There were some alternative concepts were revealed.

a. DNA was a genetic material responsible for expression of traits.

b. DNA was a genetic unit.

c. DNA was a structural component of each organ in organisms.

d. There were different kinds of DNA. A child would have similar type of DNA with parents; therefore DNA could be used to identify relationship.

Considering the result of post-implementation survey, most students have developed better understanding of DNA. Most of them have leant about significance and function of DNA and transmission of DNA from parents to children. Comparing with pre-implementation survey, most students moved to higher order of concept category for DNA component and structure. However, some students could not correctly identify components or detailed structure of DNA. Most of students who held alternative concept about DAN structure used described DNA structure as nucleotide. These students were not aware that DNA was strands of poly nucleotides and subunit of DNA was nucleotide. There was only student who held complete alternative concept. This student thought that paired bases were DNA. Moreover, there are two student participants thought that DNA was nucleic acid which was a component of each part (organ) of body.

1.10 Nucleotide

The scientific conception of nucleotide is “nucleotide is a composite of nitrogenous base, phosphate group and ribose sugar”. To explore student’s conception of nucleotide, they were asked to make a circle around an area of nucleotide on a picture and explain their answers (Question 12)
The student participants were asked to

From pre-implementation survey, most student participants did not understand nucleotide. Mostly they did not give any responses. The only alternative concept emerged here was that a nucleotide was a pair of nitrogenous bases. Again, the student participants showed development of conception. Nine students had complete concept. For the rest, three of them correctly mentioned components of a nucleotide but they could not correctly indentify structure of nucleotide on a diagram. Two other students could not identify components of nucleotide. One thought nucleotide composed of base, phosphate, ribose sugar and hydrogen. The other one thought a nucleotide composed of only phosphate group.

1.11 DNA Replication

The scientific conception of DNA replication is a process to synthesize new DNA molecule. The new strands have the same structure and series of nucleotides as on the template strand. Two strands of old DNA act as template. Direction of synthesis is 5’ to 3’ end of new DNA strand or 3’ to 5’ end of DNA template strand. To explore this concept, the student participants were asked to choose diagram(s) which represent(s) DNA replication from four different diagrams and explain their answer (Question14).

In pre-implementation survey, most student participants did not understand DNA replication; they provided no responses or chose a choice without explanation. Only accepted idea was that polymerase involved replication. Alternative concepts were revealed here was that replication was a process to synthesize precursors for translation. Another alternative concept was that products of replication were different from templates; this was to produce a great variety of DNA.

Considering post-implementation survey, four of the student participants developed scientific concept of DNA replication. The others (12 students) still held some alternative conception. For these students most of them were aware some aspects of replication but they chose only diagram A then they were put in category of incomplete concept with alternative concept.

1.12 Transcription

Scientifically, transcription is a process to produce RNA strand from a single strand of DNA template. Outcome is a single strand of RNA which has U in place of T. Direction of synthesis is 3' to 5' end of DNA template and 5' to 3' end of mRNA. Similarly with the concept of DNA replication, the student participants were asked to choose diagram(s) which represent(s) transcription from four different diagrams and explain their answer (Question15).

Before the SA-GIU implementation, most students (10 students) did not understand transcription. The rest had some alternative conceptions. The alternative concepts found here were that transcription was a process to compare DNA of parents and children. The other was that transcription was a process to decode of alphabet codes; outcomes were letters.

After the SA-GIU implementation, most of the student participants (14 students) held incomplete concept of transcription. Mostly, they just missed some a few elements of transcription but all of them know that it was a process of RNA synthesis. Only alternative concept was found here; some students thought that two strands of DNA played as templates of transcription.

1.13 Translation

The scientific conception of translation is that a process to synthesis protein (polypeptide) from mRNA. It involves tRNA, ribosome, mRNA and amino acid. Direction of synthesis is 5' to 3' end of mRNA. Similarly with concept of DNA replication and transcription, the student participants were asked to choose diagram(s) which represent(s) transcription from four different diagrams and explain their answer (Question16).

In pre-implementation survey, most of the student participant did not understand translation. Some students chose a choice(s) but did not give any explanation. Only four students showed alternative concept. Three of these students thought that translation was decoding of alphabet codes and the outcomes were letters. Another student chose a diagram of transcription and explained that translation involved coiling up a loop of DNA.

Considering post-implementation survey, most of the student participants have move into categories of incomplete or scientific concept. For students who had alternative concepts they held transcription as translation; a product of translation was mRNA or a template was single strand of DNA. Another three students who had incomplete concept with alternative concept explained that direction of translation was always 5' end to 3' end but they chose a diagram of DNA replication.

1.14 Genetic Engineering

As accepted in scientific community, genetic engineering is a technique to manipulate DNA molecules in *vitro* by cutting target gene from one organism by restriction enzyme; and then inserting this gene in to DNA of another organism. The question asked for this conception is Question 17. The student participants were directly asked to explain the term "genetic engineering" according to their understandings.

In pre-implementation survey, all students had on understanding (5 students) or held alternative concept (11 students) about genetic engineering. Alternative concepts found in this concept were follows.

a. Genetic engineering was about either adding or cutting genetic material to make new breed line.

b. Genetic engineering was about modifying of cell extract.

c. Genetic engineering was production of new organism by fusion of genes and other organic materials.

d. Genetic engineering was cross breeding to produce new organism.

Considering post-implementation survey, the number of student participants who had complete concept and incomplete concepts were increased and most students also mentioned genetic engineering as genetic manipulation which created new trait. Alternative concepts found here were different from the beginning.

a. Genetic engineering was genetic manipulation by mean of gene or DNA replacement.

b. Genetic engineering was exchange of genes.

c. Genetic engineering was mutation.

Comparing with alternative concepts before the SA-GIU implementation, it was found that alternative concepts have shifted from irrelevant concepts such as cross breeding to more relevant concepts such as gene or DNA.

2. Gained Skills and Abilities

The focus of this section was the abilities and skills that the student participants perceived they were developing while learning in the genetics instructional unit based on the sociocultural perspective. Semi-structured group interviews were used as data collection methods for this section. In the interviews, the student participants were asked to identify abilities or skills they observed in themselves and others that have developed during the SA-GIU. Classroom observations were used to enhance trustworthiness of the study. The themes of the gained skills and abilities that emerged from students’ responses were as follows:

2.1 Idea Expression

G1S2: Many [things]. Knew…reasonably.

R: How?

G1S2: [I] must know a reason underpin an answer.

R: How about you [G1S1]?

G1S1: For me, it's courage to express, to speak because there were enough reasons to speak.

Interview transcript of group 1

From the above transcript, it is apparent from what these students pointed out that they learned in a meaningful way, since they said they reasonably knew. They could synthesize some reasons to support their thoughts; consequently, they had more courage to express their thoughts as words. Another explanation for their increased idea expression was the following:

G4S4: … dare to speak.

…

R: Some of you have mentioned about daring to speak, what was your motivation?

G4S4: the others, that they were able to.

Interview transcript of group 4

On this occasion, friends were another motivation for idea expression. For this student, she adopted her friend's behavior; therefore, friends could act as role models, another type of human mediation.

This was in accordance with the teacher participant. In the week 1 journal, she wrote, "...there was a problem. It was about students' question and answering; they took too much time and their answers were not to the point." But in the week 9 journal, she wrote, "I observed that students were able to explain answers better." The teacher participant noticed students' abilities to express ideas develop since the first week. Also, from classroom observations, it was found that at the beginning of the SA-GIU implementation, there were just a few students that would speak and express their thoughts without much motivation from the teacher participant. But later, more students were willing to show ideas.

2.2 Knowledge Inquiry

S4G4: Searching [for information]

…

S4G1: Searching for information. Before, learning was something in a classroom; afterwards, we never revisited it or did further researching. But in the recent genetics class, I cannot catch up to them [friends] if I did not do it.

R: What was the motivation?

S4G1: Well… I understood and I wanted to know more about what we were learning in class, so I must do more searching. Like, if I wanted to know whether mutation could be transmitted, I had to study more.

Interview transcript of group 4

From the above transcript, it is obvious that these students agreed that they gained a desire for searching for information. It was not because they did not understand what they had learned, but it was because they understood it and wanted to know more.

2.3 Self Learning

G2S2: Developed myself. Before I just read and paraphrased from a textbook; now, I do more thinking for myself.
G2S1: Seemed like…I learned by myself. That is…we learned from doing, thinking, and making conclusions ourselves.
G2S2: Thinking about what to do next.

Interview transcript of group 2

From the above transcript, these students pointed out that they gained the ability to learn by themselves. In the SA-GIU, they had chances to do hands-on activities, discuss ideas, and make conclusions; thus, learning in the SA-GIU offered them opportunities to be more active in classroom. Consequently, they learned by themselves. This differed from their former science learning, which relied more on the textbook.

2.4 Cooperative Working

G2S1: It is not just one's self.
G2S3: Seemed like we were well united.
…
R: You mentioned about more cooperation, what is your motivation?
G2S3: Wanted work to be finished.
G2S1: They are group work, I must finish them. It was a group score.
G2S2: Well, it was group score, not just mine. One could not make one's way…

Interview transcript of group 2

For this group, they described that they worked as a group and for the group. In other words, they worked cooperatively. They understood that groups could not go if someone did not understand, then, they were willing to help each other. In this case, it was clear that high achievement was their most important motivator.

2.5 Industriousness

G2S1: Industriousness. Before she assigned homework; [I] often did not do it. [If I did] just handed it in, never mind what was inside. Opened a textbook.

R: What is your motivation?

G2S2: Friends.

Interview transcript of group 2

In this situation, this student explained that she gained industriousness from learning in the SA-GIU. From her speeches, it is clear that she did not only finish assignments more often and submitted them to the teacher, but also paid more attention to her work. She said friends were her motivation. In the SA-GIU, students were always assigned group tasks; groups could not finish a task if one did not finish, so, it was possible for friends to act as mentors.

Participants' Reflections

1. Teacher's Reflections

1.1 Difficulties and Limitation of Teaching the SA-GIU

This section focuses on the teacher participants' perceptions on the teaching difficulties that emerged during the implementation of the SA-GIU. Multiple sources of data were taken into consideration, including transcripts of interviews during meetings and the teacher's journal. In both the interviews and journal, the teacher participant was asked to identify and explain what she found as difficulties of using the SA-GIU or the sociocultural approach. Field notes of classroom observations were used to enhance the trustworthiness of the study. Based on the collected data, the major difficulties the teacher participant found were about question difficulty, analyzing difficulty, and time constraints.

1.1.1 Questioning Difficulty

Since idea sharing and discussion is important for learning in the SA-GIU, it is important that a teacher listen carefully and analyze students' presentations. After that, a teacher should ask focusing questions, in order to help clarify students' ideas and bring out important concepts. The teacher participant thought that this was the most difficult adjustment: how to ask questions and what questions should be asked. In journals, she wrote, "the difficulty was about using questions that could open discussions or lead to conclusions," (week 8) and, "there was difficulty. It was about making questions for asking what students were thinking about and asking questions that could lead students to concepts they would know," (week 9). She mentioned something similar during meetings. Therefore, it is evident that she encountered difficulties with questioning.

1.1.2 Analyzing Difficulty

In order to give students support, a teacher must observe students' actions, listen to student's talks, and analyze what they know and what they need. In other words, analyzing skills are required. In this study, the teacher participant wrote, "It was quite difficult to closely observe students' answers, in order to know how much students understood the concepts," (week 2) and, "[learning by using the sociocultural approach] had good results; students were more courageous in expressing different ideas, but the teacher must collect points for students' answers. It is sometimes difficult," (week 5). From what she wrote, it is evident that she confronted the difficulty in analyzing the concepts embedded in students' answers.

1.1.3 Time Constraint

Normally, in the SA-GIU, classroom activities involved idea sharing and discussion, after some hands-on-activities. In the first week, she wrote, "In the first class, there was a problem. It was about students' questions and answers; they took too much time and their answers were not to the point." This pointed out that the teacher participant felt learning by using the sociocultural approach took time. Because the problem was that students needed time to get to the point, she had to give more time for students to learn meaningfully. She wrote, "Using the sociocultural approach is good because students develop an understanding, not just leaning by rote memorization, but a teacher must closely motivate and guide each group, which takes time," (week 3). She judged that sociocultural learning was time consuming, but accepted it because of its effectiveness.

1.2 Teacher's Attitude toward the SA-GIU

This section discusses how the teacher participant judged or valued the SA-GIU. The data was gathered by several techniques: semi-structured interviews during meetings and teacher journals. Field notes of classroom observations were used to enhance trustworthiness of the study.

> "I like this lesson because the students had discussions and found conclusions about the role of genes… The students did activities, mix and match games, and they found differences between DNA and RNA. By watching videos and using diagrams, they could explain processes, components, and products of translation… and students had fun playing the bingo game. There was a variety of interesting activities in this lesson and an appropriately used game," (week 14).

> "I liked this learning lesson because the students broadly expressed their thoughts, and it used authentic situations as topics, which enabled students to get involved and express their ideas by means of role

> playing. Each student was able to freely express ideas after discussions…. In addition, the activity "GMOs are in our house (Really?)" helped students see that GMOs are very close to them. It also enabled students to use classifying skills to categorize GMO's contained in products they use in their everyday lives," (week 17).

Based on the above examples of journals, it is apparent that the teacher participant positively valued the SA-GIU and the sociocultural approach. She felt that the SA-GIU did help the students understand genetics concepts. She claimed that the activities and media used in the SA-GIU were diversified and interesting and could help students understand the concepts better. With various interesting activities and media, she also claimed that students enjoyed and were happy to learn in the SA-GIU. The students had chances to do various activities and actively participated in classroom activities. Also, the teacher participant noticed that the sociocultural approach motivated students to help and support each other. For instance, she wrote, "This week, students used chromosome models made from velvet wire to demonstrate stages of mitosis and meiosis. Some groups were still confused, friends and other groups helped them understand," (week 16). The teacher participant described similar situations in all her journals and support meetings.

Interestingly, the researcher found that the teacher participant adapted some teaching techniques and used them in another class. For instance, late one morning, before the genetics class, the researcher was in a grade 8 science class, which the teacher participant was teaching. In groups, she assigned them to research information about types of ecosystems. She gave each group a page of blank paper and requested students to record what knowledge they found, how they found it, and where they found it. This was a technique just like what was used in the SA-GIU. She also encouraged students to help and discuss within groups and prepare to share their findings. She acted as she had in a sociocultural approach based genetics class. This was also different from the findings found in classroom observations in a previous semester. According to student participants, the teacher participant just lectured, had fewer activities, and never gave cooperative work.

2. Students' Reflections

2.1 Factors that Enhance Genetics Learning

This section focuses on the student participants' perceptions on the factors that emerged from the SA-GIU that enhanced their science learning. Multiple sources of data were taken into consideration for this section, including transcripts of semi-structured interviews and student journals. In both interviews and journals, the students were asked to identify and explain what in the SA-GIU helped them to learn science. Field notes of classroom observations were used to enhance trustworthiness of the study. In this study, the researchers read all transcripts and journals; five main schemes of factors that influenced effective science learning emerged from the data. These five schemes of effective factors included learning activities, learning media, social interaction, human mediation, and attitude. There are different categories in each main factor. A detailed description of the main factors and sub-factors are presented in Table 5.5. In order to collect data for this section, examples of interview transcripts, quotes from students journals, and findings from classroom observations were presented. The researcher would not say students' names; individual students were represented by letters and digits. For interview transcripts, the researcher gave 4-alphabet codes representing group numbers and individuals in a group. For journals, there was no name on any journal; the researcher gave numbers for each journal for each week. Therefore, similar numbers of journals at different weeks might have come from different students.

Table 5.5 A detailed description of schemes and categories of the effective factors that enhanced science learning

Scheme of effective factors	Categories of effective factors	Description
Learning activity	Variety of activity	There are various activities in a lesson
	Hands on activity	Students have chances to perform actions
Learning media	Multiple sources of media	There are various types of sources of learning medias in a lesson
	Visual representation	There are actions, objects, or drawings as learning medias to represent ideas or concept
	Relevance media	There are medias or examples that are authentic and relevant to life or the community
Social interaction	Idea sharing and discussion	Students have chances to present and exchange their ideas and then negotiate with the others
	Role modeling	During social interaction, students adopt or adapt behaviors of the others; engaging in social interaction motivates students to change their behavior
Human mediation	Guidance and Support	Students get help, guidance, or support from their teacher or classmates
	Reflection	Students get reflections from their teacher or classmates
Attitude	Gain of positive attitude	The SA-GIU makes science learning more interesting and fun

2.1.1 Scheme 1: Activity

In this scheme of effective factors, students talked during semi-structured group interviews and wrote in journals about activities or characteristics of activities used in the SA-GIU that were effective factors in enhancing their science learning. Within this scheme, two were factors were derived from the data; variety of activities and hands on activities.

a) Variety of Activity

When student participants were asked what in the SA-GIU helped to promote their scientific understanding, it was found that using different types of activities enhanced their science learning. Examples of students' responses were:

> G1S1: [I] Like [it], there are more activities and a variety of activities…learning with many activities is better that just only talking; I understand better.
>
> Interview transcript of group 1

> G3S4: Doing different activities is interesting and makes it [science learning] easier.
>
> Interview transcript of group 3

From the transcripts, it is implied that using a wide range of activities can enhance science learning because it makes science more interesting. It also promotes positive attitudes toward science learning and acts as a learning motivator. Moreover, applying a different kind of activity is the best technique to respond to the differences between learners. The kinds of activities used in the SA-GIU were discussions, work presentations, experiments, games, and role playing. Though in this study group activities were emphasized, students were also provided with chances to work in pairs or individually.

b) Hands-on Activity

Examples of evidence given by the student participants include:

G2S3: Since I have been learning [biology], this is the most I have understood this semester.

R: Why? What is the difference?

G2S2: Before, we only learned contents but never did hands-on-activities.

G2S1: No experiments, no supporting equipments.

G2S3: All work was in a textbook, no further research

G2S4: Now, I am motivated to think.

Interview transcript of group 2

G3S2: It is…there are experiments or activities that help me to remember.

Interview transcript of group 3

G1S1: I think there I was more enthusiastic, paid more attention to learning, and was prepared to answer questions at anytime. Before, there was only listening to the teacher, no active performance. Now, I have learned a lot and have earned more knowledge. I'm ready for everything.

Interview transcript of group 1

G4S3: The activities brought into the genetics class…they made genetics easy to understand because we took actions, did hands-on-activities, thought, and researched by ourselves. When we took action, group discussions occurred more often, so better understandings were made. Even though sometimes we had different information and we were contradicted, but all the information came from what we studied by ourselves, it should be correct...at least for us.

Interview transcript of group 4

[I] understand because there were hands-on-activities to enhance understanding. Now I understand.

Journal 6/7 of week 6

From both transcripts of semi-structured group interviews and journals, it was found that learning in the SA-GIU provided chances for the student participants to take action and do hands-on-activities. The student participants perceived it as an effective factor for science learning because real experiences supported their understandings as described, by student G4S3 in their interview. In addition, doing hands-on-activity made it was easier to learn science because students could imagine and recall their actions and transform them into conceptual understanding.

G4S3: Sometimes, by thinking about activities we have done in class, I can remember without reading.
R: Thinking about activities that you'd done?
G3S3: Yes, just like yesterday (final examination day), I did not remember. I wrote [in a test] what I had done.
R: For example?
G4S3: Protein synthesis.
G4S1: Also, I did not read, so I did not remember. I thought about the cutting and pasting activity. I wrote what I had done.
G4S3: Step by step.
G4S1: I did it myself, I remembered. Like cut and paste.

Interview transcript of group 4

The activity that the student participants mentioned in the above transcript was an activity in lesson 11: How genes control characteristics (part 2). As groups, students researched information about translation and then matched descriptions and diagrams of all the stages in the process. After a whole class discussion and all the groups got the correct matches, they cut descriptions and diagrams and pasted them in order. After the class discussions, all the groups got the descriptions and diagrams in the correct order.

1.1.2 Scheme 2: Learning Media

…this week, [I] learned about transmission of inheritance. It was easy to understand because the media was much easier to understand.

Journal 2/10 of week 2

…existence of supporting equipments [learning media] and worksheets helped me develop an understanding and enabled me to see a real concept. Then, my knowledge and understanding emerged….

Journal 11/8 of week 11

R: Then, what do you think makes you understand [genetics]?
G4S1: All the learning media.
G4S3: Media.
G4S4: Watching videos.

Interview transcript of group 4

From the above examples of student journals, it is apparent that learning and teaching media and resources were some of the schemes in the SA-GIU that the student participants perceived as an effective factor for science learning. Students often named media and games used in class when they were asked what helped them learn. Furthermore, students mentioned three aspects of effectiveness of this scheme; using multiple sources of media, using visual representations, and relevant media.

a) Multiple Sources of Media

At first, some student participants thought that using different types of learning media or resources on the same topic could promote science learning. The examples of the responses are as follows:

> G1S1: Well…now we have many things that are better than a textbook. For instance, supporting documents that we could use to answer questions…With a DNA model, we could see and imagine how DNA looks exactly like…Watching videos, when we watched, it was extending my knowledge and understanding [about DNA structure]
>
> Interview transcript of group 1

> G4S3: More media, better and easier to understood.
>
> G4S1: Understood better.
>
> G4S1: Sometimes only doing worksheets does not help me understand, but with watching videos, I could understand what I could not understand at first.
>
> 4B3: By only reading a textbook, I sometimes could not imagine how something looked like.
>
> G4G1: Because we never knew and never saw it.
>
> Interview transcript of group 4

From the above examples of interview transcripts, it is apparent that the student participants valued using more than two different types of learning media as a factor to enhance their scientific understanding. The reason is that different kinds of media enabled them to see different aspects of concepts. Some media, such as models or animations may provide realistic figures of concepts, like DNA. Other media, such as diagrams and textbooks give in-depth details of concepts. Normally, in the SA-GIU, a textbook and knowledge sheets would include pictures and diagrams as basic resources for the students. There were few different additional media, such as pictures, drawings, videos, models, animations, or real examples simultaneously used in the same lesson. Sometimes, games or role plays were also used.

According to Shepardson (1999), in sociocultural theory, these media are tools. Tools act as instruments for us to talk and see phenomena in different aspects. When multiple tools are used, students can learn about concepts in different ways. Some tools, such as video tapes, models, or microscopes, provide students with aspects about concepts that cannot be accessed by a human's simple senses.

> G4S3: Then, if we could not follow, we did not completely understand. Sometimes, we could not recall what it was because there was no learning media. Now there are learning media, we can recall what we have done in each class.
>
> G4S1: That helps us understand.
>
> Interview transcript of group 4

Vygotsky (1978) believed that signs and tools mediate the formation of a learner's cognitive activity; therefore, it was not surprising when students found that it was easier for them to recall what they had learned by thinking of what they had done in the classroom. Finally, some students explained that visual representations made genetics lessons more interesting. It was a positive reinforcement that helped them to learn science.

b) Visual Representation

Some student participants thought that using different kinds of objects as media to represent concepts could promote science learning. Examples of responses are as follows:

G1S2: It was something we could touch, manipulate, and then discuss afterword; [I] deeply understood. For example, translation, I understood very well…

G1S1: Just like when you let us touch the chromosome [model] and the strand of DNA [model], I could imagine its real shape.

G1S3: Previously [in another biology courses], I just had to look in a textbook.

G1S1: Without them, I might think DNA had a flat shape.

Interview transcript of group 1

From the interview transcripts, it appears that models were an effective media to represent concepts relating to chromosomes and DNA. According to Steel (2000 cited in Steel, 2001), actions, objects, and drawings used to represent ideas or concepts are called visual representations. Therefore, the student participants perceived models, a kind of visual representation, as an effective factor to enhance science learning. They could touch and interact with the models, giving students a realistic picture of the concept, making abstract concepts concrete. Consequently, students had a better understanding of the concepts. Using models as visual representations was mentioned as an effective factor in journals.

> … Today, I had a chance to do something different than learning from listening. [I] saw big chromosome examples [model] and I could compare them for differences. I matched a chromosome with its pair. I enjoyed today very much and did not fall asleep. It was fun and I still got knowledge.

Journal 2/3

Different models were used in the SA-GIU, like DNA models, chromosome models, cassette tape chromosomes, and models of DNA in the nucleus (Figure 5.2). A few additional different visual representations were offered for each topic, such as pictures, drawings, videos, and animations. Sometimes, games or role plays were also used to represent ideas.

From classroom observations, it was found that while explaining and discussing, the teacher participant sometimes drew pictures or diagrams on a blackboard to represent ideas. Also, the student participants were always encouraged to use visual representations, such as drawing pictures on a blackboard or using models, to explain their ideas.

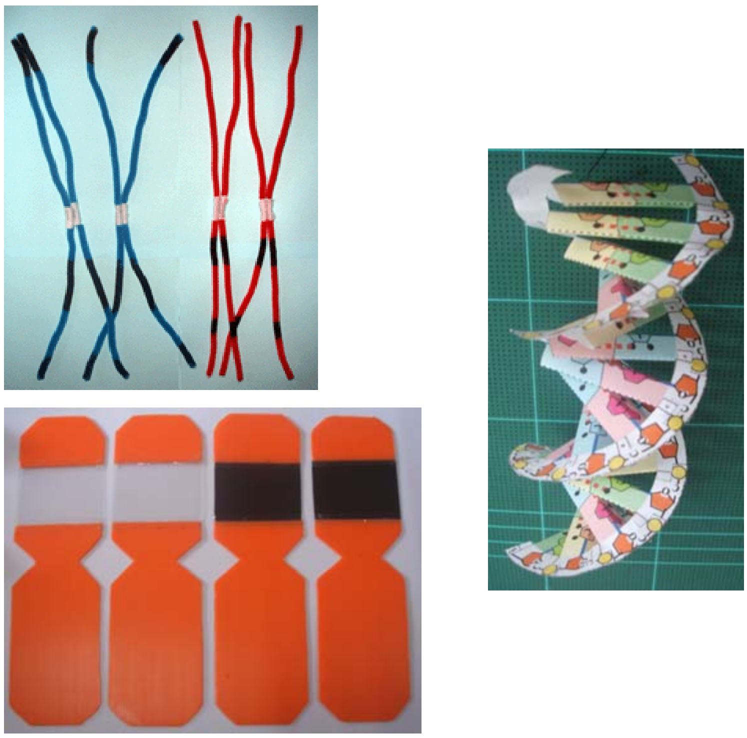


Figure 5.2 Examples of models used in the SA-GIU

c) Relevant Media

Another effective factor regarding learning media and resources was the following.

> I understand because there we used and compared characteristics on our bodies, such as dimples or tongue rolling, and referred to events or issues in current society. All of this helped me develop my understanding.
>
> Journal 2/3 of week 2

> I understood [genetics] because some topics were not too difficult to understand. Learning from authentic examples helped to promote a better understanding.
>
> Journal 7/7 of week 7

From the above responses, it can be concluded that an effective factor in teaching is using learning media or examples that are authentic and relevant to the students' lives or community. In week two, students had to observe the genetic traits of their friends and family members. From classroom observations, it was found that students were happy; they always laughed. There were discussions and ideas shared around the classroom about why they looked alike or different from their family members. In week seven, students studied about human inheritance. Again, they had a chance to investigate their characteristics and apply their knowledge in order to explain sex and popular traits in their community. There were a lot of discussions and the teacher participant wrote in her journal, "I observed that students enjoyed learning." Therefore, it appears that using relevant media and resources helped students gain an interest in genetics and made learning become meaningful.

1.1.3 Scheme 3: Social Interaction

During learning from the SA-GIU, students were always encouraged to work cooperatively with others. In such contexts, social interactions occurred. Students mentioned that activities that occurred during social interactions were an effective factor that enhanced their science learning in the SA-GIU. Students often used words such as reading, writing, speaking, listening, discussing, describing, consulting, exchanging, presenting, questioning, and answering to describe the ways they came to understand science. Two factors that enhance learning were developed from this data: idea sharing and discussions and role modeling.

a) Idea Sharing and Discussions

While engaged in learning activities, students were encouraged to express their ideas and discuss them with others. Some student participants valued this activity as an effective factor that promoted learning.

> [I] understand [genetics] well because there were chances for us to exchange ideas with each other, give information, or help each other to solve problems. If we had different thoughts, we explained and looked for an understanding. This happened because there was an expression of each other's ideas.

Journal 2/1 of week 2

> I understood genetics better because there were ideas being shared within the groups. Each one of us had different ideas; we brought it to the discussion and got the group's conclusion. When we discussed with other groups, group members helped each other. We shared responsibilities and helped to explain and give reasons to the others who did not understand. We learned better this way.

Journal 8/7 of week 8

We studied about GMOs, what they are, their risks, and applications. I Understood because of the discussions in class and the exchange of ideas with the others.

Journal 16/13 of week 16

G4S4: In the beginning, only one idea was proposed within our group, but, later, we often came up with different ideas; then, we brought them up for discussion.
R: When you had different ideas, why did you have to discuss them? How was a discussion helpful?
G4S4: To get correct conclusions and what it should be.
G4S1: Our thoughts could not always be correct.

Interview transcript of group 4

From the above examples, it was found that when students shared and discussed ideas, they found common agreements on different ideas and understood concepts better as they shared different viewpoints. Therefore, it can be concluded that assigning students to communicate their ideas encouraged learning.

R: How do you fell when someone argued against your answer?
G1S1: I thought I was right.
G1S2: They argued; they had their reasons.
G1S4: They had their reasons. They thought they were right and they argued. Their ideas might be different from ours.
R: Do you think it was good or not?
All group members: Good.
G1S2: It made me remember.
G1S4: There were many thoughts.
G1S1: We mixed many thoughts together.

G1S2: When they argued against us, we had to show our reasons. Then we remembered. It was different from before, when we just listened to the teacher.

Interview transcript of group 1

G2S4: Before [in another biology course], we did not use many thinking processes and did not understand. We did not speak or use our brains.

G3S1: Now [n SA-GIU], it seems we must think.

G2S3: That helps us remember.

G2S1: We discussed and thought together. Each one had different thought and we exchanged them.

G2S4: We were getting familiar, when we thought and spoke, we were getting familiar.

R: Getting familiar with what?

G2S4: With what we spoke out. It helped my thinking process.

G2S2: You are right. Thinking for myself helped my memory.

G2S3: In a textbook, they [genetics concepts] are academic and has long explanations. I could not put it my words.

G2S4: In a textbook, it is very official; it does not suit our age. It is a kind of super explanation, but we are young. It is too difficult to understand. If we use our words, it is easier to understand.

R: So, you understood but in your own way.

G2S1: We already synthesized. When we saw it again, we're able to write it because we understood.

Interview transcript of group 2

4G1: Normally, we just sat while the teacher taught…sat and listened. When I read a textbook for an exam, I understood what was in the book, but it is not a deep understanding and is sometimes confusing. While learning from the genetics unit, I sometimes had to do research with my family and I had to explain things to my mom. When [I] explained to another person, I understood more.

Interview transcript of group 4

According to the interview transcripts above, students who communicated ideas with others could reach an understanding because during communication students learned meanings and ways to use scientific signs and language from more competent members, such as peers and the teacher (Shepardson, 1999; Steele, 2001). According to Vygotsky (1986), meaning of concept is socially developed and not a ready-made form, meaning gradually develops when a child uses it in communication with more competent peers. Also, Cobb *et al*. said that it is very natural for students to learn from communication (as cited in Steele, 2001: 413-414). It is a chance for students to consider their own thoughts and gather pieces of understanding from others. The result is self-constructed meaning that is unique for one's self in one's own language, so there is a "taken-as-shared" scientific meaning in the classroom (Steele, 2001).

Interestingly, it was found that some students evaluated sharing and discussing ideas as a means that provided for a learning opportunity as well as a way to learn confidence. Examples of that evidence are as follows.

G2S4: In previous biology courses, it [teaching] went by fast. Now, everyone understands similarly, and has thoughts [conception] at a similar level.

Interview transcript of group 2

G4S1: I liked it because our group shared our ideas, and if they were similar to those of the others, we understood the same meanings as them.

R: If you knew you were similar or different form the others, what then?

G4S1: If they were similar, it was by watching the same video, then, the ideas were similar with the others. If I understood as the others, I was proud that I knew it. I did not like feeling like a fool when everyone else knew the concept.

Interview transcript of group 4

Normally in the SA-GIU, students first discussed with group members or partners to form group answers. After that, each group presented their answer and then discussed it again with another group. After a whole class discussion, the teacher asked students to conclude the lesson. With this process, all students had a chance to speak and learn, and, in the end, everyone had similar understandings. In such a context, students knew what the others thought. Thus, they felt confident in learning. Without idea sharing and discussion, students could not be sure whether they understood similarly or differently than the others. In addition, while students were discussing within groups, it was found from classroom observations that the teacher always visited each group and provided some support. Thus, students had equal opportunities to get support from the teacher.

b) Role Modeling

While engaging in social interactions, students had a chance to observe and learn behaviors from the others. Some student participants picked their friends' behaviors as motivations and models for themselves. Then they changed their behaviors. After they had changed, they found they learned better.

G4S3: Before, there was less discussing within our groups.
G4G1: We lacked discussions and answering the teacher's questions.
G4S4: There was less talking
G4S1: We just sat, sometimes chatted with friends.
G4S3: Or just read a book.
G4S1: But currently [in the SA-GIU] if the teacher asks a question but we did not respond or group members do not help each

other to answer, our group will not understand. If the other groups could answer, then they understood. That forced us to make more of an effort. In the beginning, our group got a low score, so we helped each other to…

S4S4: Present.

S4G1: Present more often.

G4S4: We became brave enough to think and speak

G4S1: Because in the beginning, we were shy.

Interview transcript of group 4

This situation was in accordance with the data from classroom observations. In early stages of learning with the SA-GIU, group 4 was less active. They seldom expressed their ideas or took part in classroom discussions, but, later, they shared ideas more often, especially student G4S1. According to interview transcripts, they changed their learning styles because while interacting with the others, they observed that those who were able to share and discuss ideas would learn better. Therefore, they decided to behave as the others.

1.1.4 Scheme 4: Human Mediation

Some student participants reported that during learning in the SA-GIU, they could understand genetic concepts because there was someone else to help them understand. This kind of human performance that enhances learning is called human mediation. In this study, two categories of effective factors relating to human mediation were found: guidance and support, and reflection. Some keywords in this scheme are about getting help, getting support, getting suggestions, getting guidance, giving advice, asking someone else, and teaching.

a) Guidance and Support

Some student participants pointed out that they understood genetic concepts or learned better because they got help, guidance, or support from either their teacher or classmates.

G4S1: The teacher explained if we did not understand something. Sometimes, outside the class…during homeroom, she explained how things were to us. If we asked her, she explained things to us.
R: Did you guys ask her or did she just want to explain?
G4S1: She sometimes explained to us when we did not understand. For example, before doing GMO activities, the teacher explained and advised us that we needed to do more research and what we were expected to do.
R: You mean before doing the activity, don't you?
G4S1: She gave some guidance beforehand.
R: So, do you want your teacher to continue this way of teaching?
G4S1: Yes. [The others showed their agreement]

Interview transcript of group 4

From the above dialogue, it is evident that the teacher participant provided her students with extra explanations and advice before doing the last activity in the SA-GIU, role playing as a member of the Thai cabinet and debating about genetic engineering and GMOs. She explained that students needed to do more research and what they were expected to do for the activity. At this point, the researcher talked with the teacher participant. She described that she wanted to make sure that students got information covering the important aspects, thus, she suggested student make an outline. Also, she advised students what media or equipment they might need to prepare. On the activity day, students could exchange ideas and discuss the aspects she had wanted them to know. Students also prepared charts and presentations that made debating more realistic and interesting. A positive result was illustrated in the student journals of that week. All students enjoyed the activity and understood the concept. Students could have done this activity by themselves, but they did it better with some support from their teacher. Thus, the teacher participant acted as human mediator of the learning process. Accordingly, data from classroom observations confirmed this finding. The teacher participant always stopped by each group, listened to students, and then gave support by asking and answering questions or suggested what students might need to do. The student participants also noticed and mentioned her role during their interviews.

> R: How about her role? How did she act in class? Do you think it was different?
>
> 4G1: It is different. Previously, she just lectured but now there are questions and activities
>
> R: What else did she do?
>
> 4G1: During group discussions, she came to help and explain things to us.
>
> Interview transcript of group 4

It is not only a teacher who can act as human mediator in a learning process but also students. Examples of this evidence are:

> …sometimes, in some topics, it is difficult to understand but that can be fixed by asking friends.
>
> Journal 2/9 of week 2

This student confronted their learning difficulty; some concepts were too difficult for this student to understand. However, this student overcame it by asking for help from peers. This factor was also found in semi-structured interviews. During interviews with group 2, the researcher asked for the differences between the SA-GIU and previous biology courses that helped them learn genetics. Student G2S4 said, “We did things together. By myself, I could not do it for sure.” This sentence implies that with some kind of support from friends, which could be suggestions, demonstrations, or answering questions, this student could do with others what he could not do alone. In other words, friends of this student acted as human mediators and helped this student cross the gap in the zone of proximal development.

b) Reflection

Another form of human mediation found in this study was reflection. Some student participants mentioned that they understood genetic concepts because they got reflections from their teacher or classmates.

> G4S1: Sometimes, when we finished a worksheet and handed it in to you [the researcher], you made cross marks; when we got it back, we searched for why were incorrect and read you the feedback. Next, we searched for new answers (4G4: Corrected them), so we thought they should be correct now.”
>
> Interview transcript of group 4

After finishing each lesson, all students sent the teacher participant their worksheets. The researcher read the students’ work and responded to their answers. If a worksheet was complete and correct, the researcher marked it as good job, well done, or excellent, depending on the quality. If there was something wrong or incomplete, the researcher marked it with a question mark, gave advice on what they might need to do or find, or asked questions that challenged their answers. According to student G4S1, she read these feedbacks and rethought them or researched for new and better answers. This situation suggested that reflection was an effective factor in enhancing genetics learning.

1.1.5 Scheme 5: Attitude

There was agreement between the data from the interviews and journals that more than ninety five percent of the student participants enjoyed learning using the SA-GIU. Among all the journals, just a few students replied that they did not like the SA-GIU. Therefore, most students gained positive attitudes toward the SA-GIU.

G2S4: It was inactive [previous biology course]. Now we must always think in case the teacher asks us a question.

G2S3: Before, we were separate; it was boring and made me sleepy. Now many friends think together; it is interesting and does not make me sleepy.

G2S1: We have chances to speak.

G2S4: Before, when the teacher asked questions, sometimes we did not catch what the teacher was teaching and what the question was, because we were chatting with the others.

G4S1: Now there are activities to do with equipment, such as chromosome models.

G4S2: Learning that way is fun, we enjoy it.

Interview transcript of group 2

G3S3: Because it is fun to learn, I remember. Before, I had to read and recite a lot.

Interview transcript of group 3

Now, there are activities, such as playing games, so I like learning.

Journal 12/5 week 12

The student participants said that in the SA-GIU they worked together, there were different activities for students to do, and there were various media, therefore, they enjoyed learning in the SA-GIU. In other words, they gained positive attitudes towards learning in the SA-GIU. Once the student participants had developed positive attitudes toward the SA-GIU, they wanted to learn and paid more attention to their teacher; they did not fall asleep during learning in the SA-GIU. Thus, they learned better as they said they could remember without loads of reading.

1.2 Difficulty Learning in the SA-GIU

This section focuses on student participants' perceptions on the difficulties that emerged from the SA-GIU that obstructed their science learning. Multiple sources of data, including transcripts of semi-structured interviews and student journals, were taken into consideration for this section. In both interviews and journals, the students were asked to identify and explain what obstacles they found during learning in the SA-GIU. Field notes of classroom observations were used to enhance trustworthiness of the study. Based on the collected data, the major difficulties the student participants found were students' personalities and lack of communication skills.

To report in this section, examples of interview transcripts, quotes student journals, and findings from classroom observations are presented. Four alphabet codes were used to represent individuals during semi-structured group interviews. Similar numbers of journals from different weeks might come from different students.

1.2.1 Students' Personalities

G2S3: There were activities for us to do.

G2S1: Activities, worksheets, and we discussed with the others

G2S2: Group working and sharing ideas.

G2S1: There were always contradictions. They always argued with us when we explained our thoughts.

G2S2: In the beginning, we were able to talk, but they argued with us very hard and that shut me down.

G2S4: Well, mostly, they did not listen to us. They would not give us a chance to explain.

G2S1: That destroyed our confidence.

G2S4: Sometimes, they interrupted us in the middle; [I] lost my confidence. It made me feel down and made me not want to think any more.

Interview transcript of group 2

According to the sociocultural perspective, students should communicate and discuss a lot, and students should act as good listeners, while the others are talking and have open minds, in order to accept comments or conflicting thoughts. Students in group 4 found that they were always argued with and interrupted in the middle of their presentations. In other words, students did not open their minds enough and their friends did not act as good listeners. This kind of situation happened a lot, and they lost their confidence. Consequently, they tended to participate less in classroom discussions.

R: Do you think you took more active roles in classroom?

G3S1: Yes. We answered questions and had roles during experiments.

R: How about you [G3S4]?

G3S4: Quite similar.

R: Compared to other biology courses and in recent genetic classes, what do you think?

G3S2: You two did not talk a lot. In recent genetics classes, you guys help to do activities though, except speaking, [present or discuss] you both almost never speak.

R: Why do you not talk?

G3S4: I am afraid…I may be wrong. I am afraid if I talk, on one will understand…I might beat around the bush.

R: Do you think you would understand better if you spoke out?

G3S4: Not sure.

R: How about you, why do you not talk?

G3S1: I am afraid that what I say will not be right.

It was found from classroom observations that G3S1 and G3S4 seldom participated in sharing ideas and discussions. If there were activities, such as experiments or demonstrations, they took more responsibilities than before, but if the teacher began a whole class discussion or requested volunteers, they never took a chance. Sometimes, the teacher called their names, then, they spoke quickly. From interview transcripts, it is clear that they are both bashful. They are afraid to express their ideas or to make mistakes. It was this characteristic that kept them from participating in classroom activities.

In conclusion, a student's personality can be a barrier to learning science in a class using a sociocultural approach. In this study, it was found that not being a good listener, not being open minded, and being bashful were some characteristics that were obstacles for those in a class using a sociocultural approach.

1.2.2 Lack of Communication Skills

In semi-structured interviews, group 2 also pointed out another difficulty to learning in a class using a sociocultural approach.

G2S1: …Sometimes, we came up with our conclusion but when our turn came, we did not know how to start.

R: Why?

G2S3: We were able to talk and discuss in our group but did not know how to explain it to the class.

G2S1: Each one of us had different ideas; it was hard to mix them up.

G2S4: Because, normally, we did not talk much.

R: You guys did not know how to put together the words.

G2S1: Moreover, we talked but did not know how to write a sentence.

G2S4: That is, we did not know how to explain to the others.

This group of students explained that they understood, but they did not know how to express it. Thus, they did not have sufficient communication skills. With the sociocultural perspective, students are always encouraged to communicate and discuss ideas; therefore, good communication skills are necessary. If students do not have sufficient communication skills, they find that it is difficult to learn in a class using a sociocultural approach.

1.3 Students' Attitude Toward the SA-GIU

This section discusses the students' attitude toward the sociocultural approach used in the SA-GIU. The data was gathered by several techniques, semi-structured group interviews and journals. In semi-structured interviews, the student participants were asked to reflect on their opinions on the learning activities in the units. With journals, they were asked to describe whether or not they liked the learning in the genetics instructional units with the sociocultural approach and why.

Within sixteen weeks of the SA-GIU implementation, 166 responses were collected. Almost a hundred percent of the responses in journals were positive; almost all of the student participants liked learning with the sociocultural approach. There was only one journal that showed a negative response. The reasons that emerged from semi-structured group interviews and journals are summarized as follows:

1.3.1 Concepts Are Easy to Understand

> [I] liked it a lot because it was learning that promoted understanding, and there were many activities (Journal 1/4).

> [I] liked it because it was easy to understand (Journal 7/5).

1.3.2 There Are Many Activities and Media

[I] liked it because it used new learning media (Journal 5/9).

[I] liked learning here because … there was media that could help me understand better (Journal 8/2).

1.3.3 Students Have Chances to Participate in Classroom Activities

[I] liked it because I took action, discussed, and negotiated with group members (Journal 2/2).

[I] liked it because there was interesting knowledge. … I had chances to discuss and use knowledge with others (Journal 4/1).

[I] liked it because I had chances to do activities and I understood better (Journal 6/7).

[I] liked it because I was able to express ideas and do activities with the others in the group (Journal 7/2).

1.3.4 Learning Is Relevant to the Context and Applicable

[I] liked learning genetics because it was fun and interesting. I got knowledge that could be useful (Journal 3/5).

[I] liked it because there was new knowledge and basic knowledge that could be developed and used in various ways. It was valuable for human lives (Journal 5/1).

[I] liked it because I got new and interesting knowledge that could be applied in another situation (Journal 6/9).

> [I] liked it because I could use it to investigate myself and members in my family (Journal 8/5).

1.3.5 Learning Is Fun and Interesting

> [I] liked it because learning was fun and interesting. I got lots of knowledge. I learned many things and did not get sleepy (Journal 2/7).

> [I] liked it very much because teaching and learning was fun. There was learning media (Journal 3/1).

> [I] liked it because there was interesting knowledge. Learning was fun and interesting… (Journal 4/1).

> Learning by discussion and debate was very fun (Journal 16/10).

According to a negative response, this student needed the teacher to take a more active role in the learning process. It is possible that this student was more familiar with a teacher-centered style of learning. This student wrote:

> I did not like it because I did not understand. I tried, but I still did not understand. Learning by using a sociocultural approach sometimes helped me to understand more, but the teacher should still give more explanations.

However, it was found from semi-structured group interviews that each group agreed that they liked to learn in a sociocultural genetics class. This implies that, when considering the entire unit, the student participants enjoying learning in the SA-GIU. At the end of semi-structured group interview, the researcher asked whether they wanted their teacher continue this learning environment. All groups strongly agreed that they wanted to because learning was fun and interesting.

Summary

The Sociocultural Approach-Genetic Instructional Unit (SA-GIU) based on a sociocultural perspective was implemented by the volunteer teachers in a classroom of grade 12 in a high school in Suphan Buri. The result indicated that sociocultural perspective which underpins the instructional successfully enhances students' understanding of genetics. The result also indicated that students have developed some desired characteristics. Both the teacher and the student participants claimed that the activities and media used in the SA-GIU were diversified and interesting and could help students understand the concepts better. With various interesting activities and media, both groups of participants also claimed that it was enjoyable and happy to learn in the SA-GIU. In the following and the last chapter, the researcher will discuss the conclusion of whole study, the implication of the study and suggestion for future research.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Introduction

This research study was about development of the genetic instructional unit using sociocultural perspective as a conceptual framework of development. The Sociocultural Approach-Genetic Instructional Unit was introduced into a genetics classroom. This chapter is centered on research findings and their implications to the science education research community.

Conclusions

1. The Sociocultural Approach-Genetics Instructional Unit Design and Development

Guiding by sociocultural perspective of learning recommendations for genetics teaching and common alternative concepts about genetics from literature and educational framework of Thailand; a learning intervention called the Sociocultural Approach-Genetic Instructional Unit (SA-GIU) was developed. The SA-GIU is a ready to use instructional package for the teaching of genetics in an advance biology course of Grade 12. The aim of the unit is to enhance scientific understanding of genetics, create attractive lessons, and effective learning environment to students.

The SA-GIU consists of thirteen lesson plans and required thirty six periods of fifty minutes each; overall. The topics of learning are aligned with those suggested in the Basic and Advanced Science Content Handbook: Biology 5 (IPST, 2006). However, as recommended in previous research, cell division was added into the unit. The genetics topics began with the less complex concepts in familiar higher-level organisms and progressed to the more complex concepts at the molecular level in microorganisms. Moreover, some genetics topics relevant to Thai contexts were brought into the SA-GIU, for instance, the mutation and trait improvements of the Butsarana plant, sex determination and the proportion of Suphan Buri population, and genetically modified papaya.

Regarding key ideas of sociocultural perspective including zone of proximal development, law of general development and cultural tools; the emphasized activities in the SA-GIU are cooperative work, social interaction, and using various media. The common teaching strategies employed in the SA-GIU are group or pair tasks, doing hands-on activities, presentation of ideas, and discussion. To assess learning, a teacher is suggested to evaluate students' performance while they are engaged in actual instructional activities.

Based on the literature regarding sociocultural perspective of teaching and learning, the learning sequences of each lesson have the following pattern:

1. *Initiation:* Teachers explore students' prior knowledge about the soon to be learned concepts by asking questions or mentioning everyday events. Students are encouraged to share their understanding and pose their own questions.

2. *Doing the task:* Teachers ask questions or assigned cooperative tasks. To complete the task, students are assigned to work with a partner or in a small heterogeneous group. The students design procedures to answer the question or complete the assignment with their partner or group members. During this phase, students are required to research, share, and discuss with fellow group members. The teacher gives guidance and supports in manner to help students to finish tasks. Mean while, the teacher monitor and evaluate students' performances.

3. *Making a group agreement:* Within group, students share and discuss about results from previous stage and develop a group's conclusion. Teachers aid students to communicate their thinking by prodding with questions that attempt to get students to clarify their thinking and further evaluate the value of their thoughts. Also,

the teacher might assist students by means of modeling, giving reinforcement, instructing, explaining, or guiding. This stage of learning may happen at the same time with a previous stage.

4. *Sharing and negotiation:* Each group shares its findings with the class. The teacher and the other groups give feedback. Students interpret the results of their own findings by comparing with the others' findings. After whole-class discussions, the students are able to better compare their own solutions and strategies. With the teacher's assistance, the students negotiate the establishment of a common agreement in the classroom. To demonstrate their conclusions, students are encouraged to use drawing, acting, writing, and any other method or tool that would aid them.

5. *Making the product of understanding:* Students demonstrate the final product of their understanding. This is the time for students to demonstrate their full grasp of the meanings (concepts) by using signs and tools. Not everyone's understanding was identical, but they share similar and important key ideas.

2. The Implementation and Adaptation of the Instructional Unit

The SA-GIU was implemented by a teacher in a high school in Suphan Buri. The participant teacher chose to implement the SA-GIU with a grade 12 classroom. There were 16 students in this class consisting of three boys and thirteen girls. Their age ranged between sixteen to seventeen years. They were mix of students who had high to low achievement in science and biology. In this study, three 50-minute periods were allowed for genetics every week. The teacher participant took fifty one periods to finish the SA-GIU.

In this study, the teacher participant was able to use the learning materials and learning activities effectively. She mostly followed steps and strategies suggested in the lesson plans. Considering among five steps of learning in each lesson, the teacher participant mostly took a great amount of time on stages of making a group agreement and doing the task; this is because sometime these two stages are overlapped. That suggests that students had opportunity to do activities and then discussed on their action. She also took much time than expected in the stage of initiation. This implied that this teacher was aware the importance of students prior knowledge and motivation of learning. However, at the stage of learning; making a product of understanding, she sometime neglected this step. Due to time constraint she adjusted or skipped some learning activities. However, she thought the student participant were able to learn all concepts in the rest of activities. Therefore, it may be suggest here that effectiveness of the SA-GIU is also relied on professional judgment of teachers.

Comparing with information about teaching practice of the teacher participant in another biology courses, it was found that she had adjusted her teaching style to meet criteria of sociocultural perspective. She gave a lot of opportunities and motivated students to share and discuss about thoughts and to work cooperative. She closely interacted with students at their groups. This would give her great opportunities to listen and learn students' ideas and then give appropriate support and guidance students need to make sense of concepts for themselves; a role of teachers suggested by Driver, *et al.* (1994). It could be concluded that most effective factor enhancing changes in her practices was beliefs in sociocultural perspective. She showed her beliefs during pre-implementation interview. According to Feldman (2002), it was not easy for any teacher to change his or her teaching practices when implanting curriculum; it was an ongoing process that could be influenced by several factors especially beliefs about knowing, teaching, and learning. These beliefs were socially constructed interactions that could act as both constraints and enablers of what happens in a classroom. It was because this teacher believed in benefits of sociocultural perspective that led noticeable changes on her teaching practices in this study. In addition, during the SA-GIU implementation, the researcher observed the teacher participant's teachings and gave her some feedbacks to adjust teaching. This might be another factor that supports changes in this teacher.

Changes in her teaching practice were not only found in this genetic classroom but also in another class which she taught. It was found that she also adapted teaching strategies used in the SA-GIU into another science classroom. Therefore, participation in this study provided her chances to learn new approach of teaching and develop her professional growth (Pongsopon, 2006).

There was similarity between the teacher participant' previous teaching practice in another biology course and her recent teaching practice in the SA-GIU; using of language. Before, she had used language as means to ask students questions and communicate concept. Also, in the current study, she used language in similar way. However, there was a difference; in her previous teaching practice, language was mostly used in one direction (from teacher to students) but in the current study language was used in two directions (between teacher and students). The learning outcomes were also different as some students said that before they were bored and quite did not understand but in current genetic classroom they did understand. This may imply that using signs and tools is not enough but using tools and signs as means of two-way communication is more important. Language with another various media (signs and tools) would increase effective of learning science, especially abstract concepts.

3. Accomplishments as Result of Learning in the Instructional Unit

In respect to learning accomplishments, the student participants have developed better understanding of genetics concepts in all studied concepts. Students' conceptions of concepts seemed to move from lower categories of concepts to higher one. However, there were many alternative concepts were found after learning in the SA-GIU. The most resistant to change concepts in this study were law of segregation, law of independent assortment, allele, chromosomes, and genes. No student possessed complete science concepts of these concepts after learning in the SA-GIU; on contrary, most of them held alternative concepts.

In aspect of law of segregation and law of independent assortment, students was not aware the significance these laws. This might be because this concept was learnt by giving definition, but it was never applied to explain any genetic phenomena. Moreover, it might be possible that questions used for these two concepts in the genetics concept survey that could not reveal students' understandings. In these two questions, students were asked to apply concepts but not directly asked concepts. Students might know meanings of concepts but they did not know how to use these concepts. In respect to allele, many students thought that allele were component of gene or were on gene.

Regarding chromosome, most of student participants thought that there were only two chromosomes in human gametes, even they knew that there were forty four chromosomes in human somatic cells. It is possible that, due to technical limitation, all animations and model of cell division used in the SA-GIU showed only two or four chromosomes. It led students to alternative conception.

For concept of gene, most common alternative conception about gene was that genes were found only on chromosomes in specific cells which involved expression of trait. Consequently, each cell in an individual organism possessed different genes.

It was not only genetic understandings, but also skills and abilities that the student participants have gained from learning in the sociocultural approach-oriented genetic classroom. They pointed out that they have gained abilities of idea expression, knowledge inquiry, self learning, cooperative working and industriousness.

4. Reflections on the Instructional

4.1. Teacher's Reflections

The teacher participant positively valued the SA-GIU and the sociocultural approach. She claimed that the activities and media used in the SA-GIU were diversified and interesting. The students were provided opportunities to actively participate in classroom activities. She felt that the SA-GIU did help the students understand genetics concepts enjoy and be happy to learn in the SA-GIU.

The difficulties the teacher participant found were that to use sociocultural approach, teachers needed to have well questioning skill and analyzing skills. These were considered as difficulties found from her actual practices; in another words she experienced herself. Thus as she concerned, it implied that she was aware importance of communication in science learning. She also found that using sociocultural approach required a great amount of time.

4.2. Student's Reflections

The student participant was fond that it was effective to learn in the SA-GIU. There were five schemes of effective factors found in the SA-GIU that enhancing learning science. These five effective factors were follows.

1) Learning activity: there were a variety of activities and many hands-on activities.

2) Learning media: there were various media, visual representations and relevant media used in the SA-GIU.

3) Social interaction: During interacting with the others, they were offered with chances to share and discuss ideas. Also they had opportunities to learn from the others.

4) Human mediation: they had chances to get supports and reflections from the others.

5) Attitude: learning in the SA-GIU was fun and interesting. Therefore they paid more attention for learning and activities.

It could be concluded that when using a variety of activities, it is most possible to fulfill students' differences. Usually, an individual does prefer to be actively involved in hands-on learning activities that interest him/her and are above his/her current level (Jaramillo, 1996). In this study, the students have learnt because they have chances to engage in classroom hands-on activities. When they find it is difficult to complete activities alone, mediations from teacher and peers are needed (Dixon-Krauss, 1996: 20-24). They share knowledge and discuss meaning through social interaction. Sharing and discussion in social activities requires students to use sign and tools (Dixon-Krauss, 1996: 15) which is necessary part of concept formation (Berger, 2005). With a usage of various media and visual representations, the students are provided with various tools to see and study concepts and concepts become more accessible for students (Shepardson, 1999).

However, student participants encounter some difficulties during learning in the SA-GIU. They suggested that due to students should communicate and discuss a lot during learning thus not being a good listener, not being open minded, and being bashful were some characteristics that were obstacles for those in a class using a sociocultural approach. Also, if students do not have sufficient communication skills, they find that it is difficult to learn in a class using a sociocultural approach.

Considering the whole situation of learning in genetic instructional unit using sociocultural approach, the students generally appeared to enjoy the lessons. The findings showed that learning in the SA-GIU provided contexts that lead students to become more involved in their lessons, were easier to understand, were more relevant to real life situations, and the various activities and learning media made the lessons become interesting. Another highlight of the SA-GIU was that those students who had previously been bored with biology became interested and increased their contributions to learning and classroom interactions. As they found learning in the SA-GIU is interesting, this may act as motivation or positive reinforcement for science learning.

The final remark is that, as supported by the results of this study, the students have learnt concepts; they found themselves have developed desired characteristics such as knowledge, self learning, cooperative working and industriousness; they were happy and enjoyed learning genetics using sociocultural approach. Therefore, it can be concluded here that with well designed and organized, sociocultural perspective provides an effective framework for teaching and learning science with "Excellency, Goodness and Happiness". However, this study was a case study; applicability of this study must be adjudged by readers.

Recommendation of the study

This research is an interpretive case study then the study and its finding are thereby specific to this educational context. The researcher has sought to provide sufficient description of the context, methodology, data analysis and interpretation, in order to promote transferability of the findings. This is as noted in the literature appropriate for a study of this nature, for which it is deemed more appropriate for the reader to judge the applicability of this study to one own educational context. The following recommendations are best judged by the reader how they might impact upon his or her own context.

1. Recommendations for Science Teaching and Learning

1) It was found in this study that the lessons designed under sociocultural perspective enhanced learning science. To promote learning science, therefore, students should have chances share and discuss thought with others in learning community to negotiate about meaning of learned concepts. In addition, a wide range of visual representations should be always used in classroom. Well design activities and learning environment are needed to meet this requirement. Firstly, design activities that require students to first work in small heterogeneous groups and then share and discuss their ideas with other classmates to find common understandings among them. In a mean time, a teacher must closely and carefully observe students' actions, listen to their talks, interpret that information and then give feedbacks, for instance by asking questions or giving suggestions. According to Steele (2001), this encourages social interaction and communication of students both with their peers

with different levels of developments and with their teacher. A variety of media must be utilized.

2) The findings of this study about teacher's and students' difficulties of teaching and learning suggested that, in order to take full advantage of sociocultural approach, teachers must well prepare in questioning and analyzing skills. Also, students must be informed their roles in classroom. They must learn to be good listener, generous person. Communication skills, in addition, are very important for students to learn in sociocultural approach-based classrooms. Students, especially students who are less active in classroom, may find difficulties and take lots of time to communicate their ideas at the beginning. However, as found in this study, they can do better later. The recommendation from this study is that students should always have opportunities to communicate ideas and teachers must keep encourage them.

3) Cell divisions should be taught with genetics. Students should learn how cell divisions involves heredity as well as what happens to chromosomes, DNA, genes and alleles during cell divisions. Moreover, situations and news relating genetics in Thai context should be used as learning sources in genetic classroom.

4) As found that law of segregation, law of independent assortment, allele, chromosome and gene were most found alternative concepts and difficulty to change, it is advisory for biology teacher to concentrate on these concepts. Significance of Mendel's laws must be revealed explicitly. Differences and relationship between gene and allele must be focused. In order to use learning media to represent concepts, limitation of being used media must be discussed and informed.

5) To succeed in implementing a new science program, the teachers should have beliefs in theoretical perspective underpinning the program first. Before the implementation, it is necessary for the researchers or curriculum developers to review with the teachers the emphasizing approach, the contents, and the activities of intervention. Before the implementation, the teachers should have opportunities to try out the activity and also negotiate and decide on how the program will be used with

their students according to actual context. Furthermore, supports and reflections from researchers, mentors or other teachers must be provided for the teachers throughout the implementation.

2. Recommendations for further research

To extend this study, the researcher would like to recommend the following issues for a future investigation.

2.1 As has been discussed, the teacher participant and student participant have adjudged learning in the sociocultural approach-based classroom as effective way to teach and learn genetics. However, they still found some difficulties. Further research could explore in more depth how to help teacher and students to become comfortable to use sociocultural approaches in teaching and learning.

2.2 This study has illustrated that sociocultural perspective can enhance learning environment which can promote students' understanding and happiness in genetic learning. This approach may suitable for other biological topics or even other science disciplines but these needs to be further explored. In addition, this research was conducted at high school level. Further research could explore the approach with the primary and junior high school students.

2.3 The implementation of the SA-GIU gave professional development opportunity to the teacher participant. The teacher participant showed some changes in her teaching practice which more in accordance with guidelines of science education reform in Thailand. As this research mainly focus on learning, the future research should be done to investigate the effect of the SA-GIU implementation on the growth of pedagogical content knowledge of a teacher.

2.4 The follow up study should be further done. This would show the effect of the implementation on teacher's practice in a long term. Some questions need to be investigated such as if the teacher develop Pedagogical Content Knowledge in the next year of the instructional unit implementation; if they feel more comfortable to teach and can run the SA-GIU activities on her own with less supports; or what kind of support the teachers need in the second or third year of implementation.

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APPENDICES

Appendix A

Genetic Concepts Survey

Genetic Concepts Survey

Description:

- There are 17 main items with 19 questions in this test.
- There are two types of questions in this test.
    - Two-tiers questions: please choose the answer best describe your understanding and writ an assay or draw a picture to explain your answer
    - Open-ended questions: please write an assay to describe your idea.
- You can take 2 hours to complete the test.

ENJOY AND GOOD LUCK

Name... **Class**................

Question 1

Paradorn is a man who had double eyelids, pointed nose, and wavy hairs. He is also a good tennis player but does not good at singing. He get married with Meesuk; a woman who had single eyelids, plat nose and straight hairs. She is a good reporter but does not good at acting. When they have a first child was born, what might be found in their first child?
Mark a correct sigh (/) in a front of choice (s) which you think might be found in a first born child. (You can choose more than one)

	Eyelids-Single eyelids or double eye lids
	Pointed nose or flat nose
	Wavy hairs or straight hairs
	Good at tennis playing or reporting
	Not good at signing or acting

Please explain your answer.

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Question 2

Suppose that a man who does not have a dimple get married with a woman who had a dimple. They have 2 children; one had dimple but the other does not have.

From this situation, answer following questions. What controls existence of dimple? Why do you think like that?

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Question 3

From question 2, do you think which place the thing controls dimple is? Make correct mark in front of these choices.

	Chromosomes
	Cells at your cheeks
	Reproductive cells

	Nucleuses
	All cells with nucleuses
	Mature red blood cell

Please explain your answer?

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Question 4

Natalee had two cats; a black male and a white female. Natalee has observed for several years; she has found that kittens of these two cats always have all black hairs. How you may explain this situation? Why do you think like that? (You can write a paragraph, draw a chart or diagram.)

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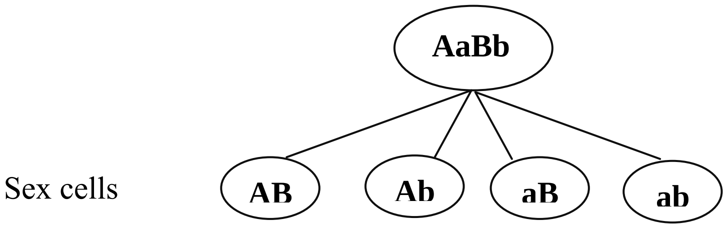
Question 5



From above picture, suppose that this dog have drooping ears and short hairs. Its form of gene is AaBb. Reproductive cells of this dog are AB, Ab, aB and ab. From this information, answers following questions using genetics principle.

5.1 What does letters A, a, B and b represent for in genetics?

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5.2 Why each reproductive cell has just latter A and B but never have reproductive cell with Aa or Bb?

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5.3 Why are there different types of reproductive cells?

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Item 6

In experiments, scientists found that within specie of bacteria, there were some cells of bacteria could produce insulin but some of the same specie could not. These scientists extracted a material from a cell with ability to produce insulin and then injected this extract into a cell of bacteria that could not produce insulin. They found that a bacteria cell that before could not produce insulin was be able to produce insulin. The scientists cultured this cell and found that later generation of this cell still could produce insulin.

From this experiment, what did the scientists extract from a bacteria cell? Why do you think like that?

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Item 7

What are the components of a chromosome? How are they important?

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Item 8

Do you think number of chromosome in a reproductive cell and a somatic cell is similar?

- If similar, why do you think like that?
- If not, how is it different? Why do you think like that?

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Item 9

What are the interrelationships among chromosomes, cell, genes, nucleus, alleles, and DNA? You may write a paragraph or draw a picture.

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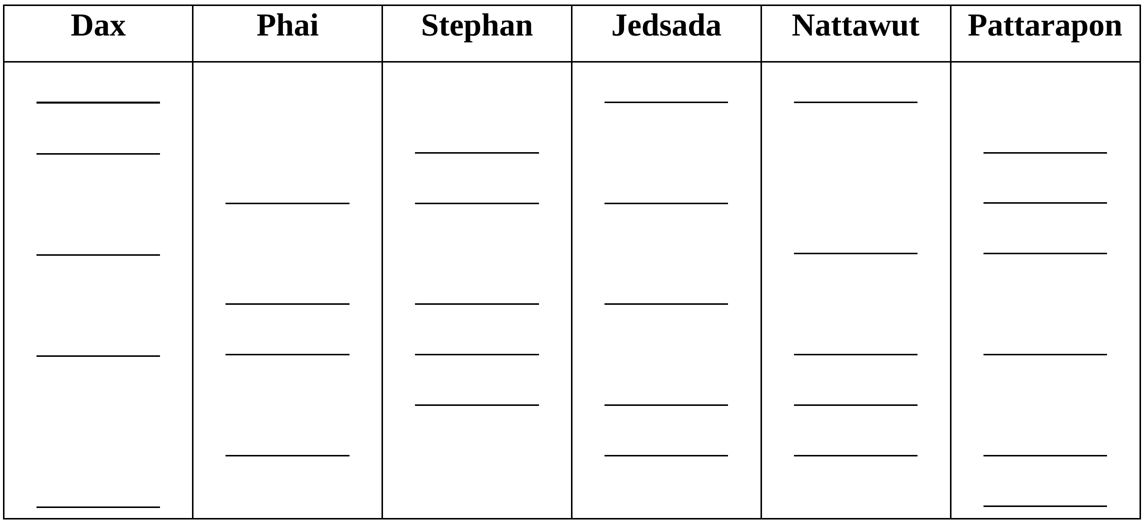
Item 10

Dax and Phai are searching for their missing child. There are 4 children including Stephan, Jedsada, Nattawut, and Pattarapon, claimed for descendant. Dax and Phai bring these to do DNA finger print test. The result is showed below. It is found that Pattapon is their child.



From this story, Why can DNA finger print tell that Pattaporn is their son? Explain your reason?

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Item 11

What is DNA and how is it important?

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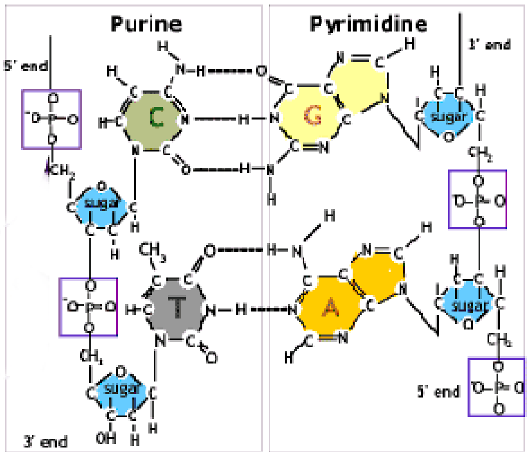
Item 12

In this picture, draw a line around an area you think it is a nucleotide?



Please explain why do you think like that?

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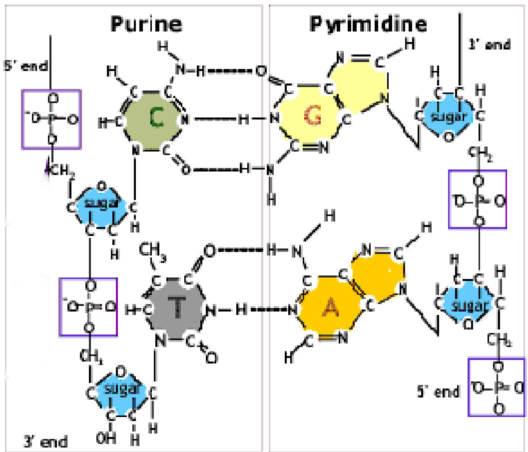
Item 13

In this picture, draw a line around an area you think it is a DNA?



Please explain why do you think like that?

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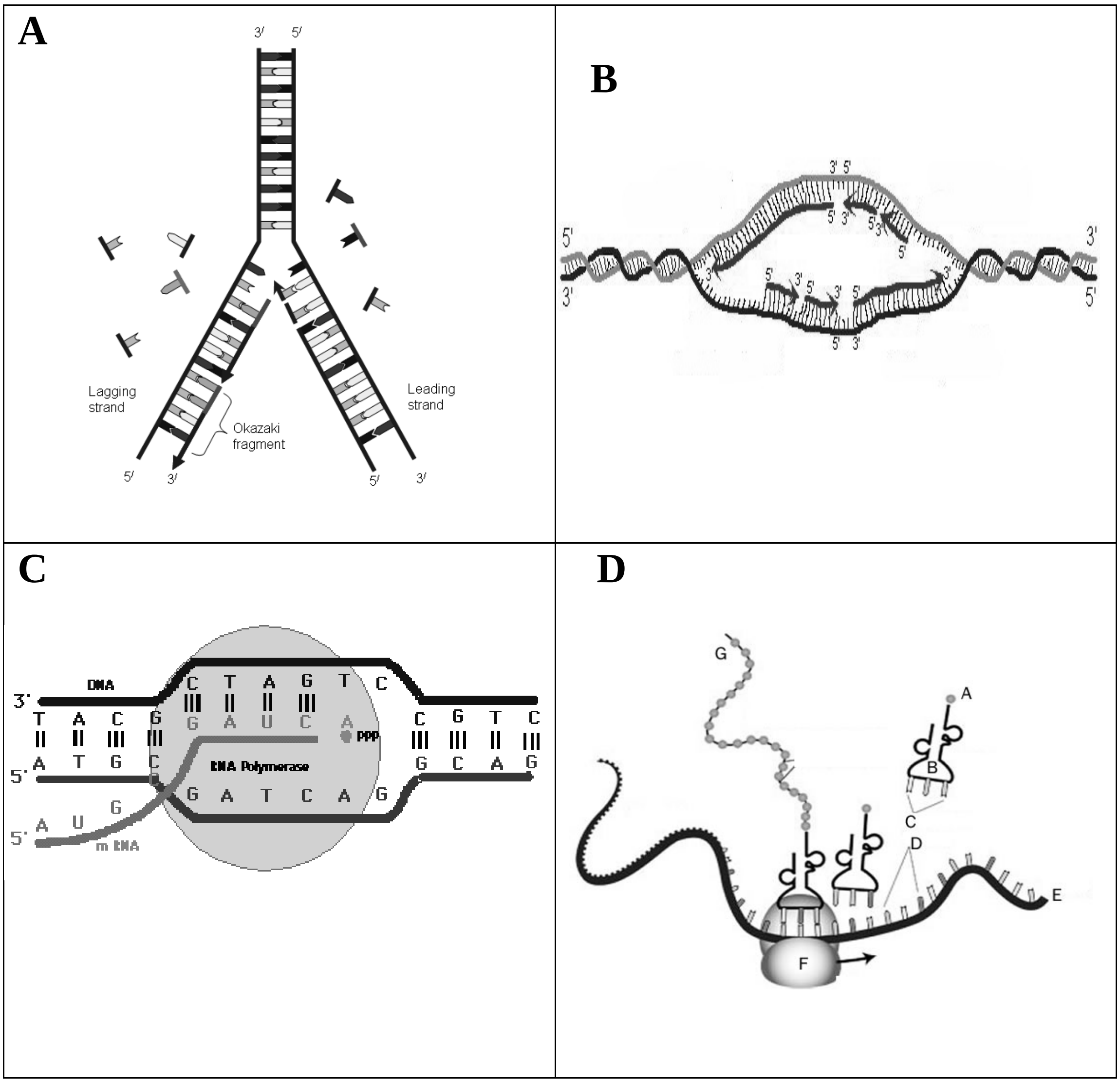
Item 14

From these four pictures, which one(s) represent(s) DNA replication? Why do you think like that?



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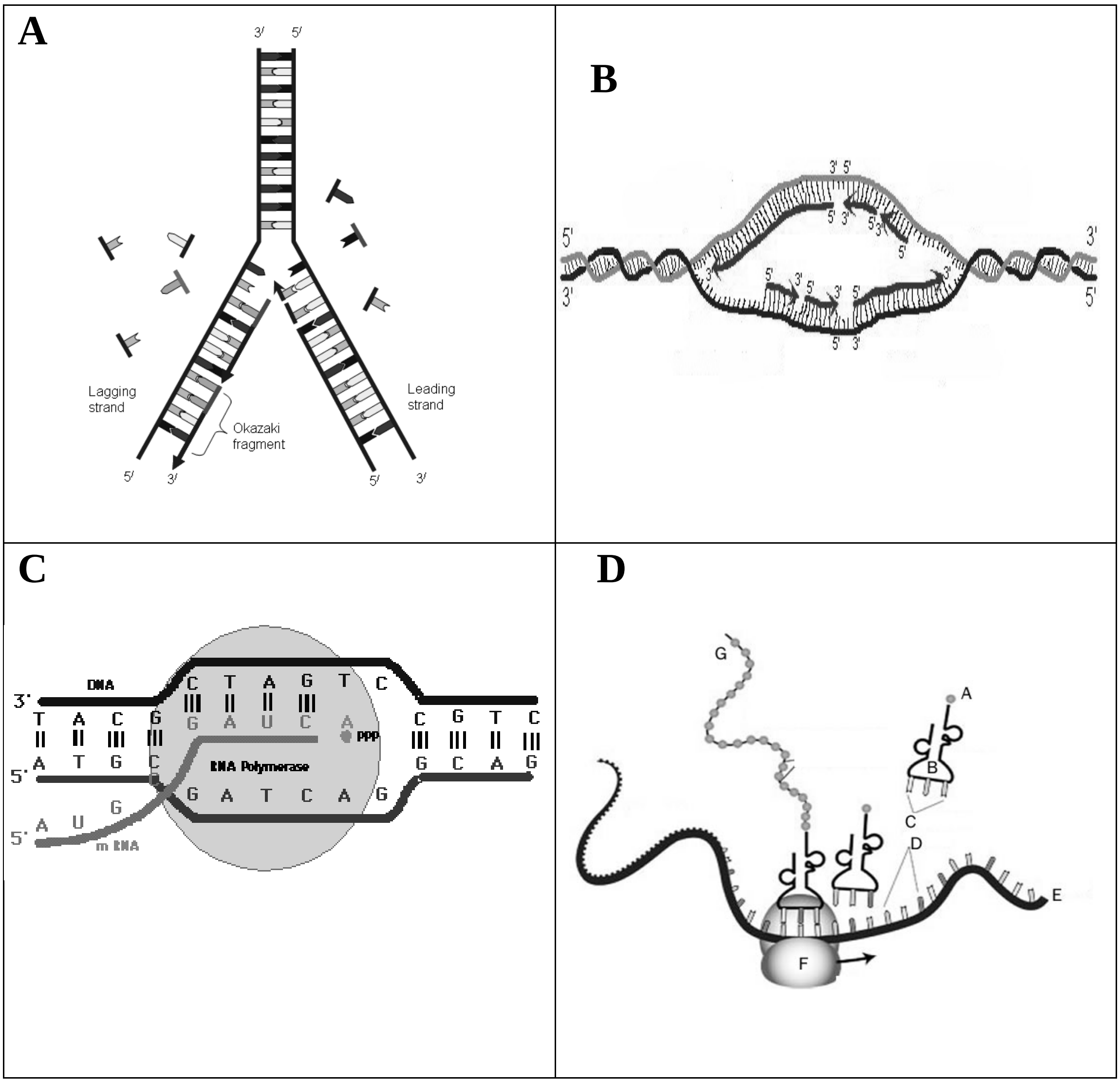
Item 15

From these four pictures, which one(s) represent(s) transcription? Why do you think like that



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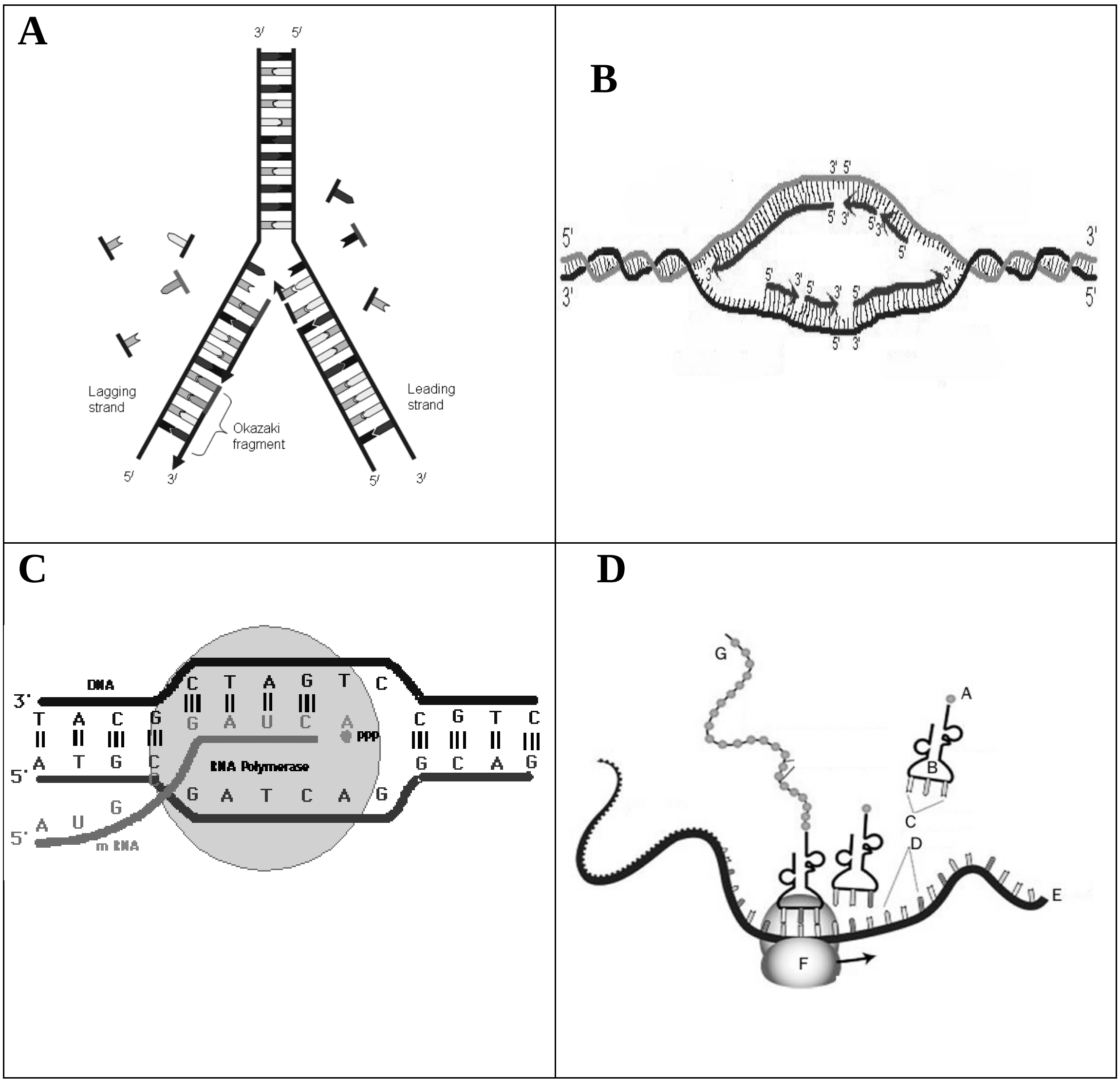
Item 16

From these four pictures, which one(s) represent(s) translation? Why do you think like that?



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Item 17

If someone said “this rat passed genetic engineering process”, how will you explain this process?

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 **Thank you so much** 

Appendix B

Teacher Interview Schedule

Teacher Interview Schedule

(In Pre-teaching meeting and supporting meeting)

Objective: To explore the reflections of the teacher participant on the SA-GIU

Main questions:

1. Why did you like or not like about teaching genetics in the instructional unit created from a sociocultural perspective?
2. How did you find teaching genetics using a sociocultural approach was useful for you?
3. What difficulties did you find from teaching genetics using a sociocultural approach?
4. What would make this unit more useful for you to teach genetics?
5. What would make this unit more useful for your students to learn genetics?

Appendix C

Students Interview Schedule

Teacher Interview Schedule

(Semi-structured group interivew)

Objective: To explore the reflections of the teacher participant on the SA-GIU

Main questions:

1. What was happening in the classroom during learning in the instructional unit?
2. How did you compare learning in the SA-GIU with former biology courses?
3. How did you find learning genetics using a sociocultural approach was useful for you to learn genetics?
4. What difficulties did you find from learning genetics using a sociocultural approach?
5. What have you or your friends been developed from learning in the SA-GIU?
6. Why did you like or not like about learning genetics in the instructional unit created from a sociocultural perspective?
7. What would make this unit more useful for you to learn genetics?
8. Would you like your teacher keeping teaching science by using sociocultural approach? Why?

CURRICULUM VITAE

NAME	: Mr. Pinit Khumwong		
BIRTH DATE	: July 12, 1979		
BIRTH PLACE	: Suphan Buri, Thailand		
E-MAIL ADDRESS	: pinit_lab@yahoo.com		
EDUCATION	: YEAR	INSTITUTE	DEGREE/DIPLOMA
	2002	Kasetsart Univ.	B.Sc. (Biology)
	2003	Kasetsart Univ.	Grad. Dip. Science Teaching

SCHOLARSHIP/AWAEDS : The scholarship to study B.Sc. and Grad. Dip. at Kasetsart University under the Project for the Production 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) 1998-2003

: The scholarship to pursue a doctoral study at Kasetsart University under the Program to Prepare Research and Development Personnels for Science Education (RDSE) which conducted jointly by the Royal Thai Government Agencies and the Institute for the Promotion of Teaching Science and Technology (IPST) 2003-2008