Social Constructivist Teaching and Learning of Genetics for Disadvantaged Students in Welfare Schools of Thailand

RATANAROUTAI, Thasaneeya
Faculty of Education, Kasetsart University
YUTAKOM, Naruemon
Faculty of Education, Kasetsart University

Abstract: The purposes of this interpretive research were: to explore the existing situations of teaching and learning genetics including basic genetic concepts; to develop social constructivist approach based genetic instructional units (GIU); and to study their impacts on the teaching and learning of advanced genetic concepts and communication skills of disadvantaged high school science students in Thai welfare schools. Phase I-survey on teaching and learning were completed by 18 biology teachers and 129 disadvantaged students, and 157 disadvantaged students were surveyed on basic genetic concepts. Phase II-the GIU were implemented with 23 Grade 10 disadvantaged students in a welfare school in Bangkok and 8 Grade 12 disadvantaged students in Nonthaburi Province. The data from classroom observations, interviews, students' work, and advanced genetic concepts survey were analyzed. The findings revealed that the difficult concepts for teaching and learning which teachers and students agreed upon were 'Chemical Structure of DNA', 'DNA Properties and DNA Synthesis', 'DNA and RNA in Protein Synthesis', and 'Genetic Codes'. The most common teaching strategies were teacher explanations, together with student discussions and presentations. Most of the instructional materials used were from students' handbooks. Tests and practical worksheets were mostly used for evaluation. From the Basic Genetic Concepts Survey, the majority of students did not have 'Scientific Conceptions' of genes, chromosomes, dominant and recessive alleles, genetic diseases, inheritance traits, sex chromosomes, and genetic engineering concepts. To teach genetics for disadvantaged students, the teachers need to motivate students to engage in the lessons, check students' prior knowledge, use practical-inexpensive-durable instructional materials, promote social interactions through a variety of teaching strategies, use periodically dynamic assessments, and put students in groups where they are capable of communicating with others. The GIU was shown to assist in promoting students' learning in genetic concepts and communication skills.

Keywords: genetic concepts, disadvantaged students, social constructivist approach, communication skills, welfare schools

Introduction

Significance of the Study

The 1997 Constitution of Thailand state that it is the right of all Thai citizens, irrespective of race, language, gender, age, physical or health condition, personal status, economic or social standing, religious beliefs, education and training, or political views, to have a good quality of life and the ability to depend on themselves (Office of the Council of State, 1997). Thailand is one of many countries which are seeking to enhance the quality of learning and teaching for students and teachers by introducing learning reform. The national education reform in 2000, which is according to the 1997 Constitution of Thailand and the 1999 National Education Act in Thailand, seeks to promote the ability of Thai children to develop their full potential and creativity (ONEC, 2000; Fry, 2002: 37).

According to the Basic Education Curriculum in 2002, genetics is in Content 1 'Living organisms with living processes' of science section. In science content standard 1.2, students should have ability to describe and discuss the genetic transfer process, variation, mutation, and the cause of biodiversity (IPST, 2002: 5-9). From the standard, it presents the importance of genetic concepts and communication skills in learning genetics.

Genetics plays a key role in the impact of biology on society and every student should know fundamental concepts about genetics (Browning & Lehman, 1988: 748; Davis & Weller, 1996: xiii; Hartwell et al., 2000: xix). The impacts on society were shown in forensic news and investigation television series, such as *Crime Scene Investigation* (CSI) and *Special Victims Unit* (SVU), which are examples of how genetics is included in "real-life" situations. Genetics at high school level constitutes a large part of the biology curriculum and many students had alternative conception in genetics. Genetics takes up more than half the time allocated to biology during the semester in Thai curriculum. Molecular genetics knowledge is a major topic in the biology curriculum of many countries and an important part of learning reform in science education (National Research Council (U.S.), 1996: 106; National Science Teachers Association, 1996: 84-92, 98-105; Ministry of Education, 1997: 64-69; Institute for the Promotion of Teaching Science and Technology (IPST), 2002: 3-9). Molecular genetics includes the contents of 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 (IPST, 1998: 1, 75, 108; IPST, 2000).

A number of research studies have examined the difficulties encountered in genetics education, and alternative conceptions in genetics held by students. In New Zealand, Wood (1996) described students at senior secondary level in difficulty to learning genetics. In Thailand, Sukpimontree (1988) and Mungsing (1993) found alternative conceptions of genetics in Thai students. Sukpimontree reported that students in Grade 11 of Surat Thani province had high alternative conceptions of polygenes, multiple alleles, monohybrid cross, dihybrid cross, inheritance traits, heterozygous gene, homozygous gene, incomplete dominance, and inheritance and environment. The students had few alternative conceptions of dominant and recessive traits. Mungsing identified students' alternative conceptions of molecular genetics in Khonkaen province, which were the equality of genetic contribution of each parent in sexual reproduction, genetic characteristics, genetic variation, dominance, recessive, dominant gene, phenotype, monohybrid cross, dihybrid cross, allele, incomplete dominant, multiple genes (polygenes), gene and chromosome, and linked gene and gene recombination.

Disadvantaged students are children from particularly difficult circumstances who have had their rights violated; who live on the streets; are prostitutes, orphans or abandoned children; have been attacked; are detained in a 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 Department, 2001: 13-15). Even though these groups of children have their own limitation in education, teachers also have to help them to accomplish the science content standards to develop their full potential. In Thailand welfare schools provide education for disadvantaged students including special needs students or learning disabilities students in the regular classroom, which are then referred to as inclusive. Data from the Welfare Education Department, which is a government unit that has responsibility to look after disadvantaged students in welfare schools of Thailand, indicates the grade point average of students in science including biology is low, approximately grade 2 in the four grade system (Welfare Education Department, 2001).

Social constructivism is a learning theory which acknowledges students' prior learning and focuses on students constructing their own knowledge through social interactions with more capable peers and or the teacher (Driver and Oldham, 1986; Vygotsky, 1978: 86; Howe, 1996: 42, 48; Palincsar, 1998; Kiraly, 2000; Bauer et al., 2001). The social constructivist approach has been proposed as a way to support students with learning disabilities (Graham and Harris, 1994; Mercer et al., 1996). Englert (1992) identified students' learning development in communication using a social constructivist approach for learning disabilities students. To teach disadvantaged students in inclusive classroom, teachers should use a number of flexible teaching techniques, such as small mixed ability cooperative grouping and cross-sexed with mixed ability pairing (Trowbridge et al., 2000). From Vygotsky's point of view, the development of special needs children is determined by the social implications of their impairment (Kozulin et al., 2003: 1-11). Vygotsky's ideas for addressing this included the development of social conditions to help student learn in inclusive classrooms in way consistent with the student-centered approaches recommended in the National Education Act (B.E. 2542) of Thailand.

According to the limitation of research findings in genetics education with disadvantaged students in Thailand, the researcher recognizes the particular importance of learning and teaching molecular genetics to Thai disadvantaged students in welfare schools: these students come from disadvantaged backgrounds but they have to reach the same science content standards as average Thai students. This is the entry point for developing the genetic instructional units in this study which should have the potential to be useful in the wider Thai education for disadvantaged students. An understanding of the teaching and learning of genetics by disadvantaged students will be of benefit for teachers and science educators who work with other students who have difficulty in learning genetics. Understanding genetic concepts and having the ability to discuss social issues involving them will help students to live happily in an ever changing world, which is one of the objectives of learning reform in Thailand. The aim of this study was to find out how to help disadvantaged high school science students in welfare schools of Thailand to learn genetic concepts and communication skills using genetic instructional units based on a social constructivist approach.

Research Objectives

The objectives of this research are as follows: 1) to examine the existing situations of teaching and learning genetics of disadvantaged high school science students in welfare schools of Thailand; 2) to explore basic genetic concepts held by high school science students in welfare schools of Thailand; 3) to develop Genetic instructional units (GIU) that help disadvantaged high school science students in welfare schools of Thailand to understand genetic concepts and develop their communication skills; 4) to study 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.

Review of the Literature

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.

Social Constructivist Teaching and Learning

Constructivism has been defined by a number of educators. 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 modeled 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. 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 artifacts, 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 (2001:599) 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.

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).

The Context of Education in Thailand

In Thailand, the 1997 Constitution and the National Education Act (1999, 2nd 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. Grade point averages of the disadvantaged students in science including biology were low.

Thai learning reform places an emphasis on a learner-centred approach (ONEC, 2000: 25-26). Constructivist teaching and learning are emphasized on this approach, and are being introduced to the Thai classroom (Wasi, 2000: i). Furthermore, teaching and learning, based on a social constructivist perspective, corresponds with the National Education Act (1999, 2nd 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.

The Institute for the Promotion of Teaching Science and Technology (IPST) developed the genetics topics for high school students (IPST, 1983: 127-128). In 2002, IPST in Thailand published the *Handbook for Learning Management in the Section of Science* (IPST, 2002: 3-9). 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). 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.

Disadvantaged Students

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 Department, 2001: 13-15).

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

In the twenty-first century, welfare schools where are in sections of the Welfare Education Department are separated to each Education Service Area Office. Students who learned in welfare schools are disadvantaged students or underprivileged children in especially difficult circumstances (Thevintarapakti, 2000: 7). Nowadays, most of welfare schools extend to high school level and the policy of welfare schools have changed. A variety of disadvantaged students, which are mixed in the same classroom, is a problem in teaching and learning in welfare schools.

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 (Office of Supervision and Development of Education Standard, 2002: 3-4). 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. However, the limitation of teachers and students in welfare schools in Thailand influenced the classroom setting including teaching and learning. Some schools had to set different types of disability children in the same class.

Teaching and Learning for Disadvantaged Students

The use of a flexible number of teaching strategies, along with an assessment 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).

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 to 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.

Genetics Conceptions

Genetic concepts in junior high school of Thailand were composed of gene, chromosome, dominant and recessive allele, the independent assortment of genes, genetic diseases, and sex chromosomes. The genetic concepts 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.

Genetics 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.

Communication and Classroom Interactions

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 et al., 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 and Mercer, 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 and Mercer, 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 and Mercer, 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).

In Thailand, 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).

To summarize, 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 emphasizes 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 emphasizes 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 teaching strategies for developing student understanding of genetic topics and communication skills 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.

Methodology

The methodology of this research is interpretive research. The study has two phases as follows: 1) Phase I-The existing situations of teaching and learning genetics and the prior knowledge of disadvantaged high school students in the welfare schools of Thailand; 2) Phase II-Developing of Genetic instructional units (GIU) and studying teaching and learning genetics using GIU that helps disadvantaged high school science students in welfare schools of Thailand to understand genetic concepts and develop their communication skills.

Subjects

The subjects in each phase is different, in Phase I: 1) the subjects in investigation the current situations of teaching and learning genetics to disadvantaged high school science students in welfare schools in Thailand were 18 biology teachers and 129 science students from 17 welfare schools; 2) the subjects for studying basic genetic concepts of disadvantaged students were 157 disadvantaged high school science students who were studying genetics in the 2004 second semester (they had finished basic genetics and will starting on molecular genetics) in 16 welfare schools of Thailand.

For Phase II, the subjects of students in *Case I* were twenty-three Grade 10 science students in a classroom of a welfare school in Bangkok (School A), Thailand and, the subjects in *Case II* were eight Grade 12 science students in a classroom of a welfare school in Nonthaburi province (School B), Thailand

Instruments

1. Phase I: *Teachers' Questionnaire* and *Students' Questionnaire* were used to survey the existing of teaching and learning genetics for disadvantaged students in Thailand. *Basic Genetic Concepts Survey* was used to survey basic genetic concepts of disadvantaged high school students. The questionnaires were checked validity and language by a genetic expert and two science educators in a university. The teachers' questionnaire was trial out with three biology teachers. The students' questionnaire was trial out with five disadvantaged high school students in welfare schools. The *Teachers' Questionnaire* was composed of 17 questions. The questionnaire consisted of open-ended questions and closed-ended questions using the Likert scale. The questionnaire had two parts. Part A was concerned with the background information of teachers including age, gender, teaching experience, experience in professional development, and their duties in school. Part B consisted of questions asking about the difficulties of genetics topics, including problems and problem-solving in genetics; teaching strategies with instructional materials, assessment and evaluation that teachers had used successively; and suggestions for teaching genetics in high school classrooms of welfare schools in Thailand; and the training topics they would need. The *Students' Questionnaire* was composed of 10 questions. The questionnaire consisted of open-ended questions and closed-ended questions using the Likert scale. The questionnaire had 2 parts. Part A was concerned with the background of students including the students' gender, age, grade, and favourite subjects. Part B consisted of questions asking about genetics learning experiences, including the difficulties of genetics' topics; problems and problem-solving in learning genetics; teaching and learning genetics; and suggestions for teaching and learning genetics; and using genetics knowledge in their daily lives.

The *Basic Genetic Concepts Survey* was validated by eight experts, including two science curriculum developers of IPST, two science educators, and four university-level genetic experts, for content validation. It composed of two-tier multiple choice, 2 diagnostic instrument items and 13 open-ended items, consisting of 7 basic genetic concepts including inheritance traits, gene, chromosome, dominant and recessive alleles, genetic diseases, sex chromosome, and genetic engineering. The survey was trial out with five disadvantaged high school students in welfare schools.

2. Phase II: The instruments for collecting students' genetic concepts were *Advanced Genetic Concepts Survey* with unstructured interview of students' responses, *videotape recording*, and *students' journals*. The instruments for collecting students' communication skills were *videotape recording*, *cassette tape recording*, *students' journals*, *observation forms*, and *teacher's journals.* The *Advanced Genetic Concepts Survey* was validated by eight experts as the *Basic Genetic Concepts Survey*. It consisted of two-tier multiple choice diagnostic questions and open-ended questions. It had 12 questions for 11 concepts; which were DNA function, DNA position, nucleotide, chemical components of DNA, DNA structure, DNA replication, DNA transcription, DNA translation, genome, mutation, and genetic engineering. The survey was trial out with five disadvantaged high school students in

welfare schools. The recording items in the *observation forms* or observer's recorded paper were teaching followed social constructivist approach, sequencing of GIU, problems and solving problems in GIU classroom, and suggestion.

Data Collections

1. Phase I: In the first semester of the 2004 academic year after students' groups had finished genetics basic part at high school level. Teachers' questionnaire and students' questionnaire were sent to 32 biology teachers and 320 high school science students in 32 welfare schools where genetics was taught for science students at high school level from 42 welfare schools in Thailand by mail. Telephone calls were used to clarify the responses and to ask for questionnaires from schools which did not send any questionnaire back. Responses of teachers' questionnaire were 18 from 32, which included telephone calls. The response-rate of teachers' questionnaire was 56.25 percent. For students' questionnaire, there were 129 responses from 320, a 40.31 percent.

Three hundred and thirty one basic genetic concepts surveys was sent by mail to disadvantaged high school students in 32 out of 42 welfare schools after finished Mendelian genetics and will start Molecular genetics at the second semester of the 2004 academic year. Each school received 10 surveys, except for school A and school B which received 23 forms and 8 forms respectively as same as number of science students in their high school program. Telephone calls were made to the schools which did not send any questionnaire back. The response of the survey was 157 from 331, or 47.43 percent. Nature of disadvantaged students in welfare schools is not stable for the whole semester. Some of them move from one school to others according to parents' job. Some schools have to stop running science program, when having a few students. The instruments were sent by based on information of Welfare Education Department, which were reported in the end of each semester.

2. Phase II: In the second semester of the 2004 academic year after students' groups had finished learning genetics by GIU at high school level, the results of teaching and learning genetics were collected. Videotape recordings, cassette tape recordings, student journals, observation forms, teacher's journals, and advanced genetic concepts survey were used for investigating students' genetic concepts. Videotape recordings, cassette tape recordings, students' journals, teachers' journals, and observation forms were used for students' communication skills.

In case I, data in school A was collected by Basic Genetic Concepts Survey and interviews with each student to clarify his/her answers in each concept. Researcher as a teacher in school A (in Bangkok), 'Kate', used the instructional units in a Grade 10 science high school classroom. Kate adapted each unit, such as contents and teaching-learning methods, with a teacher who had 6 years teaching experience in high school, along with another expert who taught biology. In each unit, data was collected by using videotape recordings, cassette tape recordings, students' journal, observer's recorded papers, and teacher's journals. Kate recorded in her journal and interviewed students. The teacher as an expert observed and recorded the classroom in each class when Kate taught in the class. Advanced genetic concepts survey and interviews with each student about his/her answers were used in school A. In case II, the genetics instructional units were implemented by a biology teacher in the school with 8 Grade 12 science students in a classroom of School B in Nontaburi Province. The researcher as an observer collected data by the instruments as in case I.

Data Analysis

1. Phase I: The data analysis of Teachers' Questionnaire and Students' Questionnaire was separated into two types. The first one was data from the Likert scales, which were analyzed into percentages and described. The second one was data from open-ended questions, which were read, categorized, and interpreted. All questions with Likert scale in both teachers' and students' questionnaires were analyzed in percentage and described. Open-ended questions were categorized, grouped, and interpreted.

The researcher studied the congruence of teachers' and students' opinions in the difficulties of genetics' topics; problems and problem-solving in genetics; and the congruence of teaching and learning genetics between Teachers' Questionnaire and Students' Questionnaire from each of the twelve schools that sent back both of the Teachers' Questionnaire and Students' Questionnaire from 17 possible schools. (1 school did not send back Teachers' Questionnaire, and four schools did not respond to Students' Questionnaire Form).

For the data analyses of results from Basic Genetic Concepts Survey, the researcher read all of the students' responses in each item and classified the students' responses into four groups which were 'scientific understanding', 'partial understanding', 'alternative conceptions', and 'no response or no understanding or no conception' (Marek et al., 1990; Haidar and Abraham, 1991; and Brickhouse et al., 2000). For the data analyses of the concepts survey, students' responses which were categorized into 'scientific understanding' referred to those who understood the concept as same as a scientist. The responses which were categorized into 'partial understanding' referred to those who understood some parts of scientists' concept without any alternative conception. The responses which were categorized into 'alternative conceptions' referred to those who had concept (s) differ from scientific concepts. The responses which were categorized into 'no response or no understanding or no conception' referred to those that did not have any theories or understanding about that concept or did not answer the question which asked for investigating their concept or did not respond at all. The categories of the responses were checked by an expert who was a content specialist.

2. Phase II: For data of students' genetic conceptions, researcher read, coded, categorized and interpreted student journals. The criterion for categorizing students in each group of Advanced Genetic Concepts Survey was as same as in the Basic Genetic Concepts Survey categorization. The researcher checked the reliability of the students' conceptions responses with an expert who was a content specialist in a university.

Videotape recording and cassette tape recording were transcribed verbatim and described students' communication skills. Student journals, observation forms, and teacher's journals were analyzed by read, coded, and interpreted for data of communication skills through answering questions, writing journal entries, presenting their knowledge or models, and discussing issues with their peers and teacher in learning molecular genetics instruction units in the classroom.

The criteria of the progression of students' communication skills were abilities to participate with their peers and with their teachers, answer questions, write journal entries, present their knowledge or models, and discuss issues with their peers and teachers among learning with GIU. The researcher read, coded, categorized and interpreted student journals, observer's recorded papers, and teacher's journals for data of genetic concepts, and communication skills. Videotape recording and cassette tape recording were transcribed verbatim, coded, and interpreted for data of communication skills. The researcher used data triangulation for analytical information.

Results

Phase I

The purposes of this part are presenting teachers' and students' perceptions about teaching and learning genetics in disadvantaged Thai high schools in respect to 1) difficult genetic concepts for teaching and learning 2) teaching and learning strategies 3) instructional materials 4) assessment and 5) problems and solving problems in teaching and learning genetics. The results of the congruence between teachers' and students' perceptions were counted from only 12 schools, which sent both teachers' and students' responses back to the researcher. Thirteen biology teachers and 120 high school science students from 12 disadvantaged schools were selected to answer the teacher's and student's questionnaires consecutively. The data were analyzed using percentage and content analysis.

1. Teachers' and Students' Perceptions about Teaching and Learning Genetics

The congruence between teachers' and students' perceptions showed that 9 out of 16 concepts were in the same level of difficulty in both teachers' and students' perceptions. These included; 'Dominant and Recessive', 'Homozygous and Heterozygous', 'Genotype and phenotype', 'Chromosome', 'Relationship between Gene and Chromosome', 'Chemical Structure of DNA', 'DNA Properties and DNA Synthesis', 'DNA and RNA in Protein Synthesis', and 'Genetic Codes'. Seven concepts which students showed a higher level of difficulty than teachers' were; 'Genetic traits', 'Law of Segregation and Law of Independent Assortment', 'Alleles', 'Multiple genes or Polygenes', 'DNA in Prokaryote and Eukaryote', and 'Mutation', and 'Genetic Engineering and Applications'.

The difficult concepts for teaching and learning which teachers and students agreed upon were 'Chemical Structure of DNA', 'DNA Properties and DNA Synthesis', 'DNA and RNA in Protein Synthesis', and 'Genetic Codes'. The overview of comparison between teachers' and students' perceptions showed that most students thought that genetics was difficult for learning, but teachers thought it was moderately difficult for teaching. This information is interesting to genetic teachers in welfare schools. From the difficult of genetics, it can have some effects to genetic concepts of the disadvantaged students in welfare schools. In Thailand, it had limitation of research studied about genetics alternative conceptions of disadvantaged students in welfare schools.

The data from teachers and students is related to each other. Even though most genetics' teaching and learning strategies were teacher explanations, students had chances to discuss and present in their classrooms. Students wanted to learn genetics by expert explanation, using CAI, and debate; even if they did not learn by these strategies.

Teachers thought that information sheets, work sheets, and picture charts promoted their success in teaching genetics. However, students argued that those instructional materials were from the students' handbook. Both teachers and students need to have more interesting instructional materials. Teachers requested some departments to develop genetics instructional materials, which were related to educational technologies in their schools. Students requested some technologies, such as videotapes, for instructional material.

The data of assessment from teachers and students was congruent to each other. Both teachers and students identified that most of the assessment procedures used were from tests and practical worksheets. Even so, the teachers' response showed that using tests and practical sheets with students' activities were parts of successful genetic teaching, but students did not identify these activities in assessment. Students asked for having tests in a variety forms more often.

Most teachers and students thought that the problems in teaching and learning genetics were students, genetics contents, instructional materials, teachers, teaching strategies, and learning time. The biggest problem for students was their basic knowledge of genetics and their attention in learning. Students thought that they had limitation in their intellect for learning. Genetics is difficult content, too much detail and complicated. Schools did not have modern and enough instructional materials. Teachers did not have enough time and did not have strong genetic content, so they did not feel confident in answering students' questions. Learning by reading information from books without doing experiments, and the limited amount time for learning about genetics were affected to teaching and learning genetics.

Teachers with lack of content and pedagogy affected their students' learning. For example, a high school biology teacher at a welfare school did not graduate from a science major. He did not show any significant problems in genetic contents and teaching strategies, but students' responses revealed that he had skipped some genetic contents. Moreover, he could not answer students' questions. Therefore, the school administrator should be concerned about the quality of students' learning before setting teachers to teach in each subject. Teachers should have chances to teach in subjects which they had ability in promoting students' learning.

2. Basic Genetic Concepts of Disadvantaged High School Students in Welfare Schools

From the seven basic genetic concepts, the majority of students had: 'Alternative Conceptions' in gene (89.8 percent), chromosome (84.7 percent), dominant and recessive alleles (82.2 percent), and genetic diseases concepts (54.8 percent); 'Partial Understanding' in inheritance traits (65.0 percent) and sex chromosome concepts (40.1 percent); and 'No Conception' in genetic engineering concepts (62.4 percent).

The students' alternative conceptions from highest to lowest frequency were as follows: 'Gene' (89.8 percent), 'Chromosome' (84.7 percent), 'Dominant and Recessive Alleles' (82.2 percent), 'Genetic Diseases' (54.8 percent), 'Inheritance Traits' (32.5 percent), 'Sex Chromosome' (30.0 percent), and 'Genetic Engineering' (24.8 percent).

Examples of students' alternative conceptions were: 'Gene'- Students identified something outside the body for controlling the traits of living organisms, such as 'Curled or straighten hair being dependent on hair gel and curled hair equipments'; 'Chromosome'- The size of chromosomes depends on the size of the trait, which it has to control; 'Dominant and Recessive Alleles'- Black male cats have black dominant genes and white recessive genes, but white cats have white dominant genes and black recessive genes; 'Genetic Diseases'- If parents have thalassemia genes, their fourth child will have thalassemia disease; 'Inheritance Traits'- Reading ability and sporting abilities, such as running ability or playing tennis can be transferred from parents to offspring; 'Sex Chromosome'- The gender of a baby depends on the 'quantity of inheritance' or 'how many of their chromosomes came from their father or mother' or 'the ability of sperm to show gender' or 'dominance of gender' or 'the quantity of the parents' sperm'; 'Genetic Engineering'- Genetic engineering is 'cutting and pasting tissue' or 'cutting and pasting cells'.

The existing situations of teaching and learning genetics and basic genetic concepts of the students were used as important parts to develop Genetic Instructional Units (GIU) for disadvantaged students accomplishing science content standards and can live as parts of society.

Phase II

The GIU were developed to help disadvantaged students to understand genetic concepts and develop their communication skills. The development of the GIU was based on guiding principles: teaching and learning genetics in Thai welfare schools; basic genetic concepts of disadvantage students in Thai welfare schools; social constructivist approach; promoting student communication skills. The genetics instructional units (GIU) included genetics materials [DNA investigation, DNA chemical structure and structure, properties (replication, transcription, and translation)]; genome; mutation; genetic engineering and applications, and molecular genetics science fair; teaching manuals; and students' workbooks. The twelve genetic topics of the Genetic Instructional Units consisted of; DNA definition and significance, DNA discovery, DNA chemical components and structure, Invention of DNA model, Presentation of DNA model, Genome, DNA properties (Part 1: DNA replication), DNA properties (Part 2: DNA Transcription), DNA properties (Part 3: Translation), Mutation, Genetic engineering, and Mini Molecular Genetics Fair. Each unit consisted of learning outcome(s), genetic concept(s), teaching and learning processes, instructional materials, and assessment and evaluation procedures. The Genetic Instructional Units were implemented with disadvantaged students in two separate welfare schools.

The Context of the Schools, Teachers, and Students

From the two cases, the different contexts of school, teacher, and students affected the implementation of the GIU. For the school context, the school objectives were different as they had different categories of disadvantaged students. The teacher who implemented the GIU in school A had less experience in teaching disadvantaged students, but as the researcher for this study she were more familiar with the GIU than the teacher in school B. This affected the teaching and learning results of the two cases. The students in school A were 23 Grade 10 disadvantaged students who were either financially poor, living with other people who were not their families, had broken homes, or had learning disabilities. The classroom was an inclusive classroom. The students in school B were 8 Grade 12 disadvantaged students who included a prostitute at-risk student, along with students from hill tribes. From a knowledge background, students in school B learned whole biology subjects in the school curriculum except for genetics and evolution topics, such as cell division. The knowledge they had already had could support their learning in the GIU.

Teaching Results

In both two cases, the benefits of checking students' prior knowledge, making inquiries, small group discussions, investigation, and whole class discussions were shown in teaching following the GIU. The instructional materials were easy to use and understand, be inexpensive, durable, easy to find and be used in a variety of activities, which were followed the principle of instructional materials for disadvantaged students. Even though in the introducing part, teacher B seemed to strict with following the GIU. In the both two cases, the teachers linked the former concepts to the new concepts. Along the activities, the teachers used dynamic assessment to check students understanding. Students had chance to learn through social interaction among peers and between student and teacher. In school A, some units also showed strong democratic way of learning together in the society. The beginning of GIU, activities, and assessment were following social constructivist approach. Seating positions in school A had recognized by the teacher A (Kate), because hearing impaired student was included in the classroom. The students in both two cases were grouped with based on mixed gender and mixed ability cooperative grouping following one of teaching techniques for disadvantaged students.

Unit 3 of Case I is an example of social constructivist teaching and learning, which teacher promoted student learning linking student prior knowledge and new genetic concept, using meaningful interesting activities, and grouping techniques to promote students' communication skills.

In the case I, Unit 3 provides a representative example of the teaching and learning genetics for disadvantaged students that occurred through a unit that incorporated the social constructivist ideas of linking to student prior knowledge and promoting student understanding through activities and student talk. The teacher began the unit by referring back to concepts from the previous unit and informing students what they would be learning in the current lesson. To link previous concept to next concepts is important for teaching disadvantaged students.

> Teacher:From DNA discovery last unit you learnt how to discover DNA. Today you will learn more about DNA. Along the way I will give each of you a pack of plastic models and you will do worksheet no. 4 'Chemical components of DNA'.

Worksheet no.4 was designed to find out students' prior knowledge of the chemical components of DNA. A sample question was, 'What are the components of DNA?'. While the students were doing the worksheet the teacher walked around the room giving a pack of models to each student and checking students' answer. Once most of the students had completed the worksheet the teacher reviewed the answers with the whole class. The worksheet had the scientific name in the left column and a space for students' answers on the right. Students had to tick in the items that they thought they were components of DNA. To use dynamic assessment and checking students' prior knowledge were importance for teaching the students.

Teacher: We will answer together. The first item, sugar, is it DNA component?
Students: Yes, it is.

Teacher: The second one, base, is it DNA component?
Students: Yes, it is…teacher, phosphate group as well.
Teacher: Only three of them? What's about acid?
Students: No, it is not DNA component.
Teacher: How could you know?
Students: We read the extra sheets on the back of our book…You told us to read when we have time. Did you remember?
Teacher: Did you?...That's good. How could they composed into DNA?
Students: I think they need something to link each other.
Students: Yes, I agree…but I don't know what it is.
Teacher: You will know after you join in the next activity.

The performance of students that reading further the lesson was surprised both teacher and observer. The observer who taught this class in the last semester told that normally the students might not read books even for examination. The observer asked the researcher for the sources of the extra reading at the back of the students' handbook. The beneficial of the extra readings, the students told the researcher that all of the extra readings were not too long and easy to understand. In case that they could not understand, they feel free to ask the researcher or post in to classroom discussion.

Once the students had answered all the questions on a worksheet (worksheet no. 4), the teacher introduced the next activity which was to use the models to explore the components of nucleotides. Activity sheet no. 2 'Looking for the chemical components of DNA' in the student practical book detailed what the students were to do. The students read the activity sheet and then the teacher asked the students to combine all six pieces of the model (1 base, 1 sugar, 1 phosphate and 3 chemical bonds). All of the students were able to do this. Some of them showed their products to the class. The teacher then moved on to teach the name of the product and each of its components. This information was included on Activity sheet no. 2 where it was stated that the product was called a nucleotide and there was a key for the names of each of the component pieces. However, because she knew that some students had reading difficulties the teacher checked student understanding of the components names using the 'Components of nucleotide' transparency. The transparency had pictures of each of the plastic model components in the left column and a space for the scientific name on the right. The teacher asked the students to match the symbol of the chemical component with each piece of model and to give its scientific name. Students pointed to each plastic piece and told the teacher which were its scientific symbol and its scientific name.

When she was sure that all of the students knew the component names, the teacher asked them to draw or explain the product. As the students drew a picture of the model in their hands, the teacher walked around the class checking that the students could identify each piece of the model. She reminded the class as a whole that they needed to identify each piece of the model.

Teacher: Identify each piece of the model in your picture as well. Students…see the activity sheet with me. In the sheet, it shows that the thing in your hands is called a nucleotide, so what do you think that what are the components of a nucleotide?
Students: Sugar.
Teacher: What else?
Students: Phosphate group.
Teacher: And?
Students: Base.

The teacher noticed that a few students did not answer in the whole class and she suggested that students who were unsure 'go back to see your drawing' because the drawings showed both the links among each component of nucleotide and the names of each piece. The teacher spoke softly to a hearing impaired student who had just smiled and said nothing during the class to make sure that he could follow what was required. She said, 'Could you follow? If you hear did not clear, you can tell me, ok?'. AM01, who was a male student number one in school A, nodded and smiled.

The next task was for the students to combine their model with that of their friends using the white or bonding pieces. When the students had done this they told the teacher that the product was called a polynucleotide and some of them taught this word to other students who did not know it.

AM08: Why did you call it a polynucleotide?
AM12: Because, it has more than one nucleotide.
AM08: Yes, I knew that it had more than one nucleotide…but, why did you call it a polynucleotide? How did you know that?
AM12: …
AM02: From chemistry.
Teacher: What do you mean?
AM02: In chemistry, if you have more than one…it was called poly…
AM05: We could call it 'bi' or 'di' in chemistry, if we had only two.
AM03: Yes, but we had more than three nucleotides linked together in this activity.
AM08: Oh, I see…Umm, I should not skip chemistry class.

The students then separated out their models. The teacher asked them to find out which bases could match with each other. Once all the students had found their matching base they read and answered the questions on the activity sheet. The teacher checked that the students realized which bases fitted together, asking:

Teacher:What are your results? Can your nucleotide match with anyone?
Students:Green has to match with yellow.
Teacher:What are they?
Students:Thymine and Adanine.
Teacher:What's about Guanine?
Students:It matched with Cytosine.
Teacher:Then, what do you have to do next?
Students:Combine our model with other couples in the white side.
Teacher:Combine it all.

The next step was for the whole class to combine their models as one piece to show how the polynucleotides combine to form the DNA structure. From the activity sheet, students had to twist their model in the clock wise direction. From the sheet, students knew that their model was called 'DNA'. After students twisted their model, one student compared it with a staircase that had been in a fire. Each step of the activities moved from easy to difficult concepts as scaffolding for helping disadvantaged students learn complicated concepts.

The conclude of the lesson, the teacher asked questions to probe and clarify student thinking and understanding, such as, 'How many types of bases do we have?', 'Which ones can combine together?', 'When you have places to step on, what's about the place for hanging?'. Students followed the questions and compared their model and teacher's model. The whole class discussion summed up the lesson ideas as the ordering of bases in DNA varies; each DNA molecule is composed of 2 polynucleotides; each polynucleotide is composed of nucleotides and each nucleotide is composed of a base, a sugar, and a phosphate group.

In this unit, the teacher used a sequence of activities to build student understanding through physical models and discussion. Students worked in pairs, in groups of 5-6 and in the whole class to compose a nucleotide and then polynucleotides and finally a DNA structure. The teacher catered for the disadvantaged students through her use of hands-on activities, physical models and the coupling of reading and drawing with talk. Dynamic assessment and evaluation were used during the answering of the activity sheet and in each step of composing the model. The plastic models in the unit were easy to use and understand which suited with principles for using instructional materials with disadvantaged students. The seating position of the hearing impaired student was such that he could see the teacher's mouth.

In the case II, Unit 10 provides a representative example of teaching and learning genetics for disadvantaged students that incorporated the social constructivist ideas of linking to student prior knowledge and promoting student understanding through classroom interactions using social context in a variety of teaching and learning. The following dialogues were examples of the teacher who started teaching by asking questions of students' prior knowledge.

Teacher:What is genetic material?
Students:DNA.
Teacher:What is DNA?
Students:DNA is genetic material which can transfer from generation to next generation.
…
Teacher:How many types of bases?
Students:Four.
Teacher:What are they?
Students:Adenine, Guanine, Cytosine, and Guanine.
Teacher:From the previous unit, you know that DNA is a genetic materials and as a template in protein synthesis. Could you tell me the steps in protein synthesis?
Students:First, DNA copy themselves…
Students:Replication.
Teacher:Then…
Students:DNA transcription…RNA was created.
Teacher:And…
Students:Translation…from RNA to protein.
Teacher:OK, from your knowledge, today we will learn about how the things you learned before link to our real life.

The communication skills are parts of scaffolding which could promote students' understanding in genetics. Both Unit 10 above and Unit 1 as following are interesting examples of using a variety of flexible activities in GIU were used and could raise students' attention in genetics. According to students' background, seven from eight students in this case were hill tribe students. They had limitation of speaking Thai accent. In the beginning of GIU implementation, they did not answer teachers much. After the researcher talked to them and let them know that their accent is quite good, they answered more when teacher asked questions. The following example of Unit 1 was differing from the example of Unit 10 in the former part.

Teacher:From this picture, where is the position of DNA in human body?
Students:Umm…
Teacher:From the picture, what is the relationship between DNA and chromosome?
Students: …

Teacher:Hmm…where is the position of DNA in human body?
Students: …

In school A, the teacher was quite clear about the aims of the activities in each unit of the GIU, because she had developed them. Thus, her teaching was followed the GIU without being too rigid in keeping to the scheduled teaching time of each unit. In school B, teacher B tried to follow the GIU which had a guiding principle based on a social constructivist approach, but sometimes she also used her own teaching style when transferring knowledge to the students.

Learning Results

The students showed their learning results through genetic concepts and by setting questions, investigating their own answers, inventing concrete models, discussing with peers and teachers, presenting their ideas using communication skills.

The GIU promoted genetic concepts of disadvantaged students along the social interaction in the activities, which were showed in students' dialogues of cassette tape recording, videotape recording, and in advance genetic concepts survey. The GIU contributed to promoting students' learning in school A, even though the class had a hearing impaired student and an autism child who had background problems in communication. In school B, the limitation of the students' languages affected their communication, along with learning activities in which they had to present their ideas, such as inquiries, small group and whole class discussions. However, the GIU showed the significance of encouraging the students in school A and B to develop their communication step by step before moving onto next level. Both students in school A and B realized that scientific knowledge can be changed when further knowledge is discovered. They should now have enough scientific knowledge to communicate with other people and to present their ideas in discussions of scientific issues in their daily lives as their presentation in molecular genetics exhibitions.

Advanced Genetic Concepts Survey were composed of DNA function, DNA position, nucleotide, chemical components of DNA, DNA structure, DNA replication, DNA transcription, DNA translation, genome, mutation, and genetic engineering. In Case I, DNA position and mutation were the concepts in which students did not have alternative conceptions. Mode of the students in each concept was 'partial understanding'. About one third of the students had alternative conceptions in nucleotide, DNA transcription, and DNA translation. Students in school B seemed to have less alternative conceptions than school A in each concept. DNA function, DNA position, nucleotide, DNA structure, DNA replication, DNA transcription, genome, and mutation concepts did not have students' alternative conceptions. Some concepts which students had alternative conceptions were developed through activities in the GIU. For example, most of the students in both schools had alternative conceptions of gene and chromosome. The alternative conceptions were edited along activities before moving through DNA position. Then, in both schools did not find students' alternative conceptions in DNA position.

Problems of the Implementation

The problems of the implementation the GIU in both schools were finding suitable classrooms and equipments. Normally, welfare schools have budgets supported by the government. However, the materials and equipments in these schools were not ready to use. When the teachers wanted to use the equipments, they could not find its and often could not use its. In addition, it was hard to find classrooms that had the equipments. To develop teachers who have both pedagogy and strong content to draw upon. The variety of students' backgrounds and prior knowledge are important problems to students' learning.

Conclusions and Discussion

In phase I, the existing situations of genetic teaching and learning showed that the teacher respondents taught genetics by a variety of teaching strategies. The main teaching strategy was teacher explanation mixed student presentation and teacher questioning to raise student thinking. The data of difficult concepts for teaching and learning was related to students' alternative conceptions in these concepts. Buntting et al. (2003) found alternative conceptions in DNA functions, which was a part of DNA properties in university students. Wood (1996:58), and Marbach-Ad and Stavy (2000) found students' difficulties in learning DNA replication. Lewis et al. (2000a), Marbach-Ad and Stavy (2000), Fisher (1983) and Fisher (1985) showed alternative conceptions of the functions of DNA and RNA in protein synthesis. Lewis et al. (2000a-b) presented alternative conceptions of genetic codes. Instructional materials were various but most came from student textbooks or a teachers' manual. Teachers assessed student learning using test and practical sheets. The teachers said they would like to attend a professional development program to develop their teaching strategies and to help them create instructional materials. Student responses showed that they would prefer a variety of teaching and learning strategies. The students expressed a preference to learn knowledge which they could use or link to their daily lives. When they had problems in genetics, they talked with more capable peers or teacher. In conclusion, the results showed that teachers and students had teaching and learning problems, which were: 1) students had low motivation and had limitations in learning genetics; 2) teachers had knowledge limitations about genetics; 3) the predominant teaching and learning strategies were teacher explanation with student presentation and discussion; 4) instructional materials were out of date; 5) the assessments were tests like the examination. These findings indicated a need to develop the teaching and learning of genetics for disadvantaged students with support for a social constructivist approach.

The 'Basic Genetic Concepts Survey' results showed a variety of student alternative conceptions. The results showed that the majority of students had 'Alternative Conceptions' about genes, chromosomes, dominant and recessive alleles and genetic diseases concepts.

They had 'Partial Understanding' about inheritance traits and sex chromosome concepts; and 'No Conception' in genetic engineering concepts. This presented the need to find some way to develop students' understanding in these scientific concepts.

The genetics instructional units (GIU) emphasized on social constructivist approach that were designed in phase II of the study were based on a social constructivist perspective to teaching and learning for disadvantaged students in the welfare schools of Thailand. The unit had two goals: to develop the genetic concepts of disadvantaged students and to promote their communication skills.

From the Basic Genetic Concepts Survey of the students in the two case study classes, the majority of disadvantaged students did not have scientific conceptions. In school A, the majority of them in each genetic concept showed that they did not have scientific conceptions in any of the 7 concepts. Most of them had 'alternative conceptions' in genes, chromosomes, dominant and recessive alleles, genetic diseases, and genetic engineering concepts; and 'partial understanding' in inheritance traits and sex chromosome concepts. The majority of disadvantaged students in school B did not have scientific conceptions in five concepts out of seven. Most of them had 'alternative conceptions' in inheritance traits, genes, chromosomes, genetic diseases, and genetic engineering concepts; and 'partial understanding' in inheritance traits, sex chromosomes, and genetic engineering concepts.

The results from implementing GIU in both two cases showed that genetic concepts of disadvantaged students were developed. To implement the GIU in an effective way, the teachers had to prepare themselves both knowledge and pedagogies before coming into the class. The teacher in school A realized that she should learn hand language in case that she had to teach hearing impaired students. The hearing impaired student could not understand some words; even he was able to hear it. The teacher in school B realized that she should find time to revise teaching and learning theories and new strategies to improve her teaching. In conclusions, to implement the GIU in each school, teachers should adapt some parts or activities to suit for the genetic prior knowledge. The researcher realized that the ordering of teaching and learning in each grade was importance to students' understanding. For example, when the teacher in school B knew that the students had alternative conceptions about chromosomes, she started the lesson by turned on videotape of cells and chromosomes, before following the instructions of the unit in GIU.

In conclusion, teaching genetics for promoting genetic concepts for disadvantaged students should: 1) checking students' prior knowledge which related to Gray (2005); 2) scaffolding student learning by creating flexible meaningful and culturally relevant activities with practical instructional materials, using dynamic assessment, which related to Palincsar (1998), Kiraly (2000), and Bauer et al. (2001); 3) believing that every student can develop their understanding; 4) using daily lives issues which students could raise students motivation into the lesson; 5) connecting among concepts in each unit or in the unit following easy to difficult concepts; 6) setting seating position that hearing impaired student could see teacher's mouth which related to Division of Disability People (2000: 14, 102, 117, and 119); 7) grouping students in small mixed ability cooperative groupings and cross-sex and mixed ability parings, which related to Schwartz (1987); 8) using instructional materials which easy to find, easy to use and understand, be used in a variety of activities, be inexpensive, and durable were related to policy of teaching for disadvantaged students (Division of Disability People, 2000: 14, 102, 117, and 119), and using practical instructional materials was another scaffolding to help students learning genetic (Palincsar, 1998; Kiraly, 2000; Bauer et al., 2001); 9) studying students' background in education, physical, and mental. To use 1) understandable activities which move from easy to the difficult one with 2) practical instructional materials with 3) grouping techniques along with 4) periodically dynamic assessment and 5) study the limitation of student communication skills individually could also promote students' communication skills. Most of participants could use language as an important tool to develop their understanding in genetics through social interaction in the GIU classroom.

To explore the advanced genetic concepts held by disadvantaged high school science students in welfare schools A and B which was a part of the second phase, the 'Advanced Genetic Concepts Survey' was used. In school A, from the 'Advanced Genetic Concepts Survey' most of the students had 'Scientific Understanding' in DNA function, chemical components of DNA, genome; 'Partial Understanding' in nucleotide, DNA structure, DNA replication, DNA translation, mutation, and genetic engineering; 'Alternative Conceptions' in DNA transcription; and 'No Conception' in DNA position. In school B, from the survey most of the students had 'Scientific Understanding' in DNA function, nucleotide, genome, mutation; 'Partial Understanding' in chemical components of DNA, DNA structure, DNA replication, DNA transcription, DNA translation, and genetic engineering; and 'No Conception' in DNA position.

The results from implementing GIU in both two cases, GIU helped the disadvantaged students in the welfare schools of Thailand understand advanced genetic concepts through a variety of activities that involved social interaction, such as inquiries, hands-on activities, investigation, small group discussion, and whole class discussion. The students as active learners had to: 1) help their group doing a variety of activities; 2) discuss among peers or with teacher; 3) answer teacher's questions; 4) set questions for finding ways to investigate the answers. The GIU also encouraged students to develop their communication skills through activities such as the presentation of a DNA model and a molecular genetics exhibition. In school A, the GIU promoted disadvantaged students' communication skills through inquiry, small group activities and whole class discussion. For instance, during the unit, an autistic child who had problems in communication was a volunteer in reading in front of the class. In school B, all students had less confidence in their Thai accent because seven of them were from a hill tribe and the eight did not speak Thai in her family. From the variety of learning activities in GIU and with some encouragements from the teacher and the researcher, they were able to develop their communication skills and to present their ideas both in their groups and in a school exhibition. In conclusion, the disadvantaged students had to 1) start to speak out their idea, which may in the small group before moving toward the whole class discussion or with teacher; 2) dare to ask questions when could not follow the class or have some ambiguous questions; 3) have contribution in group artifacts; 4) develop their writing through journals or whiteboard.

To implement GIU which based on social constructivist approach, the existing situations of teaching and learning genetics, and basic genetic concepts of disadvantaged students can help disadvantaged students developed advanced genetic concepts and communication skills.

Suggestions

From the study, the researcher had recommendations for teachers who have to teach disadvantaged students, science educators who have to deal with the students and the teachers, and policy maker as follows.

1. For teacher

1.1 To teach genetics for disadvantaged students need to link with their daily lives. To see the relationship between the knowledge they are learning in class and the potential benefits of this knowledge in the social situations of their daily lives are important to their intention and understanding.

1.2 To check students' alternative conceptions and checking students' prior knowledge before teaching allowed the teachers to better develop student understanding. The study provides that a number of ways teachers might use to develop students' understanding before moving to the new concepts. Teachers would benefit from professional development around these.

1.3 While the GIU was successful in the two cases described here teachers should be encouraged to revise and refine it to fit with their students. For instance, the teacher in school B added a videotape of chromosomes for students once she reviewed the Basic Genetic Concepts Survey results and realized her students had problems in understanding chromosomes.

1.4 It is important that teachers understand the purposes and process of GIU implementation. Implementing the units with understanding is likely to be more useful for both teacher and students in the long term. Once a teacher has understood the principles of social constructivism embedded in the units it would seem to be more likely that the teacher would develop others topic units in the same way by her or himself. Hence, it is recommended that professional development accompany the dissemination of the units.

1.5 The social interactions among peers and between the teacher and students could contribute students learning genetic concepts through the GIU.

1.6 Teaching genetics for disadvantaged students need understanding from teacher, not only because of their background of genetics knowledge but also background of their mental, physical, and society. Teachers should belief of potential development of their students. According to the 1999 National Education Act and 1997 Constitution of Thailand, which need to develop all people to fulfill their capability. However, according to social constructivist approach as Vygotsgy's perspective, everybody can develop their learning through social activities with more capable peers. Teachers have responsibility to promote disadvantaged students' learning by checking students' prior knowledge, connecting among concepts, using a variety of teaching strategies (concerning to mixed ability and mixed genders in each group) and dynamic assessment.

2. For Science Educator

2.1 The advanced genetic concepts survey should use with students in other welfare schools at the same time. Each welfare school may have specific variables which can be affected to students' conceptions in genetics.

2.2 The GIU should implement into other welfare schools where similar characteristics of students have, such as students who have limitation in communication skills or who are poor, orphans, separated family, intellectual disability, autism, and hearing impaired students to study the implications of using GIU to genetic conceptions and communication skills.

3. For Policy Maker

3.1 The teacher who teach genetics should be teacher who have background in biology. For example, the results of Chapter 4, it showed the problems in teaching and learning genetics when the teachers graduated from mathematics but had to teach genetics.

3.2 The teacher who have to teach genetics for disadvantaged students should be able to communicate with the students and have knowledge in special education.

3.3 The disadvantaged students may have different goals in their lives according from their limitation in financial, physical or mental. Then, the educational goals in learning genetics of the students may differ from the average students. The policy maker should concern about their need and their goal in education more than try to push them to accomplish the national goal for average students.

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