CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Education which focuses on subject matter is not enough to prepare students for coping with the problems which they will face in the real life situations (Wasi, 2000: i). To prepare students to be people who have the ability to cope with rapid changes in society is an important task of education. Students, as a part of society, need to be given not only knowledge, but also the ability to communicate their knowledge to the worldwide community. As Lemke (1990) argued, “When we talk science, we are helping to create, or re-create, a community of people who share certain beliefs and values” (p. x). To be an active member of society, it is necessary to have the ability to communicate with others. Communication is a way to help people understand each other.

In science education, molecular genetics is an important part of the content of genetics, which it is a part of the biology curriculum. To be a citizen in the world in the twenty-first century, it is ill-advised to ignore the advancement of molecular genetics. According to Buddhist philosophy, “life and education are identical” (Wasi, 2000: ii). Even though education in most countries of the world is separated from real life (Wasi, 2000: ii), television, journals, radio, and the internet make people aware of the number of ways in which molecular genetics have an influence on everyday life. Such media can collect the feedback of controversial issues in society from the population for the decision-makers (Kluger, 2002; Lemonick, 2002; and Stolze, 2002).

The researcher, a science teacher in a welfare school where disadvantaged students have particular circumstances, is interested in finding a way to teach genetics to these high school students in order to enhance their understanding of genetic concepts and ability to communicate their knowledge and to link it with their everyday life, which is related to the context of education in Thailand in the twenty-first century. From the rapid changes in society, many provinces of Thailand have at-risk or disadvantaged students. In Thailand, welfare education divisions call students in their schools ‘disadvantaged students’ (Welfare Education Department, 2001: 112-118).

In this chapter, the researcher will review the context of education in Thailand, disadvantaged students, social constructivist teaching and learning, genetics education overview, genetics conceptions, genetics alternative conceptions, communication and classroom interactions, and theoretical framework of the study. The information from this literature forms the main components of each molecular genetics instructional unit, which are molecular genetics topics, learning objectives, teaching and learning processes, materials, and assessment. The teaching and learning process in each unit, which are based on a social constructivist approach, was developed by the researcher.

The Context of Education in Thailand

Any proposal for a new classroom intervention, for example in molecular genetics, needs to take into account the current, developing national context of education. The National Education Act (1999), which is derived from the Constitution of the Kingdom of Thailand (1997), has a large-scale interest in national education reform (Office of the National Education Commission, 2000: 1). The rationales for learning reform and a learner-centred approach are the important themes in the national education reform.

The rationales for learning reform in Thailand are: “to improve the quality of life of the Thai people; to strengthen Thai society; to serve in harmony with the learning culture in the age of globalization; to serve the needs of learners, teachers, parents and Thai society; and to fulfil the law” (Office of the National Education Commission, 2000: 4-7). These rationales can motivate educators and science teachers in Thailand to prepare students for living in a global society.

Thai learning reform places an emphasis on a learner-centred approach. The Office of the National Education Commission (ONEC, 2000: 25-26) identifies the meaning of the learning process through the learner-centred approach as follows:

> The process involves identification of objectives, contents, activities, learning sources, instructional media and evaluation aimed at development of the "persons" and the enrichment of their "lives". Learners should therefore be allowed learning experiences to their highest potential and in line with their aptitude, interests and needs.

Constructivist teaching and learning are based on this approach, and are being introduced to the Thai classroom (Wasi, 2000: i). The learning and teaching management in science classrooms has a focus on the 'construction of meaning', and the role of the science teacher is to facilitate and mediate the construction of knowledge (Jones, 1997: 141). According to the rationales for learning reform in Thailand, teaching and learning which are based on a social constructivist approach can encourage students who live in a global world to have abilities to communicate their conceptual knowledge as a part of living in society. Furthermore, teaching and learning, based on a social constructivist perspective, corresponds with the National Education Act (1999, 2^{nd} edition 2002) in section 22 and section 24 of Thailand (Office of the National Education Commission, 2002: 13-15), in which teachers as facilitators should encourage students to fulfil their abilities.

In Thailand, the 1997 Constitution and the National Education Act (1999, 2^{nd} edition 2002) showed the significance of equity of the people. Everybody should have opportunity to spend at least 12 years in basic education. Disadvantaged students, who had particularly difficult circumstances, had chances to learn in welfare schools. However, their grade point averages in science including biology were low.

The teaching strategies for developing student understanding of genetic topics in this research place an emphasis on social constructivism, in which learners can construct their knowledge by participating with peers and having teachers as facilitators. Some of the qualities of science learners after completing 12 years of basic education include understanding about living organisms and living process, biodiversity, relations between living organisms and environment, the use of an investigation process, problem solving in science learning by hands-on, investigation, searching from a variety of learning sources, and communicating the knowledge in a number of presentations to other people (The Institute for the Promotion of Teaching Science and Technology, 2002: 3-9).

The Institute for the Promotion of Teaching Science and Technology (IPST) developed the genetics topics for high school students (IPST, 1990: 127-128). In 2002, IPST in Thailand published the *Handbook for Learning Management in the Section of Science* (IPST, 2002: 3-9). This handbook presents standards that science learners should have achieved after finishing high school. These are that the student should: understand the process of gene transfer, variation, mutation and its causes, what influences living organisms in their environment; the ability to communicate their knowledge to other people; and the ability to present their opinions about the results of developing and using science and technology in society and the environment.

IPST includes genetics in the Content 1: living organisms with living process. It sets some parts in Standard 1.2 of learning basic science and standards for students in Grades 10-12, which involve describing and discussing the genetic transfer process, variation, mutation and the causes of biodiversity (IPST, 2002: 10-16). Thus, after studying life science in Grades 10-12, the students should have the ability to investigate, describe and discuss genetic materials, chromosomes, transfer of genetic traits, genetic variation, mutation, and benefits and disadvantages of the results of inherited genetic traits (IPST, 2003: 110-111; IPST, 2002: 11, 16).

The significance of communication is presented in the aims of the principle of science teaching and learning and in the policy of the Department of General Education. A part of the aims for the learners of the principle of science teaching and learning in schools, which is related to communication, is “To develop…communication skills and ability to make decisions" (IPST, 2002: 3). A strategy in the policy of the Department of General Education is emphasized on communication, so communication skills are an important variable in this research.

A person who has life-relevant molecular genetics knowledge is aware of, and has communication skills which enable him or her to contribute to debate on scientific issues, especially those involving health and the environment, has an excellent base to become a good worker and citizen in Thailand who can make decisions about issues affecting society. This study will focus on processes used in developing instructional units that will enhance the understanding of genetics knowledge, and communication skills of the education of high school students in Thailand.

Disadvantaged Students

This topic presents information related to disadvantaged students, which includes education for disadvantaged students, schools for disadvantaged students, status and problems of welfare schools, and teaching for disadvantaged students.

In Thailand, educators realized the need for the equity of people and paid attention to disadvantaged students. All students should have the opportunity to learn science when equity becomes a part of the science classroom and environment. The 1997 Constitution of Thailand (B.E. 2540) presented that they are a part of Thai society and have the right to receive education as average students on Section 30, 55, and 80.

Section 30 of the 1997 Constitution of Thailand (B.E. 2540) warrants the rights of Thai people in education (Office of the Council of State, 1997) which is as follows:

> Section 30: All persons are equal before the law and shall enjoy equal protection under the law. Men and women shall enjoy equal rights. Unjust discrimination against a person on the grounds of difference in

> origin, race, language, gender, age, physical or health condition, personal status, economic or social standing, religious beliefs, education and training, or political views (if not in violation of the Constitution) shall not be permitted. Measures enacted by the State in order to eliminate obstacles to or to promote to eliminate obstacles to or to promote individuals" ability to exercise their rights and liberties, just as others, shall not be deemed as unjust discrimination under paragraph three.

The 1997 Constitution showed the importance of disadvantaged and disabled people in section 55 and 80 as follows:

> Section 55: The disabled or handicapped shall have the right to receive convenience in accessing public services and other assistance from the State, as provided by law;

> Section 80: The State shall protect and develop children and youth, promote equality between women and men, and create, reinforce and develop family integrity and the strength of communities. The State shall provide assistance to the elderly, the indigent, the disabled or handicapped and those lacking opportunity to enable them to have a good quality of life and the ability to depend on themselves.

According to the 1997 Constitution of Thailand (B.E. 2540), the National Education Act (B.E. 2542) showed the importance of equality in education in section 10 and section 22 (ONEC, 2002) as follows:

> Section 10: In the provision of education, all individuals shall have equal rights and opportunities to receive basic education provided by the State for the duration of at least 12 years. Such education, provided on a nationwide basis, shall be of quality and free of charge.

> Persons with physical, mental, intellectual, emotional, social, communication and learning deficiencies; those with physical disabilities; or the cripples; or those unable to support themselves; or those destitute or disadvantaged; shall have the rights and opportunities to receive basic education specially provided.
>
> Education for the disabled in the second paragraph shall be provided free of charge at birth or at first diagnosis. These persons shall have the right to access the facilities, media, services and other forms of educational aid in conformity with the criteria and procedures stipulated in the ministerial regulations.
>
> Education for specially gifted persons shall be provided in appropriate forms in accord with their competencies;
>
> Section 22: 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.

The 1997 Thai Constitution and the 1999 National Education Act showed the significance of the law in which every Thai person has to do and try to achieve the goal that everybody should have the chance to learn.

Education for Disadvantaged Students

Compensatory education and special education are education for disabled people or people who are removed from normal or average people (Cegelka, 1995). Both of them can be named as parts of multicultural education, in the beginning of an educational reform movement in the United States of America in 1960s and 1970s, which focused on equity of race, ethnicity, disability, gender, social class, and sexual orientation (Wilhelm, 1996). Compensatory education in the United States of America included an educational program for equality of education opportunity, such as Nigro-Americans and Chicanos (Mexican-American). In western countries, correcting education was education for emotionally-disordered children and children who are removed from their homes. The children in this group had to live in places like semi schools and houses of correction. In New Zealand, the particular groups of students were girls, Maori, students with special abilities, and students with special needs (Ministry of Education, 1997: 11-13). In Thailand, compensatory education was education for disadvantaged people in society and culture with average body and mind, such as hill tribes and people who lived in slums (Department of General Education, 1981: 7-23).

For the confusion of naming and grouping these children, the academic system was familiar with calling special education and compensatory education by the same term by using ‘special education’. Children who had got advantages from the special education were called ‘exceptional children’, who had different characters from normal or average children (both lower and higher than average) (Department of General Education, 1981: 7-23).

Children in compensatory education are also known by other terms, such as ‘at-risk students’ or ‘disadvantaged students’. Children in these groups have had particularly difficult circumstances in some ways. To categorize students in these groups depends on the indicators of each country. Pallas (1989) argued indicators of ‘at-risk students’ included poverty, race and ethnicity, family composition, mother’s education, and language background, which have influenced a youth to school failure. Normally, students from poor families have low expectations from people in the society and have achievement difficulties (Schwartz, 1987; Carter, 1999).

In the twenty first century, Thai society still has a number of disadvantaged students. H.R.H. Princess Maha Chakri Sirindhorn grouped disadvantaged people in Thailand (2004) as follows:

1. People in disadvantaged, remote areas, poorly served by educational services;

2. People who cannot afford to study;

3. People of limited intelligence;

4. Sick or undernourished people who do not have strength to study and work;

5. People with physical or mental disabilities;

6. Orphan children;

7. Children of transient people, e.g., construction workers, migrant labours in agriculture, people living in houseboats and fishermen;

8. Street children;

9. Child labourers, child soldiers and child sex-workers;

10. People who lacked the opportunity to study during childhood. Once beyond school age, the ability to learn may be reduced;

11. Prison inmates;

12. Refugees, illegal immigrants and people with no nationality;

13. People who do not understand the language of instruction;

14. People whose social context does not promote education, for instance, some societies beliefs that women do not need any study, or that grown-up children should work rather than study; and

15. People who have advanced ideas and great intelligence. Teachers, not knowing how to teach such children, get upset and do not want to teach them.

From the fifth item, students who have limitations in learning can be identified in the worldwide academic as ‘children with disability’. For the purposes of the Individuals with Disabilities Education Act (IDEA), the definition of a ‘child with disability’ means a child was evaluated and determined as meeting legal definitions under specifically defined categories as follows: autism, deaf-blindness, deafness, emotional disturbance, hearing impairment, mental retardation, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech or language impairment, Traumatic brain injury, and visual impairment (Childers, 2005).

In Thailand, disadvantaged students are children in particularly difficult circumstances who are violated of their rights; live on the streets; are prostitutes, orphans or abandoned children; are attacked; are detained in house of correction; are drug addicts; have severe diseases or of parents having the diseases; are poor; are of minority groups; or are gifted children (Office of the National Education Commission, 2000: 7-11; Welfare Education Division, 2000: 13-15).

Schools for Disadvantaged Students

In the United States of America, people have realized the importance of equality. They established the IDEA to safeguard the rights of at-risk children to a Free Appropriate Public Education (FAPE). IDEA is a public law that provides a federal legal structure by which federal money is distributed to assist both state and local educational agencies for educating children with disabilities (Childers, 2005). In New Zealand, the ministry of education showed the significance of curriculum for promoting girls, Maori, special abilities, and special needs students (Ministry of Education, 1997: 11-13).

Developing an educational program, which matches students and school is a responsibility of the school which has at-risk students (Pallas, 1989). Schwartz (1987) argued that family stress is a reason of achievement difficulties for students. High quality and diverse staff, such as a strong principal and director, and competent teachers, is a way to help a student to success in science.

The Educational Plan of Thailand (B.E. 2520) stated that the government had to set and support poor, disorder in body, in mind, in society, and disadvantaged education people. *Special Education Division* had responsibility in all 5 groups, which could separate into 2 sections: special education and welfare education as following in Table 2.1.

Table 2.1 Responsibility of Special Education and Welfare Education

Groups of People	Forms of Education Setting
Poor	Welfare Education
Disorder in body	Special Education
Disorder in mind	Special Education
Disorder in society	Welfare Education
Disadvantaged education people	Welfare Education

Source: Adapt from Document of Department of General Education (1981: 1-2)

In 1953, ‘Phanomthuan Welfare School’, the first welfare school for disadvantaged students was established in Kanchanaburi province. After that Department of General Education established welfare schools in each educational area and specific areas. The Educational system of each welfare schools was different, such as inclusion or specific for each disorder of children (Department of General Education, 1981: 85-97).

In 1999, thirty-nine welfare schools were in the welfare education division, Department of General Education. There were two service forms which students stayed in schools or went back home. Most welfare schools had elementary to high school levels using the normal curriculum from Ministry of Education.

In Thailand, the government section which had responsibility for the educating of children in disability circumstances was called the Welfare Education Division in the Ministry of Education. In the twenty-first century, welfare schools where were in sections of the Welfare Education Division were separated to each Education Service Area Office. Students who learned in welfare schools were disadvantaged students or underprivileged children in especially difficult circumstances (Thevintarapakti, 2000: 7).

Many countries, such as the United States of America, New Zealand, and Thailand, encouraged developing educational program for disadvantaged students in their countries. Nowadays, students with disabilities are more and more included in general or average classrooms (Bauer et al., 2001: 336-341). The educational programs which were suitable for disadvantaged students were the base education for all.

<u>Status and Problems of Schools for Disadvantaged Students</u>

Welfare schools differ from average schools, in location, types of students, and students' services. The specification of students in welfare schools and administration in schools had influenced to problems in the schools as follows (Department of General Education, 1981: 85-97):

1. The role of some welfare schools were not differs from average schools when the average schools were established nearby;

2. One of the policies of welfare schools was supporting education of disadvantaged students; but free education might be the persuasion of people to send their children *to* welfare schools;

3. The disadvantaged students who graduated from welfare schools had limitations to attend in the average school at a high level, the welfare schools should extend from elementary to at least junior high school level;

4. The free of charge tuition fee was an important factor in high expenses and the shortage of welfare budgets; and

5. Most students who studied at a higher level did not turn out to be leaders in their local areas, which did not accomplish the aims of welfare schools.

Nowadays, most of welfare schools extend to high school level and the policy of welfare schools have changed. However, most problems were stand still, such as item 1, 2, and 4. A variety of disadvantaged students is a problem in teaching and learning in welfare schools.

Teaching and Learning for Disadvantaged Students

Inclusion is a principle which implies that all children should have the same education rights. It is an effective way to promote teaching and learning for disadvantaged students. Inclusive education is the education policy based on the principle of inclusion which includes allowing disability children into the average classroom with average students. The policy ensures that the full variety of education needs is suitably accommodated and included in the average education system (Donald et al., 2002).

In New Zealand, an inclusive curriculum recognises the ideas of a particular groups of students, which include girls, Maori, special abilities, and special needs students. This policy can enrich education in science for all students (Ministry of Education, 1997: 11).

In Thailand, inclusion involves allowing disability children in average classroom from elementary to university level depending on the ability of each person

(Division of Disability People, 2000: 9; Niyomthum, 1996: 56). Disability people in the class should be able to use tools and instructional materials, be emotionally mature in, and not disturb the classroom system (Division of Disability People, 2000: 10).

Educators proposed inclusion for developing concepts and skills to work with peers (Chapman and Ware cited in Office of Supervision and Development of Education Standard, 2002: 3-4). Even though Niyomthum (1996: 55-58) argued that inclusion was a way to help each student living with happiness in society, she also suggested that an effective classroom should not set different types of disability children in the same class. Department of General Education (1981: 292) argued that inclusion was tried out in some schools in Bangkok before extending to other schools. However, the limitation of teachers and students in welfare schools in Thailand influenced the classroom setting. Some schools had to set different types of disability children in the same class.

The use of a flexible number of teaching strategies, along with an assessment and evaluation is an approach to decrease problems in inclusive classroom. For example, the seating position of hearing impaired students should be convenient to see the teacher's mouth. Instructional materials for inclusive classrooms should be easy to find, easy to use and understand, be used in a variety of activities, be inexpensive, and durable (Division of Disability People, 2000: 14, 102, 117, and 119). Schwartz (1987) suggested some ways that suited students in difficulty circumstances, which included small mixed ability cooperative groupings, solving problems independently, helping each others development skills, and cross-sex and mixed ability parings.

Vygotsky, who formulated a theoretical framework for the comprehensive, inclusive and humanistic practice of education for students with special needs, stresses the importance of social context both in the theory and practice of inclusive classrooms. He took the view that children come from different cultural and social environments, which can influence their cognition throughout their development process. Conducting a survey on students' ideas before creating some interventions or teachings, which are part of the procedure as a dynamic assessment, is thus influenced by Vygotsky's notion of 'zone of proximal development' (Kozulin et al., 2003: 7-8; Gindis, 2003: 207-217). Vygotsky (1978: 86) explained the meaning of the zone of proximal development as follows:

> The zone of proximal development is 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.

Mann et al. (1992: 24-55); Sleeter and Grant (1993: 52-58); and Palincsar (1998: 352-353) discussed that Vygotsky introduced the construct of the zone of proximal development (ZPD) as a fundamentally new approach to the problem that learning should be matched in some manner with the child's level of development. This approach can be used to explain students' learning development; even if they are learning disabilities students. It is the distance between the actual development level under adult guidance or in collaboration with more capable peers. Moreover, Vygotsky (1962: 103) argued that the child with the larger zone of proximal development will do much better in school. Sleeter and Grant (1993: 52-58) and Henson (2001: xviii-7) discussed that academic learning can be significantly enhanced when the teacher learns the culture of each child and links effectively within the child's zone of proximal development. They argued about social constructivism as the way to integrate teaching for diverse students in the education reform era.

To deal with a diversity of students, teachers have to think not only along the lines of a social constructivist approach, but also consider other theoretical perspectives for planning appropriate instruction for diverse students. Shepard (1991) argued that the perspectives recognized that intelligence and reasoning are developed abilities; choosing teaching and learning strategies which suit the concepts; the connection among the concepts; and students' social context which can be promote their learning. These theoretical perspectives related to general guidelines for helping disadvantaged students learn science. The guidelines were to identify their educational problems and background; what to expect for the students' possible achievements; to fulfill students' needs; to use concrete learning experiences; to provide experiences that the students will succeed in; to try some new educational approaches; to recognize students' talents; to provide time, materials, and experiences related to their abilities; to not underestimate the capabilities of the students; to use the same standards of grading and discipline for the whole class (including special needs students); to develop a trusting relationship with all students; and to adapt instruction and the curriculum to the students (Trowbridge et al., 2000). Lloyd (1987) discussed effective instructional strategies for students who are low achieving or having learning problems as disadvantaged students as follows: increase instructional time through small groups; preview prior learning; be careful of the sequencing of concepts and skills; receive active students' responses before moving to the next concept; introduce lessons by gaining the students' attention; provide immediate teacher feedback and correction; close the lesson by reviewing skills, concepts, or previewing the next day's lesson; and smooth transition between lessons.

Lynch (1989) argued an outline of philosophy of teaching diverse students as follows: respect individual persons, accept participatory climate, apparent human right, implement the democratic process, create environment, engage moral, facilitate cognitive process, think about communication, and engage both aims and means.

To help learning disabled and mentally challenged students learn science, teachers should use multi-sensory approaches to learning (e.g. visual and auditory), reduce interruptions in the class, avoid frustration, to start conceptual development at a sensory-motor or concrete level before moving to an abstract level, and to develop students' self-esteem. For helping hearing impaired students learn science, one should help them to choose their seat, to learn the effective way of communication with them, and to find how the listening helper should be considered (Trowbridge et al., 2000). The teacher can help learning disabilities students learn by: allowing the students to demonstrate their understanding through group projects or oral reports; presenting information using illustrations or diagrams; and incorporating rhythm or music or movement into lessons (Cheney, 1989). Tomlinson (2001: 12-15) argued the ways to promote struggling learners maximize their capacity in school were that teachers should view lessons in a positive manner and use a variety of ways to teach. Sleeter and Grant (1993: 66-69) discussed how minority students can develop their learning when talking with peers in cooperative learning contexts.

Some researchers discussed using Vygotsky's idea for disadvantaged student learning. Campione et al. (1994) reported reading, writing, and computing in the service of learning the scientific content of 6-15 year-olds by the zone of proximal development. Their report showed that disadvantaged students can develop their learning when they learned in a community which promoted their learning, such as discussion among participants. Palincsar and Klenk (1992) discussed using the zone of proximal development of instructional strategies which support collaborative discourse, flexible application of comprehension strategies, and appropriate meaningful opportunities for reading and writing would contribute to the learning of disabilities students. Mallory and New (1994) discussed social constructivist paradigms were an important way to encourage inclusive early childhood learning. Social constructivist teaching and learning was available in inclusive classrooms. It provided students' opportunities to make choices, solve problems and learn from each other by emphasis on social context and social activity (Bloom et al., 1999). Even though Graham and Harris (1994) reported unsatisfied implications of constructivism for teaching writing to students with special needs both in whole language and process approaches to writing instruction, Englert (1992) argued social constructivism could provide an important theoretical and instructional framework for promoting self-regulation and empowerment of writers with learning disabilities in writing.

In this study, the researcher developed genetic instructional units for disadvantaged high school students. The units were concerning the abilities of each student, students' prior knowledge, small group participation, the sequencing and transition of each concept, teacher and student participation, concrete learning experiences, a variety of teaching strategies and recognizing communication among peers and between teacher and students.

In Thailand, normal and disadvantaged students are motivated to achieve national goals on science content standards. Developing social relationships and creating classroom environments in an inclusive classroom that promote students' learning are the challenges. To promote disadvantaged students' learning, teachers should have both strong content and understanding in the learning development of each disadvantaged student.

Social Constructivist Teaching and Learning

Constructivism has been defined by a number of educators, including Gruender (1989), Tobin (1990) and Colburn (2000). The multiple meanings of constructivism were shown clearly by Colburn (2000:9) who argued that constructivism can be a philosophy, a theory or a teaching strategy. As a philosophy, Colburn showed that the nature of reality under constructivism was "what was generally agreed upon by the 'majority' of the scientific community" so that ideas were not held to be absolutely true or false (p.9). Colburn's ideas show the importance of the society, times and cultures in which people live that can influence people's perceived ideas of reality. Colburn's idea is related to Gruender's (1989) who said that, "Constructivism is a philosophy of education whose central theme is that learning is a process by means of which we, individually, literally construct the form and substance of our own world out of our experiences" (p.170). As a learning theory, Tobin (1990) argued that, "constructivism is a theory that assumes knowledge cannot exist outside the bodies of cognizing beings" (p.30). The view of constructivist teaching which is consistent with this and was outlined by Colburn is that individual students come into the classroom with their own beliefs and scientific knowledge (Colburn, 2000: 9).

In this research, constructivism is viewed as a philosophy of learning which describes how people learn and construct their knowledge. This philosophy recognizes the construction of new understanding as a combination of prior learning or prior knowledge and new information. In this process active learners construct their own knowledge with teachers acting as facilitators.

Social constructivism is a variant of constructivism that construes learning as a form of cultural apprenticeship in which learning and what is learned cannot be separated from the context of learning (Osborne, 1996: 60-62). In this view, human scientific knowledge depends on capabilities, culture, and conceptual tools. Vygotsky is a key writer on social views of learning. His perspective of social constructivism is well known in education. From his view, knowledge develops through the appropriation of the culture, and through social interaction between children and more expert others. He argues that concepts cannot grow without social interaction and that the discrepancy between a child's actual mental age and the level he/she reaches in solving problems with the assistance of others indicates the zone of his proximal development. He introduced the construct of the zone of proximal development (ZPD) as a fundamentally new approach to the problem that learning should be matched in some manner with the child's level of development (Palincsar, 1998: 352).

To help student learning through the development of potential in a zone of proximal development scaffolding is an important tool. Kiraly (2000) referred to scaffolding as the support offered by the teacher to assist learners in the collaborative construction of their mental models. Hence, scaffolding is a central concept in social constructivist thinking. Scaffolding can take a variety of forms of which three are meaningful and culturally desirable: dynamic assessments, a variety of supports (e.g. modelling and extensive dialogue), and support from more capable peers or adults (Palincsar, 1998; Kiraly, 2000; Bauer et al., 2001). Dynamic assessment can help teachers' understanding in students' learning. For example, when students have alternative conceptions teacher can help the students correct the alternative conceptions and moving to the scientific conception. Language is a type of supports, which is an important scaffolding tool in developing understanding through interactions with others (Howe, 1996: 42, 48). From the view of support from more capable experts, Hodson and Hodson (1998) argued Vygotskian theory gives teachers a central role in leading children and students to new levels of conceptual understanding by interacting and talking with them. Any teaching activities should also prompt a given student to participate effectively in activities with a more capable peer. Moreover, teaching and learning should also involve guided and modelled participation.

For constructivist teaching, the implementation of social constructivist strategies in science teaching requires that students use their existing knowledge as the starting point for change towards scientifically acceptable concepts (Hand et al., 1997). Driver and Oldham (1986) argued that to start teaching students should have chance to develop a sense of purpose and motivation for learning the topic, but Cosgrove and Osborne (2001: 108-110) suggested to start teaching by extracting students' ideas through discussion or written response before motivating students' experiences. Then, both of the literatures argued using a variety of activities, such as asking open-ended questions, group discussion, designing artefacts, and writing. In this stage, teachers could present evidence of scientists' view; and students could clarify and exchange their ideas with peers, construct new ideas, and evaluate new ideas. Students should have opportunities to use their developed ideas in a variety of situations. Then, the teacher should encourage students to attempt alternative conceptions, which could be comparing their ideas at least between the start and the end of the lesson.

The important stage which was argued in the science education area of social constructivist teaching is activities. Windschitl (1999: 192-193) supported using questions and activities, and Osborne (1996: 63) argued activities were composed of structure exercises and be group activities, such as group discussion. For the types of activities in social constructivist perspective, Jenkins (2000:599) and Colburn (2000: 11-12) and Donald et al. (2002) argued that practical activity, which was composed of using questions, demonstrations, and working with models suited for teaching.

To do group activities in social constructivist teaching was argued from many educators. Driver and Oldham (1986), Osborne (1996), and Colburn (2000) stated using group work in constructivist teaching. Stanbridge (1990) suggested using only small groups. In another way, Hand et al. (1997) argued using both small and large group work. Hand et al. (1991) suggested using small group work and then whole class group work.

Constructivist learning was stated in a number of papers. The Generative Learning Model (GLM) of Cosgrove and Osborne (2001) stated that teaching and learning should be composed of 'Preliminary phase', 'Focus phase', 'Challenge phase', and 'Application phase'. The learning activities were used in the last three phases. 'Focus phase' includes using materials to explore concepts, asking questions related to concepts, and presenting their views in group or class discussions. 'Challenge phase' includes considering other students and compares the scientist's view with the class's view. 'Application phase' includes discussing and debating the merits of solutions, solving practical problems using the concept as a basis, and presenting solutions to others in the class.

The participations of students in classroom activities was shown as 'Active participant' (Osborne, 1996: 63; Jaworski, 2005) or 'Active learning' (Jenkins, 2000: 599) or 'Active learners' (Perkins, 1999: 7-9; Gray, 2005), which were presented as an important indicator in constructivist learning. The role of the students in the classroom was not only as passive learners, but also play a key role to present their ideas and construct their ideas by linking among their existing knowledge and the new knowledge. Gray (2005) argued the same indicators as Perkins (1999), including that students should be able to build and create meaning and knowledge by setting hypothesis and investigating. However, each of them suggested some additional indicators. Gray (2005) argued for questioning, investigating, imagining, inventing, and reflecting and making associations with prior knowledge to reach new understandings. Perkins (1999) argued that discussion, debate, and solving in problem-based learning could be identified as student learning in a constructivist perspective.

In conclusion, social constructivism recognizes a combination of prior knowledge and new knowledge through social interaction among more capable people. Language as a scaffolding tool which students can use in their learning development through social interaction for developing their potential development from the actual development level in student's Zone of Proximal Development (ZPD). Teachers can develop student learning in concepts and communications by using a variety of practical activities with grouping techniques, and dynamic assessment. From social constructivist perspective, teachers should start the lesson by motivating students into the lesson, checking students' prior knowledge, using a variety of activities including social interactions for helping students to reach scientific view, and using a dynamic assessment to check students' understanding periodically. The researcher used the indicators for social constructivist teaching in the genetic classroom as follows: 'Orientation stage' includes invitation and checking students' prior knowledge; 'Focus stage' includes inquiry, small group discussion, or investigation; and 'Conclusion stage' includes a whole class discussion. In the orientation stage, the teacher invites the students into the lessons by referring to the former lessons or social issues. In each stage, students have chances to participate with their peers and teacher. Checking students' prior knowledge is a way to explore the existing knowledge of students as checking the beginning point of the zone of proximal development of each student. Teachers should use social interaction activities with practical instructional materials as scaffolds for helping students learning. According to Osborne's perspective, knowledge can be made by human discourse (1996: 60-68), using inquiry, small group discussion or investigation are the strategies to promote students' thinking and participating between students and the teacher or among peers through social interaction in science classroom. To encourage students in the whole class discussion is a strategy to contour students' ideas and also to promote classroom participation. In this research, students should be as active learners, who can set questions, investigate, invent, discuss by speaking, writing, and presenting. They should develop their learning in both concepts and communication skills.

Genetics Education Overview

Genetics education was a steadily growing aspect of biology curricula around the world during the twentieth century. Genetics itself was initiated when the studies of plant hybrids by Gregor Mendel in 1865 were rediscovered and promulgated by Hugo de Vries, Carl Correns, and Erich von Tschermak in Amsterdam, Tubingen and Vienna in 1900. In 1906, 'Genetics' was used by William Bateson. The word 'Gene', to describe the basic unit of heredity was used by Johansen in 1909 (Petersen, 1992:11). The importance of genetics is now universally recognised as having a direct effect on all life, and is now involved in the science curricula of many countries around the world.

Most developed countries emphasise the importance of genetics in their science curricula. For example, in the *Science Content Standards* of the United States of America, there are sections which provide standards for genetics contents to be taught to students in different grades (National Research Council (U.S.), 1996:106; National Science Teachers Association, 1996: 84-92, 98-105), such as 'Reproduction and Heredity' for Grades 5 - 8, and 'Molecular Basis of Heredity' for Grades 9 - 12, both in the 'Life Science Standards' section. In New Zealand, in *Science in the New Zealand Curriculum*, the Ministry of Education presents the achievement objectives in genetics for students in Levels 6 - 8 (about Grades 7-12), for content that includes chromosomes and DNA, mutation, and genetic engineering (Ministry of Education, 1997:64-69).

Genetics in the science curricula presents the importance of genetics knowledge to the community. Many developing countries, such as Thailand, try to develop their people to become knowledgeable in genetics.

Genetics in the Thai Curriculum

In 1972, the Institute for the Promotion of Teaching Science and Technology (IPST) in Thailand was established to develop science and mathematics curricula for students from Grades 1 to 12. IPST has responsibility for textbooks, teachers' guides, and equipment design with the contribution of the Department of Curriculum and Instruction Development in the Ministry of Education.

In 1990, the IPST developed a series of topics in genetics for high school students (IPST, 1990:127-128). Learning reform in 1999, which is an effect from National Education Act (B.E. 2542), had a significant influence on the science curriculum in Thailand. As a result of learning reform, in 2002, IPST in Thailand published the *Handbook for Science Learning Management* (IPST, 2002:3-9). Genetics is an important topic in the handbook.

The *Handbook for Science Learning Management* discusses genetics in the Qualities of a Science Learner, Science Contents, and Science Content Standards (IPST, 2002:5-9). The qualities of a science learner after finishing 12 years basic science education in genetics are to understand about living things and living processes…and relationships between living things and the environment (IPST, 2002:5-9). After finishing Grades 10 to 12, the science learner should be able to understand the inheritance process, variation, mutation, evolution of living things, biodiversity, and things that have an influence on living things in different environments.

The Science Contents are the contents of basic science which every Thai student should know. There are eight main science contents. The content of genetics is in the first science content, *Living Things and Living Processes.*

The Science Content Standards are the criteria of the qualities of learners, and the objectives for developing students. The Science Content Standards has two parts: the overview of the basic science content standards; and the specific science content standards in each range.

According to the genetics content of the basic science content standards, living things and living processes (science standard 1.2), "the students should be able to understand the processes of reproduction and inheritance, evolution of living things, biodiversity, technological applications that impact on man and the environment, carry out investigative processes, have scientific mind, communicate what is learned and apply the knowledge gained" (IPST, 2002:11).

Since 2003, the Ministry of Education in Thailand, has tried to encourage each school to create their own school-based curriculum. This means teachers should create their own lessons which suit students in each school. However, the majority base their lessons on the Ministry of Education and IPST materials. Even though the *Handbook for Science Learning Management* can be a framework for science teachers to create their own curriculum, teachers should involve the updated genetic contents and create instructional units in their own curriculum for helping students to have the ability to understand genetics, communicate their knowledge about genetics in their societies, which are related to the qualities of science learners after the students graduate from Grades 1 – 12 (IPST, 2002: 5-6).

The significance of genetics is presented in each grade level (IPST, 2002:16) as follows:

1. The genetics in science content standard 1.2 for Grades 1-3 is ‘student can explain that living organisms transfer inheritance traits from parent to offspring’.

2. The genetics in science content standard 1.2 for Grades 4-6 is ‘student can explain transferring of inheritance traits from generation to generation including variation trait from ancestors’.

3. The genetics in science content standard 1.2 for Grade 7-9 is ‘student can investigate, discuss, and explain about genetic material in nucleus which control traits and process of cell, and genetic materials can transfer to offspring, and realize the advantages of inheritance knowledge’.

4. The genetics in science content standard 1.2 at the end of Grade 12 is the final year of basic schooling, states “the student should be able to search for information, discuss and explain the process of inheritance through genetic material, genetic variation, mutation, and biodiversity”.

Teaching genetics in each grade level should rely on the science content standards. From the earlier learning reform, many teachers are still concerned about genetics in the former Thai textbooks which created were by IPST.

Genetics in Thai Textbooks

The Department of Curriculum and Instruction Development and IPST had to produce a textbook before the Ministry of Education allowed each school to develop its own curriculum. The genetics contents in the Thai textbooks, which were taught in Grade 8 and at high school level, still depended on the 1983 version (for Grade 8) and 1990 version (for high school level) of these textbooks.

The genetics contents which were in Grade 8 are genetics basics. The six basic genetics topics in Grade 8 presented in 'Science 203' are (IPST, 1983: content): genes, chromosomes, dominant allele and recessive allele, the independent assortment of genes, genetic disease, and sex chromosomes.

After students have learnt the basic genetics content in Grade 8, they have to learn these genetics contents in more detail in high school, together with some additional contents. Nine genetics topics at high school level are presented in 'Science 048' (IPST, 2000: ii): genetic characteristics, discovery of genetic knowledge, chromosomes, genes and chromosomes, genetic materials, characteristics of genetic materials, DNA in prokaryote and eukaryote, mutation, and genetic engineering.

According to the school-based curriculum in Thailand, each school does not teach genetics at the same grade in high school, e.g. they can be taught in Grade 10, 11, or 12. However, after the students graduate from Grades 10 - 12, they should have learned the whole of genetics contents and should have the abilities and the qualities of science learners which are presented in the *Handbook for Science Learning Management*. Genetics content from the 1990 textbook version can be a guideline of this.

In the handbook, which was published by the Institute for the Promotion of Teaching Science and Technology (IPST) in Thailand, not only the significance of scientific content was focused on, but also communication skills of students (IPST, 2002: 3).

Genetics Conceptions

Genetic concepts were shown in junior high school and high school levels in Thai textbooks. Even though, from the Thailand learning reform, science educators tried to encourage science teachers to create their own curriculum, which were suitable for their students, the textbooks of IPST were in fact popular for the science teachers. This section presents genetic concepts in junior high school and high school levels.

Genetics Conceptions in Junior High School

Genetic concepts in junior high school were shown in two topics, which were abnormal pregnancy and *in vitro* fertilization. The abnormal pregnancy topic had three subtopics, which were identical and non-identical twins, abnormal genetic material (gene, chromosome, dominant gene, recessive gene), and independent assortment of genes, and Thalassemia). The *in Vitro* fertilization topic had three subtopics, which were *in vitro* babies, Gamete Intra Fallopian Transfer (GIFT), and sex chromosome. Genetic concepts in junior high school were composed of gene, chromosome, dominant and recessive allele, the independent assortment of genes, genetic diseases, and sex chromosomes as follows:

1. Gene

1.1 The gene or genetic unit is the unit that controls the traits of living things.

1.2 Traits can transfer from parents to offspring.

1.3 The gene or genetic unit of each trait has a pair of chromosomes.

1.4 Each pair of genes is on each pair of chromosome.

1.5 Each genetic unit which presents a trait comes from both father and mother.

2. Chromosome

2.1 The chromosome is in the nucleus of each cell.

2.2 Chromosomes come in pairs.

2.3 The human chromosome has 23 pairs.

2.4 The number of chromosomes in a reproductive cell (sex cell) is half that of a body cell (somatic cell*).

3. Dominant and Recessive Allele

3.1 The genetic unit which presents as dominant is the ‘dominant allele’.

3.2 The genetic unit which was controlled by and is a pair of the dominant allele is the ‘recessive allele’.

4. The Independent Assortment of Genes

The independent assortment of genes is the mixing of genes by natural or uncontrolled matching.

5. The Genetic Diseases

5.1 If the abnormal recessive gene is in the normal person, the genetic unit can show in the offspring.

5.2 Marriage between relatives increases the opportunity of the wrong traits in their offspring.

6. Sex Chromosome

6.1 The gender of baby depends on the pair of sex chromosomes.

6.2 Female has XX chromosome.

6.3 Male has XY chromosome.

Genetics Conceptions in High School Level

Genetic conceptions at high school level were shown in nine topics, which were genetic characteristics, discovery of genetic knowledge, chromosome, gene and chromosome, genetic materials, characteristics of genetic materials, DNA in prokaryote and eukaryote, mutation, and genetic engineering.

Subtopics and genetic concepts of each topic were shown as follows:

1. Genetic Characteristics

1.1 Genetic characteristics and environment

1.2 Genetic variation

1.2.1 Continuous variation

1.2.2 Discontinuous variation

Genetic Characteristics concepts were;

a. Genetic characteristics are specific traits of each living thing, which can transfer from one generation to the next.

b. Some genetic characteristics have continuous variation, and some have discontinuous variation.

c. Differences in the characteristics of living things depend on both genetic differences and the influences of environment.

d. Genetic variation is variation in genetic sequences (or alleles). Phenotype is affected by both genotype and environment.

e. Continuous variation = differences cannot be clearly seen.

f. Discontinuous variation = differences can be clearly seen.

2. Discovery of Genetic Knowledge

2.1 Mendel and his genetic studies

2.1.1 Dominant

2.1.2 Recessive

2.1.3 Dominant gene

2.1.4 Recessive gene

2.1.5 Genotype

2.1.6 Phenotype

2.1.7 Homozygous (pureline, pure-breeding)

2.1.8 Heterozygous (hybrid)

2.2 Probability and Law of Segregation

2.3 Test cross/ Back cross

2.4 Law of Independent Assortment

2.4.1 Monohybrid cross

2.4.2 Dihybrid cross

2.5 Allele

2.5.1 Allelic gene

2.5.2 Incomplete dominant

2.5.3 Multiple alleles

2.5.4 Codominant

2.6 Multiple genes/ Polygene

Genetic conceptions of these topics were;

a. The probability of genotype and phenotype of offspring can be predicted by studying the genotype of parents.

b. Dominant is an allele or character that expresses its phenotype in a heterozygote.

c. Recessive is an allele or character that does not express its phenotype in a heterozygote.

d. The gene is the genetic unit which is the basic unit of heredity.

e. Genes can be in different forms, or alleles.

f. The genotype is the allelic constitution of a given individual.

g. The phenotype is physical appearance by which characteristics are expressed.

h. The pairs of alleles which control the characters of living things may be homozygous or heterozygous.

i. Homozygous, pure-breeding is having two identical alleles at an identical gene locus.

j. Heterozygous, hybrid is having two different alleles at a gene locus.

k. The Law of Segregation (determined by monohybrid cross): all gametes produced by a diploid individual will have only one member of each pair of alleles.

l. A test cross is used to decide whether an F_1 individual with the dominant phenotype is homozygous or heterozygous. Such a cross is also called a back cross because the F_1 individual is crossed with an individual with the same genotype as recessive parent (P_2).

m. The Law of Independent Assortment; genes/alleles on different chromosomes go randomly to different gametes during the production of sex cells.

n. Monohybrid cross is a cross between two individuals at a single gene locus. The researcher is interested in only one specific characteristic.

o. Dihybrid cross is a cross between two individuals at two gene loci. The researcher is interested in two specific characteristics.

p. Incomplete dominant is the heterozygote's phenotype intermediate between the two homozygotes.

q. Multiple alleles: there may be more than two alleles for a single gene locus, though any given individual will have only two alleles (e.g. human ABO blood groups: alleles are I^A, I^B, i individuals can be AA AB AO BB BO OO).

r. Codominant is two alleles whose phenotypic effects are both expressed in the heterozygote.

s. Multiple genes (polygenes) occur where a number of gene loci influence phenotype (e.g. height in humans, or skin colour in humans).

3. Chromosome

3.1 Shape and characteristics

3.1.1 Centromere

3.1.2 Homologous chromosome

3.2 Human Chromosome

3.2.1 Shape

3.2.2 Quantity

3.2.3 Karyotype

3.2.4 Autosome

3.2.5 Sex chromosome

3.3 Disabilities of human chromosome

3.3.1 Cri-du-chat/ Cat-cry syndrome

3.3.2 Down's syndrome

3.3.3 Klinefelter's syndrome

3.3.4 Turner's syndrom

Genetic conceptions of these topics were shown as follows:

a. The chromosome, containing the genes of living things, is the physical structure which is composed of DNA and protein.

b. The chromosome is a threadlike structure, which can be dyed, located in the nucleus of cells.

c. The chromosome can be dyed by 'Giemsa' stain. G-banding is a variety of bands which will appear in the ultraviolet light after being dyed.

d. The centromere is a chromosomal region where spindle fibres are attached during cell division.

e. Homologous chromosomes are chromosomes which are identical in visible structure, in order and nature of genes they carry.

f. The pairs of chromosome can be identified by size, shape, and position of centromere.

g. The size and shape of the chromosome can be studied during cell division.

h. The easiest body cell in which to study the human chromosome is the lymphocyte.

i. Human have 46 chromosomes, 23 pairs (diploid number, 2n=46).

j. Karyotype is a pictorial or photographic representation of all chromosomes in an individual. Chromosomes can be characterized by the number, size, and shape in karyotype.

k. The autosome is any chromosome other than a sex chromosome. Both male and female humans have 22 pairs of autosomes.

l. The sex chromosome is the chromosome involved in sex determination. Humans have chromosome pairs which are different in male and female. The male has XY chromosomes. The female has XX chromosomes. Chromosome Y is smaller than chromosome X.

m. Abnormal chromosomes in humans can present abnormal heritable characteristics.

n. Cri-du-chat or cat-cry syndrome in humans is caused by the deletion of a substantial part of the short arm of the chromosome 5. Humans with this syndrome generally have a characteristic high-pitched, catlike cry as well as microcephaly (small heads) and severe mental retardation. Generally, they die in infancy or early childhood.

o. Down's syndrome in humans is due to trisomy of chromosome 21. Humans with this syndrome are generally characterized by mental retardation, distinctive palm prints, cardiac problems, and a common facial appearance. In general, mortality is higher than normal.

p. Klinefelter's syndrome is found in males who have more than one X chromosome. The males have more than 46 chromosomes. The sex chromosome of the male is XXY or XXXY. The male with this syndrome generally has relatively mild abnormality. They are sterile with some female characteristics.

q. Turner's syndrome is found in females who have only a single X chromosome. They have only 45 chromosomes. They are sterile, short in stature, with some neck webbing.

4. Gene and Chromosome

4.1 Gene and chromosome location

4.2 Linked genes and gene recombination

4.3 Gene in autosome

4.3.1 Gene with Rh system

4.3.2 Gene with Thalassemia

4.4 Gene in sex chromosome/ sex-linked gene

4.4.1 Eye colour of fruitfly

4.4.2 Colour blindness in humans

4.4.3 Glucose-6-Phosphate Dehydrogenase

These are genetic conceptions of these topics.

a. The gene is the basic unit of heredity, and compasses a sequence of nucleotides.

b. Genes are found in chromosomes, each chromosome has a number of genes.

c. Alleles which are in the same chromosome can be inherited together.

d. Alleles which are in the same chromosome can separate from each other, due to crossing over and recombination.

e. Crossing over and recombination is the physical exchange between the characteristics of homologous chromosomes that takes place in meiosis I.

f. Linked genes are genes which have low probability of crossing over, and a high percentage to being inherited together.

g. Gene recombination results from crossing over and production of new combinations of alleles. Totally new genetic material is produced only by mutation. This is the raw material of evolution.

h. Most inheritance of genes on autosomes follows Mendelian patterns of inheritance except where influenced by, for example, linkage genes, incomplete dominance, polygenic inheritance, epistasis.

i. The Rh system in blood group types is controlled by one gene in chromosome 1. Alleles which are concerned with Rh system have two alleles.

j. Thalassemia is a genetic disease. The symptom is anaemia. The patient may have an enlarged liver, heart disease, etc. Thalassemia patients fail to produce a functional mRNA for one of the two major hemoglobin proteins.

k. A carrier is the person who has the Thalassemia allele, but does not present the symptoms. This person must be heterozygous.

l. Pedigree is the diagram which illustrates the inheritance relationship between people in the family.

m. A sex-linked gene is on a sex chromosome (X or Y chromosome), such as the gene which controls the eye color in the fruit fly, and the gene which controls color blindness in humans.

n. The X-linked gene is the gene on the X chromosome. Thus in humans, since the male is XY he will need only one recessive from an X gene in order to express it, while the female must be homozygous recessive.

o. The Glucose-6-Phosphate Dehydrogenase disease is an example of a disease of the X-linked gene. The patients will have a severe allergy to some food and medicines, such as medicines for malaria, antibiotics, aspirin, paracetamol, etc.

p. The Y-linked gene is the gene on the Y chromosome. The important gene is the gene which controls the male gender. The gene on the Y chromosome is transferred only from father to son, such as the gene which controls baldness in humans.

5. Genetic Materials

5.1 Discovering Genetic Materials

5.1.1 Nucleic acid (nuclein)

5.1.2 Transformation (The textbook does not use this term)

5.2 Chemical components of DNA

5.2.1 DNA structure (nucleotide, double helix strand)

The following genetic conceptions are the conceptions of these topics.

a. Nucleic acid is composed of nucleotide linked as a chainlike molecule. Nucleic acid as nuclein is a genetic material. Nucleic acid has a nitrogenous base which is composed of Adenine (A), Guanine (G), Cytosine (C) and Thymine (T). Adenine and guanine are purines; cytosine, thymine, and uracil are pyrimidines.

b. Deoxyribonucleic acid or DNA can transfer to the next generation, and is the main constituent of chromosomes.

c. DNA is composed of nucleotides which are two strands in helix (double helix), which are presented as a twisted ladder representing the sugar-phosphate backbones of the two strands and whose rungs represent base pairs.

d. DNA contains four types of nucleotides; A, T, G, C.

e. The DNA of each individual has a different number of nucleotides and sequence of nucleotides.

f. The nucleotide is composed of base, sugar and phosphate groups. The nucleotides contain a base linked to the 1'- position of a sugar (ribose in RNA or deoxyribose in DNA) and a phosphate group. The phosphate joins the nucleotides in a DNA or RNA chain through their 5'- and 3'- hydroxyl groups by phosphodiester bonds.

g. The ratios of Adenine:Thymine; and Guanine:Cytosine in DNA molecule are 1:1. Adenine matches with Thymine (Uracil in RNA), and Guanine matches with Cytosine.

6. Characteristics of Genetic Materials

6.1 DNA synthesis (DNA replication)

6.2 DNA with genetic material control

6.3 DNA with protein synthesis

6.3.1 Ribonucleic acid (RNA); rRNA, tRNA, and mRNA

6.4 Genetic code (codon)

6.5 Protein synthesis

6.5.1 tRNA with anticodon

6.5.2 Start codon

6.5.3 Stop codon

6.5.4 Relationship between transcription and translation

The genetic conceptions of these topics are as follows:

a. DNA can synthesize itself (DNA replication). The new strand has the same structure and series of nucleotide as the template strand. Accuracy of copying is ensured by a self-checking mechanism, and the ratio of Adenine plus Thymine and guanine plus Cytosine of DNA template is the same in the new strand.

b. DNA replication is semi-discontinuous. The leading strand is made continuously in a long piece, but the other strand (the lagging strand) is made in short pieces. New nucleotides are added to the 3'-end of the DNA molecule.

c. DNA acts as a template for the production of RNA. Information carried in DNA controls manufacture of proteins, RNA. It also controls cell and organism structure and function.

d. The differences between DNA and RNA are: DNA is double stranded, but RNA is a single strand; DNA is in the nucleus, but RNA is in both the nucleus and the cytoplasm; DNA contains T, RNA contains U; DNA is much larger; RNA contains many errors, because it has no self-checking mechanism.

e. Transcription is the production of an RNA strand from a DNA template. The RNA strand moves from the 5'-end to 3'-end.

f. RNA has three types; mRNA, tRNA, and rRNA.

g. Genetic code is the set of 64 codons and the amino acids they represent. The codes carry information in the sequence of bases in DNA or RNA.

h. Each group of three bases in mRNA is called a codon. There are 64 different codons; each the code for one amino acid. Genetic code is redundant: some amino acids are represented by more than one codon.

i. Anticodon is a three-base sequence in tRNA. Each anticodon matches with a specific codon. Each tRNA molecule binds to a particular amino acid.

j. Protein synthesis, translation, is the manufacture of a protein with the sequence of amino acids specified by a mRNA molecule.

k. AUG is the start codon of protein synthesis.

l. The process of protein synthesis or translation is: tRNA, which has anticodon UAC which carries methionine, moves to match with mRNA, which has codon AUG; 2nd tRNA which has another amino acid, matches with the next codon on the mRNA in ribosome, producing a peptide bond between two amino acids; 1st tRNA separates from mRNA and ribosome, ribosome moves through mRNA from 5'end to 3' end, new tRNA with new amino acid matches with mRNA and produces the peptide bond again and again, until codon is UAA or UAG or UGA. UAA, UAG, and UGA are the stop codon of translation.

7. DNA in Prokaryote and Eukaryote

7.1 DNA in Prokaryote

7.1.1 Plasmid in Prokaryote

7.2 DNA in Eukaryote

These are genetic conceptions of these topics.

a. Plasmid is a small piece of circular DNA which is replicated independently from the cell’s chromosome.

b. The eukaryotic chromosome is composed of DNA and protein which is mostly histone (a kind of protein). The eukaryotic chromosome has more protein than prokaryotic chromosome.

8. Mutation

The mutation conceptions as follows:

a. Mutations may include base deletion, base insertion, base change, or base inversion, etc. which can be caused by radiation, chemical agents or temperature;

b. Mutation of the reproductive cell can transfer to the next generation;

c. A mutagen is a mutation-causing agent.

9. Genetic Engineering

9.1 Recombinant DNA (rDNA)

9.2 Application

9.2.1 For producing protein

9.2.2 For growth increasing/ developing proteins

9.2.3 For medication

9.3 Results

9.3.1 Increase rare proteins

9.3.2 Modify microorganisms in industry

9.3.3 Modify plants and animals

9.3.4 Check and edit human, plant, and animal genetic material

The genetic conceptions of these topics are shown as follows:

a. Genetic engineering is the process of changing genetic materials. This may include deletion of genetic material or insertion of genetic material from another species by using restriction enzymes. Foreign DNA may be carried into the engineered cell using a vector, e.g. a bacterial plasmid;

b. Recombinant DNA, rDNA, is the product of recombination between fragments of DNA from different sources or organisms;

c. Genetic engineering can be applied to producing protein, enhancing growth, developing proteins, and enhancing medication;

d. The results of using genetic engineering are to increase rare proteins, modify microorganisms in industry, modify plants and animals, and check human, plant, and animal genetic material.

Genetics Alternative Conceptions

Genetics misconceptions in prior Grade level can be a cause of misconceptions at high school level. Westbrook and Marek (1992) argued that intuitive ideas about one concept can lead to alternative conceptions of other concepts. A number of genetics topics' misconceptions are shown as follows. The genetics topics are gene, chromosome, gene and chromosome, the genetic disease, sex chromosome, genetic characteristics, discovery of genetics knowledge, genetic materials, characteristics of genetic materials, mutation, and genetic engineering.

1. Gene

The concept about gene or genetic unit is the unit that control the traits of living things is one of the concepts which students have alternative conceptions. Stewart and Dale (1981: 59-64) used two audio-taped interviews with 27 individual high school biology students. The research showed that some students lacked understanding of the concept of gene. Lewis, Leach and Wood-Robinson (2000c: 74-79) studied young people's understanding of the nature of genes. The subjects were 482 school students aged 14-16 from eight co-educational comprehensive schools located in the West Yorkshire area of England, and covered a range of urban, suburban, and rural catchment areas. A series of written questions requiring individual written responses, along with a series of task-based small group interviews were used to collect data. It was found that some students lacked a basic understanding of what a gene was; its basic function, where it might be found, and how it related to other structures. Hackling and Treagust (1984: 197-209) interviewed 48 students in grade 10 (15 years of age) from six different schools and from 13 different science classes in the Perth metropolitan region several days after students had completed the genetics topic. They found that students have a misunderstanding about how genes control the features of an organism.

The concept about how traits can transfer from parents to offspring is the other concept which students have alternative conceptions. Marbach-Ad and Stavy (2000: 200-205) studied students' cellular and molecular explanations of genetic phenomena. They used: a written questionnaire with group A students who were 164 9th graders and 100 12th graders; individually interviewed and made concept maps with group B students who were 20 9th graders and 21 12th graders; written questionnaire with group C students who were 14 college students and 12 university students. They found that some students thought of the gene as a synonym for trait. Ramorogo and Wood-Robinson (1995: 60-71) studied children's understanding of biological inheritance in Batswana. The subjects were students from 12 to more than 16 years in African context who were 155 students in primary and 145 students in junior secondary schools in and around Gaborone (the capital city of Botswana). The instruments were pencil and paper questionnaires with English questions, and the other half with questions in Setswana (the vernacular language of the students). They found students' alternative conceptions were: the hand calluses acquired by farmers would be inherited and naturally fast runners of athletes would be such inheritance. Hackling and Treagust (1984: 197-209) found students' alternative conceptions were that acquired features were not passed on to offspring; body cells had genes in pairs.

Each pair of genes is on each pair of chromosome is the other concept which was included in students' alternative conceptions. Browning and Lehman reported student misconceptions in genetics problem-solving via computer programs with 132 female and 3 male undergraduate students (1988: 747-761). They found students' alternative conceptions included that gametes contained two genes from the same pair and each gamete should contain only one gene, like the gametes of the monohybrid crosses. Hackling and Treagust (1984: 197-209) found students' alternative conceptions included the location of genes and chromosomes, and that a member of a gene pair was not located on each member of a pair of chromosomes.

Each genetic unit which presents a trait comes from both father and mother is another concept which was found in student's alternative conceptions. In the past Nagy (1953: 217-226) studied children's birth theories by using interviews with 390 children aged 4 to 11 and essay writing with 300 children aged 8.0-10.11 years. Alternative conceptions of children's birth theories included that: there is no birth, as life is everlasting; there is birth, but without the mother; and birth is explained solely from the mother. More than forty years later, Wood-Robinson (1994) and Ramorogo and Wood-Robinson (1995) were the researchers who presented student's alternative conceptions in this concept. Wood-Robinson (1994: 29-47) discussed young people's ideas about inheritance and evolution. Alternative conceptions were presented in a number of ways: in the case of a pair of monozygotic twins, one maintained that the resemblance was not derived from the father, but from the mother through the egg and the father's contribution was greater than the mother's. Ramorogo and Wood-Robinson (1995: 60-71) studied children's understanding of biological inheritance in Botswana. They found the alternative conceptions in students which were babies are picked from the river or from the horns of an antelope; babies were purchased from a hospital; babies were 'seeds' which, if sown in a fertile womb will grow into a baby; baby cattle being passed on only by the mother; and baby cattle being passed on only by the father. Wood (1996: 57 and 63) had got alternative conceptions of students from 47 individual interviews (Year 6-8, age 9-13 years-old which are: mother contributed more to the baby; the unequal nature of the contribution to the sex of the baby (mother contributes more genetic material in the case of a girl, the father contributes more genetic material in the case of a boy); students did not see the genes from the two parents working together in the body (men carry the genes from the top half, and woman the genes for the bottom half); and the uniqueness of individuals was a result of their making their own genes in addition to those which they received from their parents.

Mungsing (1993) studied Thai students' alternative conceptions about genetics. She found alternative concepts of equality of genetic contribution of each parent in sexual reproduction; such as in animals, a father could transmit hereditary characteristics better than a mother because there were four different types of sperm produced each time whereas there was only one egg and a father usually had homozygous genes.

2. Chromosome

In this category, there are three sub-topics which are chromosomes in general, shape and characteristics, and human chromosomes.

2.1 Chromosomes in General

Alternative conceptions were found both in chromosome concepts alone and between concepts of chromosome and other concepts. The alternative conceptions about the second topic, Chromosome, were shown in a number of journals. Hackling and Treagust (1984: 197-209) interviewed 48 students in grade 10. They found students' alternative conception that body cells have chromosomes in pairs. Hackling (1982: 13-20) used *Meaning of concepts test* (M.O.C.) with 100 above-average Year 10 students attending a Senior High School in Perth, Western Australia. The students were in the last week of the Lower Secondary Science Genetics topic (E.D.W.A., 1972) which considered the mechanisms of inheritance and the applications of genetics to agriculture and medicine and used *Word association test* (W.A.T.) 32 above average Year 10 students who had just completed the Lower Secondary Science Genetics topic. The alternative conceptions which students showed in the research were: meiosis was defined frequently as a form of cell division but quite rarely in terms of its effect on the chromosomes and genes that pass to the daughter cells of the division; students lacked understanding of the concepts of meiosis, gamete, fertilization, and mitosis in terms of their relations to chromosomes and genes; and lacked understanding of the concepts of gamete and fertilization in terms of the role they play in inheritance. Lewis, Leach and Wood-Robinson (2000b: 189-199) used written data with 482 young people aged 14-16. They found that students did not make the distinction between somatic and germ cells and that the students thought that sex cells contained more chromosomes than somatic cells.

The alternative conceptions which were found in chromosome concepts were presented in a number of journals. Brown (1990: 182-186) found the alternative conceptions which is that each chromosome had not duplicated into identical chromatids. Lewis, Leach and Wood-Robinson (2000b: 189-199) found that students were unaware that chromosomes are copied before being shared out at cell division. The research showed the alternative conceptions included that: the chromosome number of the new skin cells would remain the same because the cells were of the same type (skin cells); young and healthy cells would have more chromosomes than old or unhealthy cells; and there would only be two chromosomes in the fertilised egg. Stewart & Dale (1989: 501-521) studied high school students' understanding of chromosome or gene behavior during meiosis by using open-ended questions with 50 high school students in grades 9-12 after completing the instruction on meiosis and basic transmission genetics. The alternative views of meiosis and chromosome model were shown in the research results. Kindfield (1994: 255-283) found the alternative conception which is that chromosome structure is a function of ploidy.

Some research results present students' alternative conception between concepts of chromosome and other concepts, such as Stewart (1982: 80-82, 84 and 89), and Peard (1983: 131-145). Stewart (1982: 80-82, 84 and 89) found the alternative conception which was the relation between gamete and chromosome. Peard (1983: 131-145) found an alternative conception which was the relation between chromosomes and linkage.

2.2 Shape and Characteristics

A number of alternative conceptions of shape and characteristics of chromosomes were shown in Kindfield (1994: 255-283) and Brown (1990: 182-186). Kindfield (1994: 255-283) found alternative conceptions which were: chromosomes consisting of a single double-stranded DNA molecule which were the kind of chromosomes that were present in haploid nuclei; chromosomes consisting of two double-stranded DNA molecules or chromatids which were the kind of chromosomes that were present in diploid nuclei; and the origin of chromosome entities consisting of two chromatids and a centromere. Brown (1990: 182-186) found alternative conceptions in homologous chromosomes which were about the concept of a homologous pair.

2.3 Human Chromosome

Hackling and Treagust (1984: 197-209) found a number of students' alternative conceptions in human chromosome which were: each feature is controlled by one or a few or many or 23 or 46 genes; and sperm carry genes for half the features found in the offspring. Peard (1983: 131-145) found students' alternative conceptions about determining autosomal linkages and determining two traits in human chromosome.

3. Gene and Chromosome

The alternative conceptions of gene and chromosome can be categorised into four sub-topics which were: the alternative conceptions of genes and chromosomes in general; gene and chromosome location; linked genes and gene recombination; and genes in sex chromosome or sex- linked genes.

3.1 Gene and Chromosome in General

Lewis, Leach and Wood-Robinson (2000a: 129-132 and 2000c: 74-79) studied young people's understanding of the genetic relationship between cells by using written questions. The written questions consisted of two parts; part 1: to probe students' understandings of the genetic relationship between cells within one individual; and part 2: to probe students' understanding of the difference between 'genes' and 'genetic information'. The 482 young people aged 14-16 were drawn from across the ability range. The alternative conceptions were as following: all cells contained different information, even in the same individual; each type of cell contains just that information which it needed in order to perform its function, such as sperm cells did not carry the same genetic information as somatic cells, or each sperm cell carries a different combination of genetic information; and that the cells of the same type would need the same information. They found that the young people were confused between the terms gene and chromosome. Moreover, many of the young people did not understand the nature and function of genes and chromosomes.

The results of their research were supported by a number of researchers, including the following. Buntting, et al. found students' alternative conceptions about the structure of genes (2003: 10-12). Treagust (1984: 197-209) found students' alternative conceptions which were: gametes carried both chromosomes and both genes from the pairs of chromosomes and genes found in the parent's body cells; and the different cell types (skin, muscle, cartilage etc.) found in a given individual's body contain different set of genes. Wood (1996) found students' alternative conceptions which were: the genes as big and little letters; genes as cell; genes had synonymous with chromosomes; gene as part of the blood; genes as body structures similar to an organ or limb rather than a component of all cells (genes as part of a specific structure like the brain, or synonymous with structure); gene as structures that could incorporate things from the environment, like a disease, which could then be passed onto the children; the genes as growing and changing in the same way as any other portion of their body; genes as a 'dose' of material that a person receives at birth; gene as a normally changing piece of information within the body (phenotypic changes or changes as the age); making new genes one could also lose genes as one gets older; and some genes were grown to help with specific processes of change (some genes are grown specifically for puberty).

In Thailand, Mungsing (1993) found students' alternative conceptions which were: genes expressed themselves differently each time; genes which were bound into each different sex cell did not control the same trait; genetic expression in each family was not constant, for example, shortness of people might be a dominant trait for one family but a recessive trait for another family; a gene was a protein compound; a pair of genes for a particular trait were located on a single chromosome; genes were usually bound together at a centromere.

3.2 Gene and Chromosome Location

Lewis, Leach and Wood-Robinson (2000c: 74-79) found students' alternative conceptions which were: genes were not on or in chromosomes; and genes were only found in specific organs or tissues, such as the reproductive system. Stewart, Hafner and Dale (1990: 228-232) used problem-solving in interview sessions with 21 female and 29 male high school students. They found students' alternative conceptions which were chromosomes are on genes and traits are on chromosomes.

Wood (1996) found students' alternative conception, which was that genes were located in or near the characteristics which they control.

3.3 Linked Gene and Gene Recombination

The alternative conceptions of linked gene and gene recombination were shown in Kindfield (1994: 255-283) and Mungsing (1993). Kindfield (1994: 255-283) found alternative conceptions which were: the two-DNA-molecule chromosomes that were presented in diploid nuclei were formed, not by the process of replication, but rather in two single-DNA-molecule chromosomes, one from each parent, join each other at the centromere region when two haploid gametes fused to produce a diploid zygote; and alternative conceptions about the timing and nature of chromosome pairing. Mungsing (1993) found students' alternative conceptions about separation and recombination of chromosomes during cell division.

3.4 Gene in Sex Chromosome or Sex-linked Gene

The alternative conceptions of linked gene and gene recombination were shown in Tolman (1982: 525-527) and MDA Publications (2001). Students' alternative conceptions was shown incorrectly identified the individual parents as probable sources of single alleles for the trait of colour-blindness in Tolman (1982: 525-527) (rephrase). MDA Publications (2001) published one an alternative conception that in genetics X-linked diseases never affect females.

4. The Genetic Diseases

The alternative conceptions of Genetic Diseases were shown in MDA Publications (2001). The publication presented many alternative conceptions, such as if a disease did not run in the family, it could not be genetic and certain diseases or harmless traits (like baldness or eye colour) consistently skip a generation.

5. Sex Chromosome

The alternative conceptions about sex chromosome were shown as follows. Ramorogo and Wood-Robinson (1995: 60-71) studied children's understanding of biological inheritance in Botswana. The alternative conceptions which they found were that the right hand was associated with strength and maleness and that the left hand was thought to be weaker and was associated with the female and the child (avoid 'kid' it sounds too informal, also, use 'males and females' instead of 'girls and boys') was more likely to inherit the mother's features than the father's. Hackling (1982: 13-20) found that most students could not associate inheritance with sexual reproduction. Lewis, Leach and Wood-Robinson (2000b: 189-199) found students' alternative conceptions about the role of sex chromosomes. Hackling and Treagust (1984: 197-209) interviewed 48 students in grade 10. They found students' alternative conception that sex or XY chromosomes determined sex and that males had the sex chromosomes XY and females XX. Wood-Robinson (1994: 29-47) discussed young people's ideas about inheritance and evolution. One of the alternative conceptions which was found was that features tend to be passed from a human parent to the offspring of the same gender.

6. Genetic Characteristics

In this category, there are two sub-topics which are genetic characteristics and the environment, along with genetic variation.

6.1 Genetic characteristics and the environment

The alternative conceptions about genetic characteristics and the environment were shown in a number of journals both in Thailand and overseas. In Thailand, Mungsing (1993) studied Thai students' alternative conceptions about genetics. She found students' alternative concepts about the effect of time on the possibility of inheritance of acquired characteristics, such as that there were two changes in inheritance-continuous and discontinuous changes and continuous change could affect the genes. As a result, if the couple of each generation continued to be physically fit, there was a possibility to have automatically fast running children; according to the law of ‘use and disuse’, children could be automatically good runners because this ability had been practiced continuously over time; a child’s body structure would ‘improve’ dramatically as a result of being a descendant of athletes (although the child would or would not be born with automatically good running skills); and the crossing over of chromosomes might be result in a genetic make-up, therefore if this happens, children could possibly be automatically good runners.

From overseas journals, Reiss (1987: 159) found students’ alternative conceptions of inheritance of height which were that phenotypes were determined by genotypes alone and that the influence of the environment was implicitly assumed to be minimal. Lawson and Thompson (1988: 733-746) studied misconceptions in genetics and natural selection with 131 seventh-grade students who enrolled in 5 sections (all taught by the same teacher) of a required life-science course at a modern public junior high school. This school was located in a suburban middle- to upper-class community near Phoenix, Arizona. They used an essay test on principles of genetics and natural selection following instruction. The alternative conceptions which they found were involved amputated fingers: ‘the finger was cut off too fast for the genes to change’; ‘if there was a change in the bodily functions it is likely to be passed on’; ‘the child would probably have a finger missing because the traits of both parents were strong’; ‘if parents had amputated fingers their children would have the same problem with their finger ’cause of the trait’; ‘some of the cells would be gone from both parents so the offspring would have less cells’; ‘not normal because there were no traits for fingers to give to the offspring’; ‘the fingers would be short because she is not a carrier’; ‘the children would have missed one finger because the parent would miss that cell and it can’t reproduce’; and ‘the lost finger would be inherited from the parents’.

The research is related to Stewart (1982) and Wood (1996). Stewart (1982: 80-82, 84 and 89) studied the difficulties of high school students when learning genetics. He found that students have difficulties in understanding the relationship between genes and traits and between alleles and traits. Wood (1996) found alternative conceptions of students which were related to the influencing of the environment on gene expression, such as characteristics resulting from environmental influence and the environment as the determinant of gene expression.

6.2 Genetic Variation

The alternative conceptions about genetic variation, which included continuous variation and discontinuous variation, were shown in a number of journals in both students and teachers. The alternative conceptions in students were presented in Ramorogo and Wood-Robinson (1995) and Mungsing (1993). Ramorogo and Wood-Robinson (1995: 60-71) found students' alternative conceptions which were that the cause of variation was a supernatural being (i.e. God) and that the origins of variation in sorghum came from some environmental factor, such as soil, climate or moisture. Mungsing (1993) found students' alternative concepts which were: the difference between environmental and hereditary characteristics; the crossing over of chromosomes during fertilization caused variation between siblings; variation within a family was a continuous variation; therefore, there were some likenesses and some differences between siblings; and the relationship between the height of a son and a daughter and the heights of their parents (the genes for height were sex-linked).

The alternative conceptions in teachers were presented in Yip (1998: 461-477), who identified misconceptions in novice biology teachers. Yip used a written test consisting of 67 questions, each one made up of a short statement on a particular biological concept with 26 secondary school biology teachers. One of the results of the research showed that some secondary school biology teachers thought that genetic variation made individuals better suited to adapt to different environments.

7. Discovery of Genetic Knowledge

In this category, there are six sub-topics which are Mendel and his genetic studies; probability and Law of Segregation; test cross or back cross; Law of Independent Assortment; alleles; and multiple genes or polygenes. These sub-topics were followed by the textbook of the Department of Curriculum and Instruction Development for high school students, Science 048 (IPST, 1990).

7.1 Mendel and His Genetic Studies

The sub-topic 'Mendel and his genetic studies' covers dominant, recessive, dominant and recessive alleles, genotype, phenotype, homozygous (pureline, pure-breeding), and heterozygous (hybrid). The alternative conceptions about Mendel and his genetic studies were shown in Stewart, who found students' alternative conceptions about the relationship between genes and alleles (1982: 80-82, 84 and 89).

7.1.1 Dominant

Hackling and Treagust (1984: 197-209) found students' alternative conceptions which were that: two genes control each feature. Some students could not understand that some features were controlled by several pairs of genes; a baby born of two hybrid parents would definitely have the dominant trait; three out of four children produced by a particular set of hybrid parents, would definitely have the dominant trait; all the children produced by a pair of hybrid parents will have the dominant trait. Allchin (2000: 633-639) argued in an article about alternative conceptions in genetics, which were that: some traits were more likely to be inherited than others; dominant traits were more frequent in the population; and adaptive traits eventually became dominant through natural selection. Mungsing (1993) found alternative conceptions in Thai students which were that a couple of dominant and recessive traits would definitely produce dominant trait offspring. Lawson and Thompson (1988: 733-746) found students' alternative conceptions which were about '*skin colour*', such as that 'in Africa the sun shines hotter and people's skin gets much darker, so when children were born their skin would be a little darker than normal'; and '*dyed hair*', such as that 'the hair was dyed constantly so the genes had to change' etc.

The alternative conception of relationships between dominant and phenotype was shown in Peard (1983: 131-145). Peard used a questionnaire about their past and present educational experiences, in addition to a genetics assessment test (GAT-1) or (GAT-2), individual interviews. The students (do you mean 'teachers') were also asked to again demonstrate the process of meiosis and to answer specific content and affective questions with 40 other students. The students' alternative conception that the predominant phenotype was dominant was shown in the research.

7.1.2 Recessive

The alternative conceptions were shown not only on the topic of dominant genes, but recessive genes also. Allchin (2000: 633-639) wrote about an alternative conception in genetics, which was that mutations or 'abnormal' genes are recessive. Mungsing (1993) found an alternative conception in Thai students which was that one out of four offspring produced in the F2 generation would have a recessive trait.

7.1.3 Dominant and Recessive Allele

The alternative conceptions about the third topic, dominant alleles and recessive alleles, are shown as follows. Ramorogo and Wood-Robinson (1995: 60-71) studied children's understanding of biological inheritance in Botswana. They found an alternative conception in students about dominant alleles which was that 'no tail' of a goat was dominant over 'normal tail'. Hackling (1982: 13-20) found that students failed to rationalize the everyday meaning of dominance, dominant, recessive, and blending with the particular meaning ascribes to these concepts in genetics and some students thought that dominance referred to power and authority.

The alternative conceptions about dominant and recessive alleles were shown in Hackling and Treagust (1984), Allchin (2000), Mungsing (1993), and Peard (1983). Treagust found alternative conceptions which was that dominant alleles was more powerful than recessive alleles (1984: 197-209). Allchin (2000: 633-639) found an alternative conception which was that dominant alleles subdue or control recessive ones. Mungsing (1993) found an alternative conception which was that dominant alleles were more powerful than recessive alleles. Peard (1983: 131-145) found alternative conceptions which were that: the dominant alleles for two traits had to be linked, likewise for the recessives and dominant alleles for 2 traits had to be linked together. The alternative conception of the relationship between dominant alleles and phenotypes was shown in the research also, which was that, 'The phenotype that was predominant in the first litter was assumed to be dominant'.

7.1.4 Genotype and Phenotype

The difficulties and alternative conceptions about genotype and phenotype were shown in Wood-Robinson (1994), Stewart and Dale (1981), Stewart (1982), Peard (1983), and Mungsing (1993). Wood-Robinson (1994: 29-47) found alternative conceptions which were about the equal contributions of both parents in the formation of the genotype of their offspring; and that some characteristics were inherited from one parent while other features come from the other parent. Stewart and Dale (1981: 59-64) found an alternative conception about the generation of gametes from the parental genotypes. Stewart (1982: 80-82, 84 and 89) found that students could not identify gamete genotypes. Peard (1983: 131-145) found an alternative conception about determining genotypes and one trait crosses and that some students did not make links between phenotypes and genotypes (or "between the terms 'phenotype' and 'genotype'"). Mungsing (1993) found alternative conceptions which were that the F1 generation should have the same phenotypes; and a phenotypic expression of a hybrid trait was inferior to a homozygous dominant trait.

7.1.5 Heterozygous (hybrid)

The difficulties and alternative conceptions about heterozygous (hybrid) were shown in Brown (1990: 182-186). The researcher used the examination question which was a part of the University of Cambridge Local Examinations Syndicate A-level biology practical paper of summer 1989 with 2,219 candidates (in university and pre-university biology courses). The students who did not attempt to label alleles had experienced difficulties with the concept 'heterozygous' as well as that of 'alleles'.

7.2 Probability and Law of Segregation

The difficulties and alternative conceptions about sub-topics, probability and the Law of Segregation, was shown in Kindfield (1994) and Stewart (1982). Kindfield (1994: 255-283) interviewed five individuals from each of the three levels of expertise in genetics for 1.5-2.0 hours using individual interviews with individual 4x6 cards. The research's results showed misunderstanding of both occurrences of alignment/segregation, and an alternative conception which was that sister chromatids were not attached to one another at any time during meiosis. Stewart (1982: 80-82, 84 and 89) showed that students lacked the appropriate concept about meiosis and segregation when doing monohybrid cross problems.

The difficulties and alternative conceptions of the relationships between probability and Law of Segregation and Law of Independent Assortment was shown in Stewart (1982) and Peard (1983). Stewart (1982: 80-82, 84 and 89-code 31) found an alternative conception which was that the definitions of segregation and independent assortment is like addition and subtraction. Peard (1983: 131-145-code 33) found some students did not relate the ideas of independent assortment or segregation to her use of the Punnett square.

7.3 Test Cross/ Back Cross

Peard found the alternative conception of test cross or back cross in various interpretations of testcross (1983: 131-145).

7.4 Law of Independent Assortment

The alternative conceptions about the Independent Assortment of Genes were shown in Ramorogo and Wood-Robinson (1995: 60-71). They studied children's understanding of biological inheritance in Botswana. The alternative conceptions which they found were that genetic information could not be changed after meiosis and that students were unaware that the egg and sperm made equal inputs.

The sub-topic 'Law of Independent Assortment' is covered with the terms 'monohybrid cross' and 'dihybrid cross'.

7.4.1 Monohybrid Cross

The alternative conceptions of the sub-topic Law of Independent Assortment were shown in the alternative conceptions of monohybrid cross and dihybrid cross in the following journals which were Buntting et al. (2003), Mungsing (1993), Tolman (1982), Stewart and Dale (1981: 59-64), and Stewart (1982: 80-82, 84 and 89). Buntting et al. (2003: 10-12) used semi-structured interviews and a purpose-designed questionnaire with students at New Zealand universities for studying students' prior knowledge of biology-related concepts who came from different academic backgrounds. The found that students had alternative conceptions about simple monohybrid crosses. This result was similar to Mungsing (1993), who did her research with Thai students. The example of students' alternative conception which Mungsing found could show in a cell diagram which students could not explain the results.

7.4.2 Dihybrid Cross

The research results of Tolman (1982), Mungsing (1993), Stewart and Dale (1981: 59-64), and Stewart (1982: 80-82, 84 and 89) showed the alternative conceptions of dihybrid crosses. Tolman (1982: 525-527) studied difficulties in genetics problem solving by using three different types of genetics problems with 30 junior or senior students in one Colorado high school. One of the results of his/her research was that students had errors about alleles for each trait which were shown in Punnett square of dihybrid crosses (or "square of the dihybrid cross"). Using a cell diagram in Mungsing (1993) can show alternative concepts about dihybrid crosses. She found that some alternative concepts about dihybrid cross came from using the wrong symbols for incomplete dominant or multiple alleles to represent complete dominant alleles; for example, BW or H^BH^b for representing a heterozygous black dog. Mungsing's results using Punnett square were similar to Stewart (1982: 80-82, 84 and 89), which was related to Stewart and Dale (1981: 59-64), who found an alternative conception in the solving by students of the dihybrid problem by treating it as two separate monohybrid crosses, or by the involvement of 8 chromosomes.

7.5 Allele

Pashley (1994a and 1994b); Lewis, Leach and Wood-Robinson (2000c); and Mungsing (1993) found students' alternative conceptions about the meaning of allele. Pashley (1994a: 157-161; 1994b: 120-126) used a chromosome model for surveying 96 students, who were studying A-level biology in Years 11 and 12, about problems with genes and alleles. The alternative conceptions of alleles were as follows: genes contained alleles; alleles contained genes; and alleles and genes were the same. Lewis, Leach and Wood-Robinson (2000c: 74-79) found an alternative conception which was that alleles were interchangeable with genes or chromosomes. Mungsing (1993) found an alternative conception which was that an allele was a pair of genes responsible for contrasting traits.

The alternative conceptions of the relationship between ‘allele’ concept and others were found in a number of journals, such as Brown (1990: 182-186), Hackling and Treagust (1984: 197-209), Stewart and Dale (1981: 59-64), Stewart (1982: 80-82, 84 and 89), and Peard (1983: 131-145). Brown (1990: 182-186) found an alternative conception which was that sister chromatids carry the same allele(s) and alleles were labelled at different positions on homologous chromosomes. Hackling and Treagust (1984: 197-209) found an alternative conception which was that gametes carry one chromosome and one gene from each pair. Stewart and Dale (1981: 59-64) found an alternative conception which involved using different letters to symbolize the alleles of gene. It showed lacking of understanding the concept of allele of students. Peard (1983: 131-145) found alternative conceptions which were related to linkage, allele, and gamete such as, ‘If no linkage, each allele was in separate gamete’; between alleles and meiosis; and between multiple alleles and multiple genes. Stewart (1982: 80-82, 84 and 89) found alternative conceptions which were related to the relationship between zygotes and alleles; and between alleles and chromosomes.

In the textbook of IPST for Grade 8 students, Science 203 (IPST, 1990: contents), the concepts of allele was linked to incomplete dominant and co-dominant. The alternative conceptions of incomplete dominant were found in a variety of journals, such as Hackling and Treagust (1984), Mungsing (1993), and Peard (1983). Treagust (1984: 197-209) found an alternative conception which was that incomplete dominance involved a mixing of genes; Mungsing (1993) found an alternative conception which was that a couple of black and white mice might produce a recessive trait offspring if black and white were incomplete dominant (alternative concept); and Peard (1983: 131-145) found alternative conceptions which were both about incomplete dominance and sex linkage with incomplete dominance. On the topic of co-dominant, Tolman (1982: 525-527) found that students did not realize the need for only one allele from each parent.

7.6 Multiple Genes or Polygenes

A number of alternative conceptions of multiple genes or Polygenes were shown in Reiss (1987: 159) and Mungsing (1993). Reiss (1987: 159) found that students' alternative conceptions of inheritance of height which were that any particular characteristic or trait is determined by the action of genes at just one locus. Mungsing (1993) found the alternative conceptions about multiple alleles in students because students could not use accepted symbols to represent alleles involved in a question of incomplete dominance; therefore, the father with a genotype H^PH^g could not give a purple-haired offspring. Moreover, some students thought that polygenes and incomplete dominant genes were the major factors of variation within a family.

8. Genetic Materials

The alternative conceptions about genetic materials were shown in Lewis, Leach and Wood-Robinson (2000c: 74-79); Marbach-Ad and Stavy (2000: 200-205); Buntting, et al. (2003: 10-12); Lewis, Leach and Wood-Robinson (2000b: 189-199); Wood (1996). Lewis, Leach and Wood-Robinson (2000c: 74-79) found students' alternative conceptions which included that some organisms could contain chromosomes without containing genetic information, and that DNA was only found in specific parts of the body, most commonly the blood. Moreover, the students were confused about: the relationship between chromosomes and genes; the related structures extending beyond DNA, genes, and chromosomes to cells; the relationship between nucleic acids and amino acids; and the relationship between the structure and function of nucleic acids (production of proteins). They were not aware that genes contain DNA and that all cells would contain the same genetic information (2000b: 189-199).

Marbach-Ad and Stavy (2000: 200-205) found a students' alternative conception which was that DNA in the daughter cells was identical to the DNA that was in the mother cell because the DNA (or the cell) duplicates and then divides. The students were confused about concepts such as meiosis, mitosis, crossing over, and

DNA, such as ‘the DNA duplicates and divides equally, as in meiosis, so the strands are the same’.

Buntting, et al. found students’ alternative conceptions about the importance of DNA in the cells (2003: 10-12). Wood (1996) found students’ alternative conceptions which were: genes are located inside the body and are thereby controlling their external features; and gene expression as being linked to the amount of genetic material from the parents, such as for specific characteristics, genes could be larger in number or bigger in size to create more effect.

9. Characteristics of Genetic Materials

The alternative conceptions of characteristics of genetic materials which were found a number of research and articles are composed of the function of DNA, DNA replication, genetic code, and protein synthesis.

9.1 The Function of DNA

Lewis, Leach and Wood-Robinson (2000c: 74-79), Buntting, et al. (2003: 10-12), and Wood (1996) presented the alternative conceptions of the function of DNA, such as in Lewis, Leach and Wood-Robinson (2000c: 74-79) that no student explicitly linked a gene with a gene product. Wood (1996) reported on students’ ideas on how the way various organisms inherited their characteristics would differ.

9.2 DNA Replication

The alternative conceptions of DNA replication were presented in Wood (1996) and Kindfield (1994: 255-283). Wood (1996) found that students did not see genetic material as capable of replication, such as parents only contribute what they did not used; more genetic material would be needed for a baby but provided for this by making new ‘spare’ genes rather than copying the old ones; genes as having to be shared between parents and children because there is no replication but both need the genes; genes might be weaker in the offspring because a whole gene cannot be passed on. In Kindfield (1994: 255-283), the research results showed alternative conceptions of the timing of replication and the structure of replicated and unreplicated chromosomes.

9.3 The Genetic Code

The alternative conceptions of genetic codes were presented in Lewis, Leach and Wood-Robinson (2000c: 74-79; 2000b: 189-199), and Marbach-Ad and Stavy (2000: 200-205). Lewis, Leach and Wood-Robinson (2000c: 74-79) found that not one response referred to the role of the genetic code in translating the information encoded in the DNA into a gene product, and most students did not show that DNA provides information for the production of proteins. Leach and Wood-Robinson (2000b: 189-199) found confusion between genetic information and the genetic code in young people. Marbach-Ad and Stavy found students' alternative conceptions on the transcription and translation processes, and the function of RNA (2000: 200-205).

9.4 Protein Synthesis

The alternative conceptions of protein synthesis were presented in Fisher (1983: 425-437; 1985: 53-62). Fisher studied alternative conceptions of amino acids and translation by using individual interviews, multiple-choice questions, and essay exams with students in a recent biology class. The study showed that the students had difficulties and alternative conceptions with protein synthesis and amino acids, such as amino acids come from: synthesized in body or cell, or obtained from food, plants, living things, or other amino acids; elements and molecules; mystical sources, god, primeval seas; and had always been there.

10. Mutation

MDA Publications (2001) presented alternative conceptions of mutation of gene defects which were always caused by environmental factors. Bahar, Johnstone and Hansell (1999: 84-86) used one-to-one interviews with first-year university students and teachers. They found alternative conceptions which were that mutations happen in response to problems faced by organism. Albaladejo and Lucas (1988: 215-219) used open-ended questions and a questionnaire for asking students about mutation and mutants. The research results presented alternative conceptions which were that mutation was a change, such as referring to a metamorphic change or a developmental change.

11. Genetic Engineering

The alternative conception about genetic engineering was presented in Hill and O'Sullivan (1998: 103-110), who studied biology students' understanding of cystic fibrosis, gene therapy, and gene screening. They used a multiple-choice-type questionnaire with 290 Year 1 biology undergraduate students and found the alternative conception about how gene therapy could be effective for cystic fibrosis.

Communication and Classroom Interactions

The Thai Government has emphasized communication as an important strategy in Thai educational reforms, especially in science. Science education and communication are concerned not only with everyday life, but also the classroom environment. Students should be prepared to be a part of communities with the ability to communicate their ideas about science topics which are related to their social situation.

Communication skills are one of the goals and important strategies of Thai educational reforms for students who learn science. Communication skills are one of the eight *Science Contents* in the *Handbook for Science Learning Management* is *Nature of Science and Technology*. Two of thirteen items for high school students Grade 10-12 must have before graduating from school are: record and describe the results of surveying by giving the reasons…; and present the tasks, write report and/or explain about concept, process and the results of project of the artifact to make other people understand it (IPST, 2002: 16).

It is difficult to find a complete definition of communication. While Elstgeest (1985: 109) noted that communication can be a part of the process or product of learning, Crick (2001: 35) defined communication as the way that people can participate, and thus it is an essential skill for all students.

Civikly (1992: 10-18) stated that the principles of communication are composed of process and message. Where communication is regarded as a process it is nevertheless in constant change; a system of rules; transactional; involves different levels of prediction; mutual influences; occurs in a context which influences the process; both complex and subtle. In teaching and learning, the communication process is an important factor in student conceptualization and can facilitate learning in the classroom (Hansford, 1988: 3, 15 16).

Communication is also regarded as messages, which are both verbal and non-verbal; and can be intentional or unintentional. Every communication message has a content and relationship level. Communication between teachers and students or students and students is important to help the teachers, the students, and the researcher understand students' ideas and understanding in each topic. Edwards (1987) commented that (“says” is a little informal. It is better to use “comments that” “explains that” “demonstrates that”:

> The content of classroom communication is influenced by such things as: “the responsibilities of teachers as representatives of a culture, and as agents of society; the immediate, practical difficulties facing an adult with limited resources in charge of a group of young children; teachers' implicit beliefs about how children learn, and how they can best be helped to do so” (p.31).

Verbal and non-verbal communication is received from ‘what the people say’ and ‘how they said it’ (Hansford, 1988: 5). Verbal communication has more influence on cognitive learning; non-verbal communication has more influence on affective learning (Hansford, 1988: 78).

The work of Vygotsky and Bruner (Edwards, 1987: 19) showed the importance of verbal communication and how it influences students’ cognition. Even though Barnes et al. (1990) showed that language which people used in the classroom had an influence on other people’s understanding, Elstgeest (1985) argued that “discussion should be included in all science activities” (p.109). Elstgeest’s idea can link to Lemke (1990: x), who explained that language plays an important part in the scientific classroom.

Language is significant because it is present in both teaching and learning, and in forming people’s thoughts and ideas. The roles of language for student understanding are as a medium for teaching and learning, and as a material for students to construct their own ways of thinking (Edwards, 1987: 20). Students should have activities and conversation with other people in their societies, to develop their learning and thinking (Edwards, 1987: 19). According to Vygotsky’s theory, the interaction and talk between teachers and students can promote the students’ conceptual understanding (Edwards, 1987: 20).

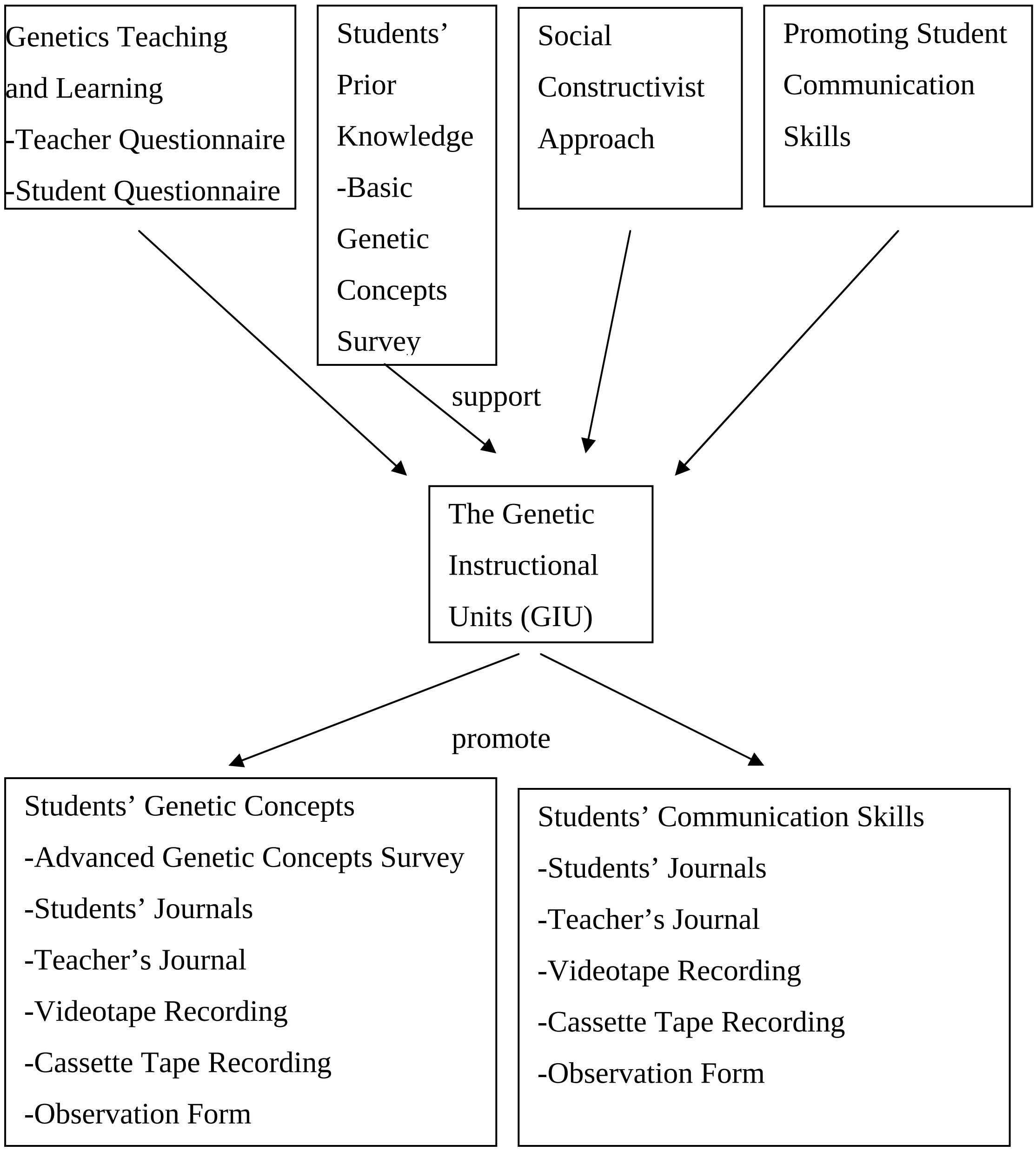
Vygotsky’s idea is that when language and thought come together they combine to create “a cognitive tool for human development” (Edwards, 1987: p.19). Vygotsky argues that human development is “intrinsically social and educational” (Edwards, 1987: p.22). He presented a theory of intellectual development for explaining student understanding.

Communication occurs constantly in science classroom interactions (Hansford, 1988: 15; Bentley and Watts, 1992: 4-5). However, there is more than one style of communication which can be used to explain science and to encourage student thinking about science (Lemke, 1990: 138). Communication can be found in a number of science activities, such as whole-class discussion, small-group discussion with the teacher, small-group discussion without the teacher, notebooks, tape recorder, drawing, painting, modelling, dancing, acting or playing music (Elstgeest, 1985: 92-109; Bentley and Watts, 1992: 17). Lemke (1990) described how to teach students to talk about science, suggesting that the teacher should: "give students more practice talking science; … teach students how to combine science terms in complex sentences; … discuss students' commonsense theories on each topic; … and teach students the minor and major genres of science writing" (p. 168-172). Dialogues can be used to promote a new zone of proximal development for the students (Edwards, 1987: 29). The zone of proximal development (ZPD) which Vygotsky referred to, can be defined as the progression or development of each student's intellect under the guidance of adults or capable peers (Edwards, 1987: 23; Lloyd, 1997: 145).

Communication has an important role in promoting student understanding of science through scientific interaction in the classroom. The way each student learns may be different and teachers should try to find ways to promote each student's understanding. Education can be a process which guides students to be active and creative participants in their culture (Edwards, 1987: 36). Then, to participate in their culture, students have to communicate with others. Both science and communication are social processes (Lemke, 1990: xi-xii), in which people talk, observe, analyse, or write about science for discovering or solving or presenting their own ideas about controversial issues. Communication is an element which characterizes a school as a caring community, which is a component of effective programming for education reform and students at risk (Irmsher, 1997: 1-2).

Teaching science by emphasizing communication is a way to encourage students to be adults who can live in a world where the solution of many science and technology based issues is of paramount concern. In this research, communication skills are students' abilities to participate with colleagues and with teacher, answer questions, write journal entries, present their knowledge or models, and discuss issues with their classmates and teachers in the classroom.

Theoretical Framework



Summary

To summarise, encouraging disadvantaged students to learn genetics involves developing their communication skills and through social constructivism is related to the aims formulated for science teaching and learning in Thailand (IPST, 2002: 3). The 1999 National Education Act of Thailand emphasises equity in education. Disadvantaged students in Thailand need to accomplish the same science content standards and benchmarks as al other students. Genetics is an important part of the Thai science content standard one for which, according to literature, students are likely to have a number of the alternative conceptions. The limitation of the research studies concerning how to promote disadvantaged student learning in genetics for both concepts and communication skills, shows the need for significant research in the area of teaching and learning genetics for disadvantaged students. From a social constructivist perspective it was important that the researcher survey the existing situation of teaching and learning genetics for disadvantaged students and also disadvantaged students' prior knowledge before developing genetic instructional units. The literature suggests that instruction units based on social constructivism would need to include an 'Orientation stage', 'Focus stage', and a 'Conclusion stage' to invite student involvement, check students' prior knowledge, and promote inquiry, investigation and small group and whole class discussion. This view emphasises teachers working in students' zone of proximal development with student as active learners, who participate with capable peers and the teacher to construct their knowledge through social interaction. The following research questions arise from the review of the literatures:

1. What are the current situations of teaching and learning genetics to disadvantaged high school science students in welfare schools of Thailand?

2. What are the basic genetics concepts held by high school science students in welfare schools of Thailand?

3. How to develop Genetic Instructional Units (GIU) that helps disadvantaged high school science students in welfare schools of Thailand to understand genetic concepts and develop their communication skills?

4. What are the impacts of the Genetic Instructional Units (GIU), based on a social constructivist approach, on teaching and learning of disadvantaged high school science students in welfare schools of Thailand?

4.1 What are the advanced genetic concepts and communication skills of disadvantaged high school science students in Thai welfare schools after using the Genetic Instructional Units?

To answer the research questions as above, research methodology was presented in the Chapter 3.