THE COMPARATIVE EFFECTS OF PREDICTION/DISCUSSION-BASED LEARNING CYCLE, CONCEPTUAL CHANGE TEXT, AND TRADITIONAL INSTRUCTIONS ON STUDENTS' GENETICS UNDERSTANDING AND SELF-REGULATED LEARNING

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ABSTRACT

THE COMPARATIVE EFFECTS OF PREDICTION/DISCUSSION-BASED LEARNING CYCLE, CONCEPTUAL CHANGE TEXT, AND TRADITIONAL INSTRUCTIONS ON STUDENTS' GENETICS UNDERSTANDING AND SELF-REGULATED LEARNING

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The purpose of this study was to investigate the comparative effects of prediction/discussion-based learning cycle (HPD-LC), conceptual change text (CCT), and traditional instructions (TI) on 8^{th} grade students' understanding of genetics concepts and on their perceived motivation and perceived use of learning strategies.

This study was carried out during 2006-2007 fall semester at a public elementary school in Ankara. A total of eighty-one 8^{th} grade students from three intact classes were involved in the quantitative part of this study. Students in the first and second experimental groups instructed with HPD-LC and CCT, respectively. The students in control group received TI. In the qualitative part, pre- and post-instructional interviews held with six students were interpreted by using a multidimensional interpretive framework of conceptual change.

In this study the Genetics Concept Test was administered as pre-test, post-test, and delayed post-test in order to examine the effects of instructional strategies on students' genetics understanding and retention. The Motivated Strategies for Learning Questionnaire was administered as pre-test and post-test to examine the effects of instructional strategies on students' motivation and use of learning strategies.

The results of mixed between-within subjects ANOVA revealed that students in both experimental groups understood the genetics concepts and retained their knowledge significantly better than students in control group. One-way MANOVA results revealed that HPD-LC students used elaboration strategies significantly more than CCT students. Interview analysis by considering ontological, epistemological, and social/affective perspectives of conceptual change indicated that some students from each group underwent conceptual change concerning the genetics concepts.

Keywords: Prediction/discussion-based learning cycle, conceptual change text, motivation, learning strategies, ontological-epistemological-social/affective perspectives

ÖZ

TAHMİN/TARTIŞMAYA DAYALI ÖĞRENME EVRESİNİN, KAVRAMSAL DEĞİŞİM METİNLERİNİN VE GELENEKSEL ÖĞRETİM YÖNTEMİNİN ÖĞRENCİLERİN GENETİK KONULARINI ANLAMALARINA VE ÖZ-DÜZENLEME BECERİLERİNE OLAN ETKİLERİ

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Bu çalışmanın amacı tahmin/tartışmaya dayalı öğrenme evresinin, kavramsal değişim metininin ve geleneksel öğretim yönteminin öğrencilerin genetik konularını anlamalarına ve öz-düzenleme becerilerine olan etkilerini incelemektir.

Bu çalışma 2006-2007 öğretim yılı sonbahar döneminde Ankara iline bağlı bir devlet ilköğretim okulunda gerçekleştirilmiştir. Çalışmanın nicel araştırma yöntemlerinin kullanıldığı kısmına, üç ayrı sınıfta yer alan 81 sekizinci sınıf öğrencisi katılmıştır. Birinci deney grubundaki öğrenciler genetik konusunu tahmin/tartışmaya dayalı öğrenme evresi ile, ikinci deney grubundaki öğrenciler kavramsal değişim metini ile, kontrol grubu öğrencileri ise geleneksel öğretim yöntemiyle işlemişlerdir. Çalışmanın nitel kısmında ise, 6 öğrenci ile uygulama öncesi ve sonrasında yapılan yüz yüze görüşmeler kavramsal değişimin çok yönlü perspektifleri kullanılarak incelenmiştir.

Bu çalışmada, adı geçen öğretim yöntemlerinin öğrencilerin genetik konularını anlamalarına ve bilgilerinin kalıcılığına olan etkilerini belirleyebilmek amacıyla Genetik Kavram Testi ön-test, son-test, ve ertelenmiş son-test olarak uygulanmıştır. Öğrenmede Güdüsel Stratejiler Anketi bahsedilen öğretim yöntemlerinin öğrencilerin motivasyona ve öğrenme stratejilerine olan etkilerini araştırmak amacıyla ön-test ve son-test olarak uygulanmıştır.

Karışık varyans analizi sonuçları, deney gruplarında bulunan öğrencilerin genetik konularını kontrol grubundaki öğrencilere göre istatistiksel olarak daha iyi anladıklarını ve öğrendikleri bilgilerin daha kalıcı olduğunu göstermiştir. Çok yönlü varyans analizi sonuçları, tahmin/tartışmaya dayalı öğrenme evresiyle öğrenim gören öğrencilerin, kavramsal değişim metinleriyle öğrenim gören öğrencilere göre detaylandırma stratejilerini daha çok kullandıklarını göstermiştir. Yüz yüze görüşmelerin, kavramsal değişimin ontolojik, epistemolojik ve sosyal/duyuşsal boyutları ele alınarak yapılan incelemelerinin sonuçları da bazı öğrencilerde kavramsal değişimin meydana geldiğini göstermiştir.

Anahtar sözcükler: Tahmin/tartışmaya dayalı öğrenme döngüsü, kavramsal değişim metini, motivasyon, öğrenme stratejileri, ontolojik-epistemolojik-sosyal/duyuşsal perspektifler.

To my beloved mother and father

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LIST OF SYMBOLS

EG: Experimental Group

CG: Control Group

HPD-LC: Prediction/discussion-based Learning Cycle

CCT: Conceptual Change Text

TI: Traditional Instruction

GCT: Genetics Concept Test

MSLQ: Motivated Strategies for Learning Questionnaire

IGO: Intrinsic Goal Orientation

EGO: Extrinsic Goal Orientation

TV: Task Value

CLB: Control of Learning Beliefs

SELP: Self-Efficacy for Learning and Performance

TA: Task Anxiety

R: Rehearsal

E: Elaboration

O: Organization

CT: Critical Thinking

MSR: Metacognitive Self-Regulation

MANOVA: Multiple Analysis of Variance

CHAPTER I

INTRODUCTION

Over the years, researchers have concerned about the factors that have an important role in the development of students' conceptions such as; pre-existing knowledge, everyday language, reasoning ability, and type of instruction. Among these factors, the most attention has been given to the role of students' pre-existing knowledge in understanding how learners acquire knowledge. It was mentioned by Hewson and Hewson (1983) that pre-existing knowledge of learners has a big role in the construction of the new knowledge in science. Educational research has consistently reported that students come to class with varying ideas about science and natural world (e.g. Duit & Treagust, 2003). In fact, Ausubel (1968) mentioned the importance of students' existing knowledge in constructing the new knowledge in a meaningful way. When the students cannot construct effective linkages between their existing knowledge and the new knowledge, development of conceptions is prevented (Novak, 1988) which in turn leads to rote learning. It is claimed that rote learning lead students generate misconceptions concerning scientific concepts (BouJaoude, 1992; Williams & Cavallo, 1995). Genetics is among such topics which students tend to learn by rote (Cavallo, 1996) and consequently develop various misconceptions. Several research have shown that genetics is one of the most important and difficult topics of science (Bahar, Johnstone & Hansell, 1999; Banet & Ayuso, 2000; Kindfield, 1991; Venville & Donovan, 2007). Major concepts of genetics which the students do not fully understand are shown in the research as chromosomes, genes, alleles, homozygous, heterozygous, dominance, recessiveness, mitosis, meiosis, and fertilization

(Clark & Mathis, 2000; Lewis, Leach & Wood-Robinson, 2000a; Lewis, Leach & Wood-Robinson, 2000b; Slack & Stewart, 1990). Major reasons of students' incomplete understanding of genetics concepts lies under their abstract nature (Law & Lee, 2004) and their relatedness to different levels of organizations namely; macroscopic level (organismal), microscopic level (cellular), and submicroscopic level (biochemical), which need connection among each other for coherent understanding (Marbach-Ad & Stavy, 2000). Students should connect each genetics concept with each other in a meaningful way in order to understand further scientific concepts better like; reproduction, biological diversity of organisms, mutation, adaptation, evolution, and daily life applications of genetics like; cloning, medicine, agriculture, forensic science, genomics (Tsui & Treagust, 2007; Rotbain, Marbach-Ad & Stavy, 2006). Moreover, in order to be effective scientific literate citizens in the future, individuals should have an understanding of basic concepts of genetics (Venville, Gribble & Donovan, 2005). Therefore, meaningful learning of genetics concepts has become an important issue.

Researchers offer alternative strategies to promote meaningful learning in genetics. One of them is the conceptual change approach. Based on Piaget's notions of assimilation, accommodation, and disequilibrium, conceptual change theory focuses on conditions for students modify their existing conceptions with new ones. Four conditions should be met in order to change students' assumptions about knowledge and about knowing. According to Posner, Strike, Hewson and Gertzog (1982) there must be dissatisfaction with existing knowledge, the new conception must be intelligible, referring that the students understand the meaning of the new concept, the new conception must be plausible, referring that the student finds the new concept believable, and the new concept must be fruitful, referring that the student can solve other problems by the new concept. If these conditions are met, accommodation of the new conception may occur. There are several research studies that utilize different teaching strategies based on conceptual change theory. Prediction/discussion-based learning cycle (HPD-LC) and conceptual change texts (CCT) are two of these teaching strategies.

HPD-LC is a type of learning cycle in which a prediction/discussion phase is added at the beginning of three-phase Karplus learning cycle involving exploration, term introduction, and concept application phases (Lavoie, 1999). In prediction/discussion phase, hypothetico-predictive problem sheets are administered to the students in which they make predictions about the related problem and form hypothesis. This phase is followed by whole-class and small-group discussions in which the students discuss their predictions and their reasons. In the exploration phase, students explore and test their own predictions by observing and collecting data related with the question while involving in an inquiry activity. In the term introduction phase, the teacher explains related terms and discusses the results obtained in the exploration phase. In the final phase, concept application phase, students extend the new concept while solving problems and answering questions about it. When compared with traditional learning cycle instruction, HPD-LC provided significantly greater gains in using process skills, logical-thinking skills, science concepts, and scientific attitudes (Lavoie, 1999).

CCT is another teaching strategy that is designed according to conceptual change approach. The aim of conceptual change texts is to activate students' misconceptions by posing questions and presenting common misconceptions. Once students' misconceptions are activated, disequilibrium between students' existing conceptions and the scientific conception is created. Afterwards, scientific explanations that are supported by examples are provided. Several studies showed that conceptual change texts are very effective in creating conceptual change and leading to meaningful learning of many science concepts (e.g. Wang & Andre, 1991; Chambers & Andre, 1997).

How to assess conceptual change, however, is a main concern of educators for years. For example, Slotta, Chi and Joram (1995) mentioned that it is not accurate to evaluate whether students' misconceptions are removed or not based on the improved test scores on a quantitative task. A multidimensional interpretive framework of conceptual change was proposed by Tyson, Venville, Harrison and Treagust (1997) for analyzing conceptual change. This framework includes ontological, epistemological, and social/affective perspectives. From an ontological perspective, conceptual change is seen as a change in the ontological category of a concept in student's mind from a nonscientific category to scientifically correct category (Chi, Slotta & de Leeuw, 1994). Posner et al.'s (1982) conceptual change model describing students' conceptions as intelligible, plausible, and fruitful, is from an epistemological perspective since it includes not only the students' knowledge about a concept but also the status of their conceptions which is their judgments and opinions about their own knowledge (Venville & Treagust, 1998). The status of a person's conception is explained as the extent to which the conception meets the conditions of intelligibility, plausibility, and fruitfulness, and as more conditions are met, its status becomes higher (Hewson, 1992). Both ontological and epistemological perspectives of conceptual change focus mainly on students cognitive processes. However, Pintrich, Marx and Boyle (1993) mentioned the inadequacy of this cold conceptual change model in explaining the reason of why some students are not able to involve in school tasks although they have adequate prior knowledge. They suggested that individual differences in motivational beliefs and classroom contextual factors may shed light on this problem. According to authors, the role of social factors, classroom contextual factors, and affective factors on conceptual change should not be ignored. These dimensions form a holistic picture of conceptual change. However, there are few studies in the literature that examine conceptual change from ontological, epistemological, and social/affective dimensions. Also, the studies in the literature which consider a multidimensional interpretive framework of conceptual change did not compare the effects of different instructional strategies on conceptual change.

Recent research also mention that, besides promoting students to discover and construct knowledge about the world around them, their ability to self-regulate their own learning should also be fostered due to assumed relationship between self-regulation and academic achievement. Self-regulation refers to the ability of the learner to understand and control her learning environment and has three components; cognition, metacognition, and motivation (Schraw, Crippen & Hartley, 2006). Cognition component includes the necessary skills for encoding, memorizing, and recalling information. Metacognition component includes skills that aid the learners to monitor and regulate their cognitive learning processes. Motivation component includes beliefs and attitudes that influence the use of cognitive and metacognitive skills. Self-regulatory skills aid the students to become active participants of their own learning in developing life long learning skills (Zimmerman, 2002). Although it was mentioned that instruction has an important role in teaching self-regulatory skills which promote students' motivation and achievement (Schunk & Zimmerman, 1997; Zimmerman, 2002), there are no studies conducted to provide empirical evidence related with the effectiveness of HPD-LC instruction and CCT instruction on self-regulation.

With the consideration of mentioned gaps in the literature, this study aimed to investigate the effects of the HPD-LC instruction, CCT instruction, and traditional instruction on students' genetics understanding and retention. In order to further probe students' understanding about related genetics concepts a multidimensional interpretive framework of conceptual change was used including ontological, epistemological, and social/affective perspectives. Additionally, the effects of the HPD-LC instruction, CCT instruction and traditional instruction on different facets of student' self-regulated learning, including motivation and use of learning strategies, were investigated. The findings of the current study will be a focus of interest of the teachers, curriculum designers, and other researchers. Teachers will be able to implement above mentioned instructional strategies in their classroom instructions about genetics or other science concepts. Moreover, this study will open a new gate for the researchers to conduct further studies about implementing above mentioned instructional strategies with different science concepts, with different group sizes, and with different grades.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter includes research studies concerning students' understanding of genetics concepts, conceptual change approach, and students' motivation and learning strategies.

2.1 Research on Students' Understanding of Genetics Concepts

There is a considerable amount of research related with teaching and learning genetics concepts. Several of them have shown that students are having difficulties with concepts in genetics (Bahar, Johnstone & Hansell, 1999; Banet & Ayuso, 2000; Kablan, 2004; Kindfield, 1991; Kubika-Sebitosi, 2007; Tsui & Treagust 2004; Venville & Donovan, 2007). Major concepts of genetics which the students do not fully understand are shown in the research as chromosomes, genes, and alleles (Longden, 1982; Lewis, 2004; Lewis, Leach & Wood-Robinson, 2000a; Pashley, 1994); homozygous, heterozygous, dominance, and recessiveness (Heim, 1991; Slack & Stewart, 1990); mitosis, meiosis, and fertilization (Cavallo, 1996; Clark & Mathis, 2000; Kindfield, 1994; Lewis, 2004; Lewis, Leach & Wood-Robinson, 2000c). One major reason of students' incomplete understanding of genetics concepts was mentioned by Law and Lee (2004) as the abstract nature of genetics concepts that are not observable. Another reason was stated by Marbach-Ad & Stavy (2000) as genetics concepts and processes belong to different levels of organizations namely; macroscopic level (organismal), microscopic level (cellular), and submicroscopic level (biochemical) and students have difficulty in connecting concepts across different levels.

In one of the earlier study, Longden (1982) investigated major sources of misconceptions and learning difficulties in genetics by interviewing 10 academically sound A-level students who were having difficulties with genetics. Concerning areas in genetics were identified as; confusion of the terms of genes, alleles, chromatids, and chromosomes; misunderstanding of replication of DNA and meiosis; using symbolic representation while solving a problem and mathematical bias of genetics. It was indicated in this study that misconceptions were related with the nature of concepts used in genetics and teaching strategies.

In another study related with students' misconceptions, Lawson and Thompson (1988) studied with 131 seventh grade students attending a life-science course at a public junior high school to investigate the role of formal reasoning ability, mental capacity, verbal intelligence, and cognitive style on students' misconceptions related with genetics and natural selection. After the instruction, a posttest including open-ended essay type questions about principles of genetics and natural selection was administered. Students' posttest responses were evaluated based on the number of misconceptions contained and this number was compared with students' reasoning ability, mental capacity, verbal intelligence, and cognitive styles in order to explore the relationships. The results indicated that only the reasoning ability was related with the number of misconceptions held by the students and incorrect responses were generally based on the misconception that parents' environmentally acquired characteristics determine child's characteristics. Formal-operational students were found to have fewer misconceptions than concrete-operational ones. Also, formal-operational students were able to understand that a combination of parental genes carried in the sex cells determines a newborn child's characteristics and the changes in parents' characteristics due to the environment will not affect the offspring. The authors suggested that in order to eliminate some biological misconceptions formal reasoning patterns are necessary.

Pashley (1994) explored the role of a chromosome model on resolving secondary students' misconceptions about gene and allele. According to Pashley, the chromosome model was a tool that allows the students to recognize where their problems lie and to see the contradiction between their own concepts and the accepted scientific concepts. Ninety six students, who studied the identical genetics components of the syllabuses, from four different educational establishments were involved in this study. Five main groups of students were formed according to type of instruction. They were asked to explain the relationship between the 21 different pairs of genetic terms. A test booklet was used to identify the misconceptions which were centered on the terms 'gene' and 'allele'. Three general types of misconceptions were identified as: (1) Genes contain allele; (2) Alleles contain genes; (3) Genes and alleles are the same. It was mentioned that these misconceptions caused confusion of the other terms like homozygous, heterozygous, recessive, and dominant. The results indicated that use of the chromosome model was an effective way to resolve misconceptions. Additionally, the results showed that students' genetics performance improved once the teachers were aware of their students' misconceptions and when the students managed to resolve their misconception about the relationship between gene and allele.

Students' understanding of genetics concepts were also investigated by Lewis and Wood-Robinson (2000). They studied on 482 students' (14-16 years of age) knowledge and understanding about the nature of genetic information, the ways of the transfer of this information, and how this information is interpreted. To collect data, written questions and small group discussions were used. Findings indicated that there was confusion about the relationship between genes and genetic information, location of genes, relationship between genes and chromosomes, the meaning of genetic information, relationship between chromosome and genetic information, how genetic information is transferred from cell to cell within an organism, distinction between somatic and sex cells, distinction between mitosis and meiosis, mechanism of fertilization, link between cell division and continuity of genetic information. Additionally, students were unaware of how a gene determines a characteristic. It was mentioned that students had widespread confusion, uncertainty and lack of basic knowledge about genetics.

Lewis, Leach and Wood-Robinson (2000a, 2000b, 2000c) conducted a series of studies to determine students' (*N*=482, mean age of 15) understanding of various genetics concepts. In the first research, Lewis et al. (2000a) investigated students' understanding of size sequence of basic structures of genetics; relationship among living things, chromosomes, and genetic information; and basic terms of genetics. Authors used written questions to collect the relevant data. Results showed that students had lack of understanding and confusion about size sequence of the six structures-organism, cell, nucleus, chromosome, gene, and DNA; unclear about the relationship between these structures; location of genes, chromosomes and DNA; structure of genes, chromosomes and DNA; importance of genes, chromosomes and DNA, and role of alleles. It was mentioned that making links between related concepts was difficult for the students and the authors suggested that these relations should be taught clearly.

In the second research, Lewis et al. (2000b) examined participants' understanding of the continuity of genetic information between the cells of an individual which forms a basis for understanding inheritance. Results indicated that students were not able to make the genetic relationship between cells of an individual and could not realize the distinction between a gene and the information coded within that gene. The possible reason for this was mentioned as the absence of a conceptual framework which would explain the relations among the facts and provide coherent understanding.

In the third research, Lewis et al. (2000c) explored students' understanding of cell division and fertilization. Results of the written data obtained from questions showed that students' were confused about the related topics and showed limited and inconsistent understanding. It was suggested that once the students understand the relationship between basic structures like genes and chromosomes, they can comprehend the processes of mitosis, meiosis and fertilization better.

Recently, Rotbain, Marbach-Ad and Stavy (2006) investigated the contribution of using models in genetics instruction on students understanding of concepts in genetics. A total of 258 grade 11 and grade 12 students participated in their study. Students were randomly assigned to the bead group, the illustrations group, and the control group. The bead model had a three-dimensional structure constructed by the students by using colored beads to stimulate the structure of DNA and RNA, DNA replication, and protein synthesis. The illustrations model consisted of two-dimensional graphical illustrations similar the ones in the textbooks. Same topics were included in this model with the bead model. Data were collected by using three instruments: a multiple-choice questionnaire, an open-ended written questionnaire, and personal interviews. The results indicated that students who used one of the two types of models understood related genetics concepts better than the students in the control group. Additionally, results of the open-ended questionnaires showed that bead model activity was significantly more effective than illustration activity. The authors concluded that, using model activities in teaching molecular genetics improves students' achievement when compared with traditional instruction.

In another recent study, Saka, Cerrah, Akdeniz and Ayas (2006) conducted a cross-age study to investigate 175 Turkish students' understanding of gene, DNA, and chromosome concepts. Participants were 8^{th}, 9^{th}, 11^{th} grades, and university students who would soon become biology and science teachers. Data were gathered through written questions and interviews. All the students were asked to define gene, DNA, and chromosome concepts and draw them into a cell. The results showed that students at all grades had some misconceptions related with gene and chromosome. Additionally, students drew each of the three concepts separately indicating that they had problems about linking the concepts meaningfully. The authors suggested that the students at junior high school should learn the basic concepts meaningfully in order to construct new concepts successfully in their future education.

Atay (2006) explored relationships among 213 eight grade Turkish students' gender, relevant prior knowledge, meaningful learning orientation, reasoning ability, self-efficacy, locus of control, attitudes toward science and achievement in genetics in learning cycle and traditional classrooms. Students were randomly assigned to experimental group receiving learning cycle instruction and control group receiving traditional instruction. Results indicated that when compared with traditional instruction, learning cycle instruction improved students' understanding in genetics. Additionally, results showed that student' meaningful learning orientation was the main predictor of achievement in genetics in learning cycle classrooms. On the other hand, the main predictor of students' achievement in traditional instruction classrooms was their attitudes toward science.

In a recent case study conducted by Venville and Donovan (2007), the effects of intervention lessons, where students worked in small groups while participating in hands-on activities and discussed their ideas, on young children's (6 and 7 years of age) understanding of living and non-living things, inheritance, and concepts of the gene and DNA were examined. Their study focused on both ontological and epistemological aspects of students' understandings. From ontological perspective, the results revealed that students were able to connect their gene and/or DNA concepts with inheritance. Additionally, after the intervention lessons more students were able to distinguish living things from non-living things with using more criteria during classification. From epistemological perspective, it was investigated that whether students developed their new understandings meaningfully. The results showed that students' understanding of inheritance was connected with gene and DNA concepts which indicated meaningful learning. The authors concluded that young children were able to learn about abstract things like gene and DNA when they were given the opportunity.

More recently, Kibuka-Sebitosi (2007) studied with hundred grade 11 biology learners, attending schools located in rural areas, to investigate their opinions and misconceptions about genetics concepts namely; genetic information in cells and Mendelian inheritance. Data were collected using questionnaires, case scenarios, concept maps, interviews, and group discussion. Results of concept map analyses indicated that students had difficulty in understanding some genetic concepts like the difference between genes and chromosomes, things that are inherited and not inherited, and Mendelian inheritance. Additionally, analyses of case scenarios revealed that students related inheritance with faith, blood, hormones, and traditional beliefs. Students expressed as the sources of their ideas are their own ideas, teachers, and their communities. It was suggested that students' prior knowledge, especially the ones related with traditional beliefs, should be identified by the educators before teaching concepts related with genetics and inheritance.

In another recent study, Mbajiorgu, Ezechi and Idoko (2007) explored the nonscientific presuppositions of students before and after instruction, the relationship between students' nonscientific presuppositions levels and their achievement in genetics and the effect of an instructional program which was based on conceptual change strategy on students' understanding of genetics concepts; mutation, sickle-cell anemia, albinism, and sex determination. About 282 students aged between 17-18 years participated in this study. Students in the experimental group received the instructional program. In the first step of the instructional procedure students' nonscientific presuppositions were identified, in the second step the phenomena was explored, in the third step results were discussed, in the fourth step students were dissatisfied with their presuppositions, and in the final step students apply their understanding to other life situations. Students in the control group were exposed to instruction based on textbook sequencing approach. Data were gathered by using the presupposition instrument and a biology achievement test. The results revealed that 99% of the experimental group students moved from high level of presupposition to intermediate and low levels. On the other hand only 41% of the control group students were able to make this change. It was concluded that in order to increase students' science understanding, a conceptual change model that considers students nonscientific presuppositions is necessary.

To sum up, research indicates that genetics concepts are poorly understood in all ages and these inadequate understanding lead students to depend on rote learning (Banet & Ayuso, 2000). Additionally, research shows that traditional teaching strategies have limitation in promoting students' sound understanding of genetics concepts. Since genetics is one of the important and difficult topics in science, different instructional methods must be employed to eliminate or prevent misconceptions and to promote meaningful learning. One of these methods is the use of conceptual change approach which is based on constructivist learning theory.

2.2 Constructivism

Constructivism dominates recent research in science education. It is a theory about knowing and learning which highlights the active role of the learner in constructing knowledge rather than directly transmitting it (Wu & Tsai, 2005). Constructivism was also described as "the knowledge construction of learners rather than the knowledge acquisition of learners" (Hare & Graber, 2007, p.1). According to constructivist theory, the main concern is the active participation of the learner in the learning process and the significance of each learner's prior knowledge that affects further learning in science. Brooks and Brooks (1999, p.17) compared the traditional and constructivist learning environments as in Table 2.1.

Table 2.1 Differences between traditional and constructivist classrooms

Traditional Classrooms	Constructivist Classrooms
Curriculum is presented part to whole, with emphasis on basic skills.	Curriculum is presented whole to part with emphasis on big concepts.
Strict adherence to fixed curriculum is highly valued.	Pursuit of student questions is highly valued.
Curricular activities rely heavily on textbooks and workbooks.	Curricular activities rely heavily on primary sources of data and manipulative materials.
Students are viewed as "blank slates" onto which information is etched by the teacher.	Students are viewed as thinkers with emerging theories about the world.

Table 2.1 (continued)

Teachers generally behave in a didactic manner, disseminating information to students.	Teachers generally behave in an interactive manner, mediating the environment for students.
Teachers seek the correct answer to validate student learning.	Teachers seek the students' points of view in order to understand students' present conceptions for use in subsequent lessons.
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing.	Assessment of student learning is interwoven with teaching and occurs through teacher observations of students at work and through student exhibitions and portfolios.
Students primarily work alone.	Students primarily work in groups.

It is suggested that meaningful learning can be promoted by constructivist-oriented instruction (Tsai, 1998). Meaningful learning is described as forming appropriate relationships among ideas, concepts, and information (Ausubel, 1963). In fact, Ausubel (1968) mentioned the importance of students' previous knowledge in constructing the new knowledge in a meaningful way.

Piaget (1950) described three phases of meaningful learning: assimilation, accommodation, and equilibrium. Assimilation is a cognitive process in which new information is interpreted in order to make them consistent with the existing mental structures. Disequilibrium occurs when this new information conflicts with existing mental structures. As a result of disequilibrium the learner seeks equilibrium and changes and adapts her existing mental structures to be consistent with new information which is called accommodation.

However, research also show that sometimes students' pre-existing knowledge may contradict with the ideas accepted by scientists and these ideas are called alternative conceptions (Arnaudin & Mintzes, 1985), children's science (Gilbert, Osborne & Fensham, 1982), or misconceptions (Fisher, 1985).

Fisher (1985) reported basic characteristics of misconceptions as; they are persistent, resistant to change, and they are well-embedded in learners' minds and inhibit further conceptual development. When the students cannot construct effective linkages between their existing knowledge and the new knowledge, development of conceptions is prevented (Novak, 1988). As it is known, this situation leads to rote learning. This approach is actually what constructivist view of learning supports.

> According to this view, when students are learning about science they interpret any new information in the light of their existing ideas and beliefs, which may then become modified or defined. Learning then proceeds as the students' ideas become progressively reconstructed (Palmer, 2003, p. 663).

Research identified the sources of misconceptions as; science textbooks, teacher's instruction, and unscientific use of everyday language (Adeniyi, 1985). Therefore, it is obvious that students may develop misconceptions before formal education and during their school years. There is considerable amount of research on students' misconceptions about basic science concepts. Some common concepts are; diffusion and osmosis (Odom & Barrow, 1995), solution (Uzuntiryaki & Geban, 2005), human circulatory system (Arnaudin & Mintzes, 1985; Sungur, Tekkaya & Geban, 2001), respiration (Sanders, 1993; Mann & Treagust, 1998), law of conservation of energy (Edens & Potter, 2003), ecology (Adeniyi, 1985; Palmer, 2003), mechanics (Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou, 2001; Oliva, 2003), electricity (Wang & Andre, 1991; Chambers & Andre, 1996), projectile motion (Hynd, Alvermann & Qian, 1997), force and motion (Beeth, 1998), plant nutrition and growth (Mason & Boscolo, 2000), and genetics (Lawson & Thompson, 1988; Pashley, 1994; Lewis & Wood-Robinson, 2000; Atay, 2006).

Since misconceptions inhibit further conceptual development, identifying students' misconceptions and assisting them to change these misconceptions are significant issues in science teaching. One of the alternative strategies to eliminate misconceptions and promote meaningful learning is the conceptual change approach.

2.2.1 Conceptual Change Approach

Learning is not only the addition of the new knowledge into memory but also changing the structure of existing knowledge frameworks and this restructuring is called as conceptual change or conceptual change learning (Sinatra, 2005). According to Novak (2002) conceptual change is the necessity for meaningful learning to occur. Based on Piaget's notions of assimilation, accommodation, and disequilibrium, conceptual change theory focuses on conditions for students modify their existing conceptions with new ones. It is reported that there are two types of conceptual change which are assimilation and accommodation (Posner, Strike, Hewson, & Gertzog, 1982). In assimilation students use their existing concepts while interpreting the new knowledge and make the new knowledge consistent with existing knowledge. However, in accommodation students change and adapt existing knowledge to be consistent with the new knowledge. Four conditions should be met in order to change students' assumptions about knowledge and about knowing. These conditions are: (1) There must be dissatisfaction with existing knowledge (2) The new conception must be intelligible, referring that the students understand the meaning of the new concept (3) The new conception must be plausible, referring that the student finds the new concept believable (4) The new concept must be fruitful, referring that the student can solve other problems by the new concept (Posner et al., 1982). If these conditions are met accommodation of the new conception may occur.

With considering the importance of the effect of students existing knowledge on their understanding in science, Hewson and Hewson (1983) investigated the effect of conceptual change based instruction on students' understanding of mass, volume, and density concepts. A total of 90 grade 9 students (with a mean age of 16 years) participated in their study. The students in the experimental group instructed with the instructional strategy and materials that was developed by considering students' prior knowledge and misconceptions about the related concepts whereas the students in the control group received traditional instruction and materials. In order to assess conceptual change pre- and posttests were used for both of the groups. The results indicated that students receiving the developed instructional strategy showed significantly better acquisition of the related concepts and could eliminate alternative conceptions when compared with the students who received traditional instruction.

In another study related with conceptual change approach, Beeth (1998) investigated 12 fifth grade students' (ages 10 to 11) understanding of force and motion concepts. The instruction was based on conceptual change approach in which the students expressed their conceptions about force and motion by using the status constructs of intelligibility and plausibility. By this way students could actively examine their own conceptions instead of passively receiving information and monitor the progress of their own learning about force and motion concepts. Additionally, the teacher evaluated students' understanding from their own comments and planned the instruction according to the students' progress.

Based on over thousands of studies like the ones mentioned before about students' understanding of scientific concepts Mintzes and Wandersee (1998, p.76) offered 12 knowledge claims about understanding and conceptual change in science:

> 1. Learners are not "empty vessels" or "blank slates"; they bring with them to their formal study of science concepts; a finite but diverse set of ideas about natural objects and events; often these ideas are incompatible with those offered by science teachers and textbooks.
>
> 2. Many alternative conceptions are robust with respect to age, ability, gender, and cultural boundaries; they are characteristic of all formal science disciplines including biology, chemistry, physics, and earth and space sciences; they typically serve a useful function in the everyday lives of individuals.
>
> 3. The ideas that learners bring with them to formal science instruction are often tenacious and resistant to change by conventional teaching strategies.
>
> 4. As learners construct meanings, the knowledge they bring interacts with knowledge presented in formal instruction; the result is a diverse set of unintended learning outcomes; because of limitations of formal assessment strategies, these unintended outcomes may remain hidden from teachers and students themselves.
>
> 5. The explanations that learners cling to often resemble those of previous generations of scientists and natural philosophers.
>
> 6. Alternative conceptions are products of a diverse set of personal experiences; including direct observation of natural objects and events, peer culture, everyday language, and the mass media as well as formal instructional intervention.
>
> 7. Classroom teachers often subscribe to the same alternative conceptions as their students.
>
> 8. Successful science learners possess a strongly hierarchical, cohesive framework of related concepts and they represent those concepts at a deeper, more principal level.
>
> 9. Understanding and conceptual change are epistemological outcomes of the conscious attempt by learners to make meanings; successful science learners make meanings by restructuring their existing

knowledge frameworks through an orderly set of cognitive events (i.e., subsumption, superordination, integration, and differentiation).

10. The differential ability to solve problems in novel, real-world settings is attributable primarily to the advantages conferred on individuals possessing a highly integrated, well-differentiated framework of domain-specific knowledge which is activated through concentrated attention to and sustained reflection on related objects and events.

11. Learners who excel in the natural sciences habitually employ a set of metacognitive strategies enabling them to plan, monitor, regulate, and control their own learning.

12. Instructional strategies that focus on understanding and conceptual change may be effective classroom tools.

In order to fulfill Posner et al.'s (1982) conditions for conceptual change, instructional strategies that yield to active learning should be used. There are several research that utilize different teaching strategies based on conceptual change theory. For the purpose of the present study, learning cycle and conceptual change texts will be discussed as teaching strategies in the following sections.

2.2.1.1 Research on Learning Cycle

The learning cycle is an inquiry approach developed by Karplus and Thier (1967) which initially consists of three phases; exploration, term introduction and concept application. It was first formally used in and be the foundation for the Science Curriculum Improvement Study (SCIS) program. It is based on Piagetian theory and holds constructivism as a teaching philosophy. Marek and Cavallo (1997) explained the relation between Piaget's model of mental functioning and the learning cycle. According to the authors, students should use materials that address their various senses while experiencing a concept. They need to explore the interactions between the materials by their own or by teacher's directions. The authors mentioned that this is exploration phase of the learning cycle and promotes assimilation. Disequilibrium may occur while students are assimilating. Therefore, assimilation and disequilibrium can be fostered by exploration phase. New mental structures are constructed by the second phase, which is term introduction, and this corresponds to accommodation. In the last phase, concept application, students extent their new concepts by applying them in other situations and this phase matches with process of organization. Marek and Cavallo (1997, p.70) illustrated the derivation of learning cycle from Piaget's model of mental functioning as in Figure 2.1.

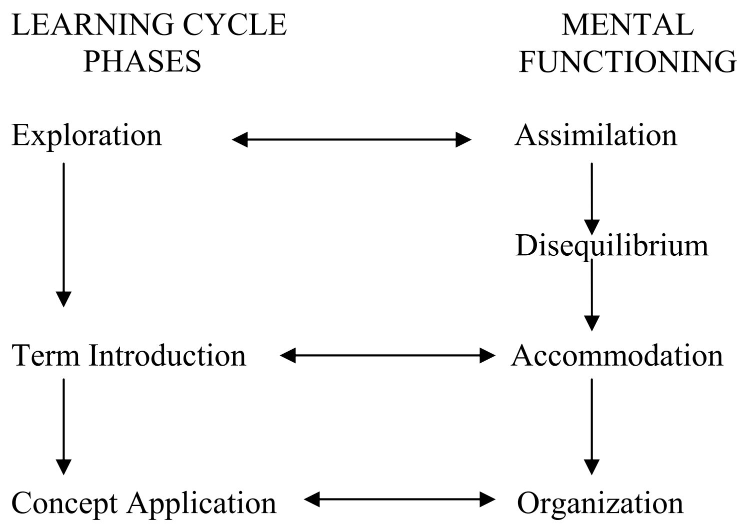


Figure 2.1 The learning cycle and Piaget's model of mental functioning (Marek & Cavallo 1997, p.70)

Karplus (1977) explained each phase of learning cycle as: (a) in *exploration* phase students try to explore new concept through their own effort with minimum guidance (b) in *concept introduction* (or *term introduction*) phase the new concept is introduced by the teacher, a textbook, or other means, which facilitates the students use new reasoning patterns to their experiences (c) in *concept application* phase students extend the new concept by applying it to new situations and new contexts. It is stated by Odom and Kelly (2001, p. 618) that "learning cycle provides opportunities for students to explore their belief systems, which may result in argumentation, prediction, and hypothesis testing, resulting in self-regulation and knowledge construction”. Investigating the effectiveness of learning cycle has been the focus of several research studies (Ates, 2005; Balci, Cakiroglu & Tekkaya, 2006; Cavallo & Marek, 2003; Lee, 2003; Odom & Kelly, 2001; Wise, 2006). Different types of learning cycles, such as three-phased learning cycle, 4E learning cycle, 5E learning cycle, 7E learning cycle, metacognitive learning cycle, and prediction/discussion-based learning cycle, have been reported in the literature.

Following studies present the applications of different types of learning cycles in science lessons. Barman, Barman and Miller (1996) examined 34 fifth grade students’ ideas about sound concept and compared three-phased learning cycle instruction with textbook/demonstration method of instruction to determine which method was more effective in promoting conceptual change. Students were randomly assigned to one of the two treatment groups that were taught by the same teacher. Students who received textbook/demonstration instruction, a teacher-centered instruction, read information from the textbook. Additionally, class discussions and demonstrations were used in order to verify the information in the textbook. Students receiving learning cycle instruction, on the other hand, worked in small groups, engaged in hands-on activities, discussed their ideas within small groups and whole class in the exploration phase. The teacher introduced new concept considering students’ observations and ideas obtained in the exploration phase. Students extended their new ideas by using them in new situations in the application phase. Data were obtained by pre-instructional and post-instructional interviews. Results showed that both classes improved their understanding of sound, however, students who were taught with learning cycle approach improved their understanding significantly better than the students who received textbook/demonstration instruction.

In another study, Yılmaz and Huyugüzel Çavaş (2006) investigated the effectiveness of 4E (Exploration, Explanation, Expansion, Evaluation) learning cycle on 79 sixth-grade students' understanding of electricity concept and attitude toward science. Experimental group students received 4E learning cycle instruction, whereas, control group students received traditional instruction. Data were collected by using the Flowing Electricity Achievement Test and the Attitudes Scale toward Science. Results indicated that students who received 4E learning cycle instruction were more successful in understanding electricity concept than students who received traditional instruction. Furthermore, 4E learning cycle instruction significantly produced more positive attitudes towards science than the traditional method.

In their study, Balci, Cakiroglu and Tekkaya (2006) compared the effectiveness of 5E learning cycle instruction and conceptual change text instruction over the traditional instruction on 101 eight grade students' understanding of photosynthesis and respiration in plants. Three intact classes were randomly assigned as control and experimental groups. In the first experimental group the students were exposed to 5E learning cycle instruction, whereas in the second experimental group the students received conceptual change text instruction. Students in the control group instructed with traditional instruction. In order to collect relevant data Photosynthesis and Respiration in Plants Concept Test and Attitude Scale toward Science as a School Subject test were administered. Results indicated that students in both experimental groups scored significantly higher in the posttest than students in the control group. It was concluded that students in the both experimental groups improved better in understanding photosynthesis and respiration in plants. However, no statistically significant difference was found between the two experimental groups.

Recently, Mecit (2006) investigated the effect of 7E (Elicit, Engage, Explore, Explain, Elaborate, Evaluate, Extend) learning cycle, which is an expanded form of 5E learning cycle, on 46 fifth grade students' critical thinking skills. Besides the effect of 7E learning cycle, effects of gender and family income of students on critical thinking skills were also investigated. Two classes instructed by the same teacher were randomly assigned as experimental and control groups that received 7E learning cycle instruction and traditional instruction, respectively. Water cycle concept was chosen as the unit of the study since it contains cause and effect relationships. In order to obtain relevant data the Cornell Conditional Reasoning Test and the Science Achievement Test were used. Results showed that students instructed with 7E learning cycle improved their critical thinking skills significantly better than the students who received traditional instruction. However, the effects of gender and family income on improvement of students' critical thinking skills were not significant.

Learning cycle instruction was also combined with other teaching tools like concept mapping. Odom and Kelly (2001) investigated the effectiveness of concept mapping, the learning cycle, expository instruction, and a combination of concept mapping/learning cycle in facilitating conceptual understanding of 108 students (grades 10-11) about diffusion and osmosis concepts. Students attended four classes and instructed by the same teacher. Data were collected by using the Diffusion and Osmosis Diagnostic Test and the Logical Reasoning Test. Results indicated that students attended concept mapping/learning cycle and concept mapping treatment classes performed better in conceptual understanding of diffusion and osmosis concepts than students who received expository treatment. However, no significant difference among the learning cycle treatment and other treatments was found.

The Metacognitive Learning Cycle, a revised version of learning cycle, was used by Blank (2000) in order to investigate its effect on 46 seventh grade students' understanding of ecological concepts. Students were randomly assigned to one of the two classes in which the Science Curriculum Improvement Study Learning Cycle was used in one class and Metacognitive Learning Cycle was used in the other. The only difference between the two learning cycles was that in the Metacognitive Learning Cycle classroom the students were asked to talk about their science ideas and the status of their conceptions during the instruction. Relevant data were collected by using the ecology assessment instrument, pre-instructional and post-instructional interviews held with the teacher, student status journals, and dialogues. Results revealed that the Metacognitive Learning Cycle instruction did not promote greater content knowledge of ecology; however, according to delayed ecology assessments students experienced deeper knowledge construction of ecology concepts by this method.

Another type of learning cycle is prediction/discussion-based learning cycle (HPD-LC) which includes a prediction/discussion phase added at the beginning of three-phase Karplus learning cycle involving exploration, term introduction, and concept application phases (Lavoie, 1999). In prediction/discussion phase, hypothetico-predictive problem sheets are administered to the students in which they make predictions about the related problem and form hypothesis followed by whole-class and small-group discussions in which they discuss their predictions and reasons. The importance of hypothetico-predictive reasoning as a thinking skill was mentioned as enhancing problem solving, stimulating peer group discussion, increasing motivation, revealing prior knowledge, and facilitating conceptual change. In the exploration phase, students explore and test their own predictions by observing and collecting data related with the question while involving in an inquiry activity. In the term introduction phase, the teacher explains related terms and discusses the results obtained in the exploration phase. In the concept application phase students extend the new concept while solving problems and answering questions about it. Lavoie (1999) investigated the effects of HPD-LC and traditional learning cycle instructions on students' use of process skills, logical-thinking skills, understanding science concepts, and scientific attitudes. Ten separate learning cycle lessons were developed related with genetics and inheritance, homeostasis, natural selection, and ecosystem concepts. Approximately 250 students were assigned to HPD-LC and LC classes instructed by five 10^{th} grade science teachers for three months. Both qualitative and quantitative research methods were used in this study. In order to obtain relevant data teachers' daily logs, field observations, questionnaires that assess both teachers' and students' attitudes, the Process of Biological Investigation Test, the Group Assessment of Logical Thinking, and the concept understanding test were used. Results indicated that the HPD-LC treatment was more effective than the LC treatment in terms of improving students' conceptual understanding, logical thinking abilities, science process skills, and scientific attitudes. The role of hypothetico-predictive sheets in revealing students' prior knowledge and identifying several alternative conceptions was also mentioned.

As the related literature shows, leaning cycle is an effective instructional method that provides improvement in both cognitive and affective aspects of students' learning and promotes conceptual change.

2.2.1.2 Research on Conceptual Change Texts

Conceptual change text is another teaching strategy that is designed according to conceptual change approach. The aim of conceptual change texts is to activate students' misconceptions by posing questions and presenting common misconceptions. Once students' misconceptions are activated, disequilibrium between students' existing conceptions and the scientific conception is created. Afterwards, scientific explanations that are supported by examples are provided. Several studies showed that conceptual change texts are very effective in creating conceptual change and leading to meaningful learning of many science concepts (e.g. Wang & Andre, 1991; Chambers & Andre, 1997). In their study, Wang and Andre (1991) investigated the effects of conceptual change text and application questions on 139 college students' understanding of electricity concepts. Conceptual change text was prepared by inserting conceptual change sections in a traditional text. Sixteen application questions were inserted for half of the conceptual change text and half of the traditional text. The results revealed that usage of conceptual change text improved students' acquisition of electricity concepts when compared with traditional text instruction. Additionally, application questions led to better understanding of electricity concepts.

Another study was conducted by Alparslan, Tekkaya, and Geban (2003) which explored the relative effectiveness of conceptual change instruction and traditional instruction and also gender difference on students' understanding of respiration. In this study conceptual change texts were used to promote conceptual change concerning respiration concept. This study consisted of 68 eleventh-grade students from two classes taught by the same teacher. The data were obtained from 34 students (18 boys and 16 girls) participating in the experimental group receiving conceptual change instruction in which conceptual change texts were used with considering students' misconceptions and 34 students (19 boys and 15 girls) participating in the control group taught with traditional instruction with no consideration of students' misconceptions. The instruments used in this research were The Respiration Concepts Test and Science Process Skill Test (SPST). The results of this research showed that conceptual change oriented instruction led a significantly better understanding of scientific concepts than the traditional instruction. Also, results indicated that girls performed better than boys on understanding of respiration concepts.

In another study, Çetin, Ertepınar and Geban (2004) investigated the effectiveness of conceptual change texts accompanied with small group work on ninth grade students' learning of ecology. This study consisted of 79 ninth grade students in a high school. Two classes were assigned as the experimental groups and the other two classes were assigned as the control groups. The experimental groups were taught with conceptual change text oriented instruction within group work accompanied with demonstration while the control groups were taught with the traditional instruction. In order to collect relevant data the Ecology Concepts Test and non-participant classroom observation was used. The results showed that the conceptual change texts oriented instruction within small group work accompanied with demonstration caused a significantly better acquisition of scientific conceptions than the traditional instruction. It was also concluded that the main difference between the two methods was that the conceptual change oriented instruction explicitly dealt with students' misconceptions relating ecology while the traditional method did not.

Conceptual change texts were also integrated with other teaching tools like concept mapping and discussion webs. For example in Uzuntiryaki and Geban's (2005) study, conceptual change texts accompanied with concept maps to provide an alternative for teaching solution concepts in the classroom. This study consisted of 64 eighth-grade students from two classes of a general science course taught by the same teacher. The data were obtained from 32 students participating in experimental group receiving the conceptual change text accompanied with concept mapping instruction and 32 students participating in control group receiving traditional instruction. The instruments used in this research were Solution Concept Test, Attitude Scale toward Science as a School Subject, and Logical Thinking Ability Test. The results of the research showed that combination of the conceptual change text and concept mapping instruction caused a better acquisition of scientific conceptions and elimination of alternative conceptions, as well as produced more positive attitudes than the traditionally designed instruction.

In another study, Yenilmez (2006) integrated conceptual change texts with ‘writing for learning’ and ‘discussion webs’ as an alternative mode of instruction to promote conceptual change concerning photosynthesis and respiration in plants concepts. In that study, relative influences of prior knowledge, meaningful learning orientation, formal reasoning ability, and mode of instruction on 233 eight grade students’ understanding of related concepts were investigated. Students attended six intact classes instructed by the same teacher and half of the classes were randomly assigned as experimental group whereas, the other half assigned as control group. The experimental group instructed with conceptual change texts accompanied with ‘writing for learning’ and ‘discussion webs’, and control group received traditional instruction. In order to collect relevant data the Photosynthesis and Respiration in Plants Concept Test, the Test of Logical Thinking, and the Learning Approach Questionnaire were used. The results showed that the experimental group significantly better understood the concept when compared with the control group. Students’ prior knowledge was found to be the main predictor of achievement in the experimental group, whereas, in the control group it was reasoning ability. Additionally, in the conceptual change classrooms meaningful learning orientation accounted for a small amount of variance. However, in the control group it did not contribute to students' understanding of related concepts.

Other than conceptual change texts, refutational texts may also be used to promote conceptual change. The major difference between refutational texts and conceptual change texts is in conceptual change texts students are asked some questions to activate their misconceptions before scientifically correct explanation is given, however, in refutational texts, related alternative conception is presented, and then it is refuted by scientific explanations (Guzzetti, Williams, Skeels & Wu, 1997) without asking the students to make predictions about the concept. For instance, Palmer (2003) investigated whether assimilation or accommodation could be induced by refutational text for ecological role concept. The participants of this study were eighty-seven grade 9 (14-15-year-old) students from three different secondary schools. The instruments used in this research were four-phased; pretest phase (interview), intervention phase (refutational text & control text), immediate posttest phase, and delayed posttest phase. Throughout these phases students were also asked questions that were designed to identify their situational interest, individual interest, motivation to engage in the task, and metacognition of any change in their thinking. The target misconception was "organisms that do not do much, or only seem to do unpleasant things, do not have ecological roles". The students were divided into three main groups as; group 1 students who demonstrated an acceptable understanding of ecological role and showed no evidence of having the target misconception, group 2 students who did have the target misconception, and group 3 students whose responses were incomplete or vague. The main focus of the study was the group 2 students. The results of this study showed that refutational text was highly effective in inducing accommodation (68%). Although it was not expected control text also induced accommodation (41%). These findings suggested that high motivation of the students, encouragement of the metacognition, agereadiness of the students, and a relative lack of robustness of the misconception facilitated conceptual change process.

It is apparent that students hold various conceptions about scientific concepts which often need to change. Teachers should be aware of students' preexisting knowledge and their misconceptions in order to help the students realize their misconceptions and facilitate conceptual change. In the light of the research it can be concluded that conceptual change approach is an effective way to remediate students' misconceptions and facilitate meaningful learning. Therefore, in the present study, prediction/discussion-based learning cycle (HDP-LC) and conceptual change text (CCT) instructions were used to promote conceptual change concerning genetics concepts. However, assessing conceptual change is a main concern. Slotta, Chi and Joram (1995) mentioned that it is not accurate to evaluate whether students' misconceptions are removed or not based on the improved test scores on a quantitative task. Therefore, to further probe students' understanding about related genetics concepts a multidimensional interpretive framework of conceptual change was used from ontological, epistemological, and social/affective perspectives (Tyson, Venville, Harrison & Treagust, 1997). Next section presents related literature about the multidimensional interpretive framework of conceptual change.

2.2.1.3 Multidimensional interpretive framework of conceptual change

As it was mentioned before, there are various views and studies in the literature about conceptual change that are based on a unique theoretical framework. However, Tyson et al. (1997) suggested that for a holistic picture of conceptual change, different theoretical perspectives should be considered while interpreting learning situations. They proposed a multidimensional interpretive framework that includes different views of conceptual change namely, ontological, epistemological, and social/affective dimensions.

Ontological perspective of conceptual change is related with the examination of students' perceptions about the nature of the thing being studied (Tyson, et al., 1997). Chi, Slotta and de Leeuw (1994) proposed a theory of conceptual change which explains the reason of why some kinds of conceptual change are more difficult than others. They suggested that entities in the world belong to different ontological categories mainly, matter (or things), processes, and mental states. These three categories further divided into several subcategories presented in Figure 2.2.

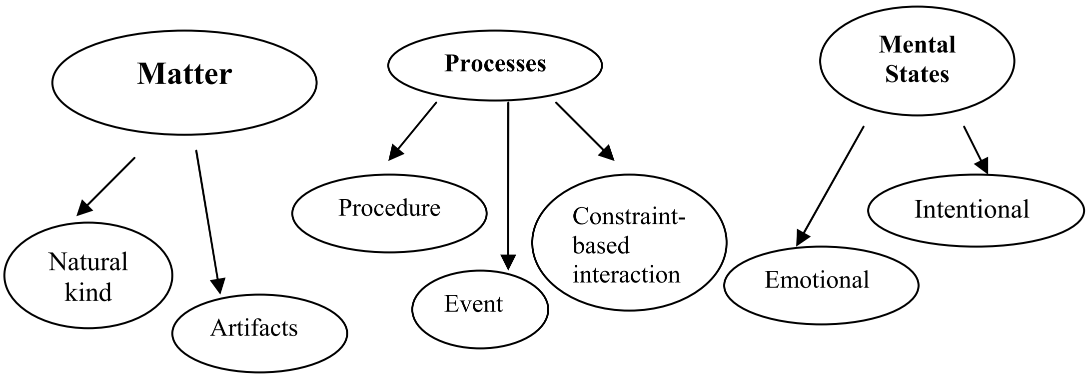


Figure 2.2 Ontological categories (Chi et al., 1994, p.29)

These categories and subcategories have different attributes. For instance, entities in the "matter" category have ontological attributes like "being red", "being heavy", "having weight", "having volume", and so on. Entities in the "processes" category have such attributes as "being carried out", "having a beginning and end", "being dynamic", and so on. The last category, "mental states", includes entities having ontological attributes like "being true", "being about something", and so on. Chi et al. (1994) mentioned that many scientific concepts belong to constraint-based interaction category, which is a subcategory of processes category. However, it is claimed that students prefer to categorize concepts as matter-based rather than process-based since matter-based concepts are more familiar to them (Chi & Slotta, 1993;

Chi et al., 1994; Tsui & Treagust, 2004). When students initially place the science concepts into inappropriate ontological categories misconceptions are developed (Chi et al., 1994). Chi et al. also mentioned that if students' existing science concepts belong to different ontological categories than the ones that the scientists accepted, then conceptual change should involve re-assignment of students' conceptions into new ontological categories. Two kinds of conceptual change were distinguished by Chi (1992); gradual conceptual change and radical conceptual change. Gradual conceptual change takes place within an ontological category, whereas, radical conceptual change takes place across ontological categories. Learning science concepts requires radical conceptual change; therefore, students often have difficulties in learning science concepts (Chi et al., 1994). They stated that "conceptual change occurs when a concept has to be re-assigned to an ontologically distinct category (across trees)" (p.31) which is radical conceptual change.

There are several studies which examine conceptual change from an ontological perspective (Tsui & Treagust, 2004; Lee & Law, 2001; Pocoví, 2007; Slotta & Chi, 2006). One of these studies was conducted by Lee and Law (2001). In their study, the authors investigated the role of ontological categorization framework on students' alternative conceptions about electric circuits and on developing a teaching strategy that promotes conceptual change. A series of four studies were conducted for the purposes of that study. In the first study, they investigated six secondary school students' (17 years of age) alternative conceptions about electric circuits and ontological categories of different conceptions. They used a written test and semi-structured interviews to obtain relevant data. The results showed that there was a relationship between students' test performance and their conceptions' ontological categories. The student who had the best test performance conceptualized circuit concept as constraint-based interaction, whereas, students who performed poorly interpreted this concept as matter.

In the second study, the authors investigated whether encouraging the students to reason using constraint-based interaction would promote conceptual change. Students worked in groups performing predict-observe-explain tasks and generating analogies to explain the observed phenomena. Three students with the lowest test score in study 1 formed one group and six students from a secondary science four class (15 years of age) who had not learnt elementary circuit theory formed the other group. The results indicated that self-generated analogies helped students explain circuit phenomena and communicate their understanding with others. Additionally, predict-observe-reason tasks encourage the students to use constraint-based interaction reasoning. The third study was conducted to test the hypothesis which states "in order to have conceptual change, students should be guided not only to reason in terms of constraint-based interactions, but they should also be guided to focus on the appropriate constraint". The same subjects except one student of study 2 participated in that study. Predict-observe-explain tasks were redesigned focusing on the voltage concept. The results indicated that when the students were guided to focus on voltage concept they reasoned circuit phenomena as processes. In the last study, the authors investigated the effectiveness of a teaching strategy that includes a combination of hands-on experiments, predict-observe-explain tasks, and analogical discussions on conceptual change. Six secondary four students who had not been taught elementary circuit theory and had not been involved in previous studies participated in this study. In order to obtain relevant data written tests were used as pre-test and post-test. Additionally, individual interviews were held after both the pre-test and post-test. Results indicated that the teaching intervention had a significant effect on all the students' improvements in the test performance. The authors concluded as a result of these four studies that the alternative conceptions related with electric circuits are matter-based and students at all age may hold these alternative conceptions. Additionally, it was mentioned that giving some knowledge about constraint-based interaction ontology is not enough for conceptual change to occur. Students should also be guided to focus on the appropriate constraint.

In another study, Tsui and Treagust (2004) investigated students' ontological conceptual change about genetics by using computer-based multiple representations. *BioLogica*, an interactive computer program, was used over six weeks which enabled the students manipulate processes of genetics and to visualize the changes they made. 24 senior high school students (14 and 15 years of age) were participated in that study. In order to obtain relevant data student and teacher semi-structured interviews, online tests, computer data log files, classroom observation field notes, audio and video recordings and lesson transcripts, author's reflective journals and various documents were used. The results indicated that students' gene conceptions belonged to matter category, instead of belonging to the process category and instructions included the use of *BioLogica* did not promote conceptual change across ontological categories. The authors mentioned that students' prior knowledge and teacher's teaching has a big role on ontological conceptual change.

Recently, Slotta and Chi (2006) investigated the role of ontology training on conceptual change. 24 university undergraduate students who had no formal training in electricity concept participated in this study. Participants were randomly assigned to experimental and control groups. Experimental group students received a computer-based module by which they learned about emergent processes. On the other hand, students in the control group received a computer-based module that did not give any information about ontology. After receiving the modules, both groups studied a physics text related with electricity. Data were collected by pre and post-tests of electricity concepts, the training module post-test, the control module post-test, and the physics learning post-test. The results indicated that experimental group students better improved their understanding of electric current. Additionally, it was suggested that in order to facilitate conceptual change, firstly students should be trained about the target concept's ontology then the topic is given by normal instruction.

As the related literature shows, Chi et al.'s theory explains the robustness of alternative conceptions in science and provides a framework for assessing and facilitating conceptual change in the learning of science (Lee & Law, 2001).

Another perspective of conceptual change is epistemological perspective. Tyson et al. (1997) described epistemology by comparing it with ontology. They stated that "If ontology is described as the study of how students view the outside world (i.e. how they look from within to the outside) then epistemology is the study of how students view their own knowledge: that is, looking inward and making qualitative judgments and commitments about various theories and conceptions they might have" (p.400). Posner et al.'s (1982) conceptual change model, which describes students' conceptions as intelligible, plausible, and fruitful, is from an epistemological perspective since it includes not only the students' knowledge about a concept but also the status of their conceptions which is their judgments and opinions about their own knowledge (Venville & Treagust, 1998). The status of a person's conception is explained as the extent to which the conception meets the conditions of intelligibility, plausibility, and fruitfulness, and as more conditions are met, its status becomes higher (Hewson, 1992). Tsui and Treagust (2007) mentioned the importance of status in identifying students' conceptual change. According to them, "The key factor to conceptual change is the status of a new conception held or considered by a learner according to three conditions for conceptual change" (p. 206). These three conditions are intelligibility, plausibility, and fruitfulness. They explained the role of the status in measuring the extent to which the learner: knows the meaning of new conception; believes the new conception is true; finds the new concept useful in solving other problems. With the consideration of the important role of status in identifying conceptual change, Tsui and Treagust (2007) conducted a study in which they investigated the role of multiple representations on students' conceptual understanding of genes and on the status of their conceptual learning measured by intelligibility, plausibility, and fruitfulness. Eighty-nine students from three senior high schools participated in that study. Computer-based activities of *BioLogica*, an interactive computer program, and other web-based interactive multimedia activities were included in the classroom instructions. Related data were colleted by interviewing students and teachers, observing classrooms, and collecting documents and other artifacts. In order to analyze nine selected students' conceptual status, the authors used selected categories from Thorley's (1990) status analysis categories presented in figure 2.2.

Table 2.2 Thorley's status analysis categories (1990, pp. 191-193)

Status of Conceptions	Status Elements
Intelligibility	*Representational models:* Intelligibility analogy (analogy or metaphor used as primary representation) Image (use of pictures, diagrams) Exemplar (real-world exemplar of conception) Attribute (description of significant features of conception) Language (linguistic or symbolic representation of conception)

Table 2.2 (continued)

	Consistency factors:
	Other knowledge ('reasoned' consistency with other knowledge)
	Past experience (particular events cited as consistent with conception)
	Epistemology (consistency with epistemological commitments)
	Metaphysics (reference to ontological status of objects, or metaphysical beliefs about science)
	Plausibility analogy (another conception or phenomenon is invoked as analogous to first conception or phenomenon)
	Transient categories:
Plausibility	
	Lab experience (consistency with laboratory data or observations)
	Thought experience (consistency with features of thought experiment)
	Hypothesis (consistency with laboratory experience)
	Other factors:
	Real mechanism (casual mechanism invoked)
	Neotheory ("embryonic" theory)
	Anomaly (conception resolves an anomaly)

Table 2.2 (continued)

Fruitfulness	Power (conception has wide applicability) Promise (looking forward to what new conception might do) Compete (two competing conceptions are explicitly compared) Extrinsic (recognition of conception as important in discipline or associated with some "expert")

Results indicated that only four of the nine students had intelligible-plausible-fruitful gene conceptions after instruction, whereas, the other four students had intelligible-fruitful conceptions. Additionally, *BioLogica* activities helped most of the students to improve their understandings of genetics and facilitate conceptual change. Also, multiple representations of genes intrinsically motivated many students in the three schools.

Another perspective of conceptual change is social/affective perspective. Both ontological and epistemological perspectives of conceptual change focus mainly on students cognitive processes. However, Pintrich, Marx and Boyle (1993) mentioned the inadequacy of this cold conceptual change model in explaining the reason of why some students are not able to involve in school tasks although they have adequate prior knowledge. They suggested that individual differences in motivational beliefs and classroom contextual factors may shed light on this problem. According to them, the role of social factors, classroom contextual factors, and affective factors on conceptual change should not be ignored. They also claimed that "an individual student's goals for knowledge, learning, and for classroom life in general may have a significant impact on the conceptual change process" (p.173). Other than individual beliefs, they mentioned that classroom contexts and interactions between students and the teacher influence conceptual change process. Therefore, including social effective perspective in multidimensional interpretive framework forms a holistic picture of conceptual change.

A few studies investigated conceptual change from multidimensional interpretive framework. One of the studies was conducted by Liu (2004) to investigate how concept mapping accounts for relational conceptual change in terms of ontological, epistemological, and social/affective perspectives. Fifteen grade 12 students were participated in that study. They worked in groups while constructing computerized concept maps about chemical equilibrium unit. In order to collect relevant data students' concept maps and interviews were used. Results indicated that students' conceptions about the related concept changed from ontological matter and ontological event to a good mix of ontological matter, ontological event, and constraint-based interaction which can be evidence for ontological conceptual change. Additionally, intelligibility, plausibility, and fruitfulness of conceptions increased from the beginning to the end of the instruction which provides evidence for epistemological conceptual change. The results also indicated that, computerized concept mapping and working with a partner motivated the students.

In another study, Venville and Treagust (1998) investigated 83 grade 10 students' (ages 14-15 years) understanding of the gene concept during a 10-week genetics course and analyze the changes in terms of ontological, epistemological, and social/affective perspectives. Data were collected by student worksheets, observations of lessons, videotape and audiotape recordings of the classroom discourse, and student interviews. Results indicated that from the ontological perspective, students' conceptions of the gene changed from a passive particle that passed from parents to offspring, to an active particle that controls characteristics. However, only two of the 29 students interviewed were able to conceptualize the gene as productive sequence of instructions that belongs to process category. For the epistemological examination two students were selected. From the epistemological perspective, the status of one students' gene conception was intelligible-plausible, and the other one's was intelligible-plausible-fruitful. Therefore, it was concluded that conceptual change had not taken place for the first student because his gene conception was only plausible but not fruitful for him. However, conceptual change had taken place for the second student because his gene conception was fruitful for him. From the social/affective perspective, the results indicated that students were enjoyed studying the genetics concept, however, almost all of them demonstrated that they were not very interested in the microscopic nature of genes.

With the similar approach, in this study, in order to further probe students' understanding about related genetics concepts, a multidimensional interpretive framework of conceptual change from ontological perspective (Chi, Slotta, & de Leeuw, 1994), epistemological perspective (Posner, Strike, Hewson, & Gertzog, 1982), and social/affective perspective (Pintrich, Marx, & Boyle, 1993) was used.

Apart from investigating the effects of different instructional strategies on students' genetics understanding, present study also interested in examining the effects of above-mentioned instructional strategies on students' ability to self-regulate their own learning due to the assumed relationship between self-regulation and academic achievement.

2.3 Research on Self-regulation

Recent research mention that, besides promoting students to discover and construct knowledge about the world around them, their ability to self-regulate their own learning should also be fostered. Self-regulation is "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (Pintrich, 2000, p. 453). Self-regulated learners are aware of their strengths and limitations; they set goals effectively; use strategies to achieve their goals; monitor their progress; and manage use of time efficiently (Zimmerman, 2002). There are three main components of self-regulated learning: cognition, metacognition, and motivation (Schraw, Crippen, & Hartley, 2006). Cognition component includes the necessary skills for encoding, memorizing, and recalling information. Metacognition component includes skills that aid the learners to monitor and regulate their cognitive learning processes. Motivation component includes beliefs and attitudes that influence the use of cognitive and metacognitive skills.

From the social cognitive perspective, self-regulation is viewed as an interaction of personal, behavioral, and environmental triadic cyclical processes (Bandura, 1986, as cited in Zimmerman, 2000). Personal processes involve students' beliefs, attitudes, and goals. Behavioral processes involve self-observation, self-judgment, and self-reaction. Environmental processes involve enactive outcomes, modeling, and verbal persuasion (Zimmerman, 1989). It is mentioned that these self-regulatory processes fall into three cyclical phases: forethought, performance or volitional control, and self-reflection (Zimmerman, 2000; 2002). The phase structure and sub-processes of self-regulation is presented in Table 2.3.

Table 2.3 Phase structure and sub-processes of self-regulation (Zimmerman, 2000, p. 16)

Cyclical self-regulatory phases		
Forethought	Performance/volitional control	Self-Reflection
Task Analysis Goal setting Strategic planning	Self-control Self-instruction Imagery Attention focusing Task strategies	Self-judgment Self-evaluation Casual attribution
Self-motivation beliefs Self-efficacy Outcome expectations Intrinsic interest/value Goal orientation	Self-Observation Self-recording Self-experimentation	Self-reaction Self-satisfaction/affect Adaptive-defensive

Forethought phase refers to processes that set the stage for action and includes two major closely linked categories: task analysis and self-motivational beliefs. Goal setting is a key form of task analysis which refers deciding upon specific outcomes of learning or performance. Another form of task analysis is strategic planning that the learner needs to plan methods for performing a task appropriately. Self-regulated learners continuously change their goals and choices of strategies according to change in intrapersonal, interpersonal, and contextual conditions. It is also mentioned that, the learner should motivate herself to use the self-regulatory skills otherwise they have no value. There are a number of key self-motivational beliefs that form a basis for goal setting and strategic planning. These are self-efficacy, outcome expectations, intrinsic interest or valuing, and goal orientation (Zimmerman, 2000). Self-efficacy refers to one's beliefs about her own capability to perform a task. Outcome expectations are related with one's beliefs about the ultimate result of a performance. Intrinsic interest is related with valuing the content of a task and goal orientation is related with one's purposes while engaging in a task. Wolters and Yu (1996) mentioned that two primary goal orientations are suggested as; learning goal orientation where the student gives importance to learning the new material and performance goal orientation where the student confirms her ability and performance in relation to other students.

Performance or volitional control phase includes self-control and self-observation. Self-control is related with the organization and use of specific methods or strategies which were selected during the forethought phase. Self-instruction, imagery, attention focusing, and task strategies are among self-control processes that help students to focus and perform a task better. Self-instruction is related with explicitly or covertly describing how to proceed while a student completing a task. Imagery is related with forming mental pictures. Attention focusing is related with concentrating on the task being studied and ignoring external events. Task strategies help students to focus the essential parts of a task and organize them meaningfully. Zimmerman (2002, p.68) explained the relationship among these self-control methods by an example as "in learning the Spanish word *pan* for 'bread', an English-speaking girl could form an image of a bread pan or self-instruct using the phrase 'bread pan'. She could also locate her place of study away from distracting noises so she could control her attention better. For a task-strategy, she could group the Spanish word *pan* with associated words for foods". The second type of performance or volitional control process is self-observation. Self-observation includes two types of methods; self-recording and self-experimentation. For instance, a student self-records the time he uses while studying and may realize that he finished his homework more quickly when he studied alone than studying with a friend. By conducting a self-experiment he tests his hypothesis about time use (Zimmerman, 2002).

Self-reflection phase includes two processes that are closely related with self-observation: self-judgment and self-reaction. Self-judgment includes self-evaluation and casual attribution. Self-evaluation is comparing one's own performance with other standards like one's prior performance or others' performances. Casual attribution is beliefs about the causes of the result. These two processes, self-evaluation and casual attribution, are also closely linked with processes of self-reaction; self-satisfaction and adaptive-defensive inferences. Students' perceptions of high self-satisfaction may enhance motivation. Adaptive or defensive inferences are related with one's conclusions about adjusting his or her self-regulatory approach according to efforts for learning. Processes of self-reaction cyclically affect forethought processes. For instance, it is mentioned in Zimmerman (2000) that self-satisfaction increases the level of self-efficacy in mastering a skill, learning goal orientations, and intrinsic interest in the task.

Zimmerman also (1998) identified the differences between self-regulatory sub-processes of the naive learners and skillful learners as in Table 2.4.

Table 2.4 Self-regulatory sub-processes of naive and skillful learners (Zimmerman, 1998, p.6)

Self-regulatory phases	Classes of self-regulated learners	
	Naive self-regulators	Skillful self-regulators
Forethought	Nonspecific distal goals	Specific hierarchical goals
	Performance goal orientation	Learning goal orientation
	Low self-efficacy	High self-efficacy
	Disinterested	Intrinsically interested

Table 2.4 (continued)

Performance/volitional control	Unfocused plan	Focused on performance
	Self-handicapping strategies	Self-instruction/imagery
	Outcome self-monitoring	Process self-monitoring
Self-reflection	Avoid self-evaluation	Seek self-evaluation
	Ability attributions	Strategy/practice attributions
	Negative self-reactions	Positive self-reactions
	Non-adaptive	Adaptive

Self-regulated behavior is characterized by the use of specific cognitive learning strategies and regulatory strategies as mentioned by Trifone (2006). According to him, fostering students to use cognitive learning strategies in obtaining a conceptual understanding of a concept is one of the most important goals of education. Learning strategies are grouped in two categories; cognitive and metacognitive, which help the students to encode information and consequently influence the learning outcome. However, it is argued that learning should be understood as a multidimensional process which involves interaction of cognitive and motivational variables (Alao, 1997). Actually, empirical evidence shows that more affectively charged motivational beliefs, such as students' self-efficacy beliefs, and their goals for learning can influence their cognitive engagement in an academic task therefore students' motivational variables are potential mediators of the process of conceptual change (Pintrich, Marx, & Boyle, 1993).

The importance of self-regulation for an individual in developing life long learning skills was mentioned by Zimmerman (2002). Additionally, it was mentioned that instruction is important to teach self-regulatory skills which promote students' motivation and achievement (Schunk & Zimmerman, 1997; Zimmerman, 2002). Also, Perry, VandeKamp, Mercer, and Nordby (2002) confirmed that students may engage in self-regulated learning in classrooms if they engage in complex-open ended activities, make choices which influence their learning, control challenge, and evaluate themselves and others. Therefore, the effects of prediction/discussion-based learning cycle (HPD-LC) instruction, conceptual change text (CCT) instruction, and traditional instruction (TI) on students' self-regulated learning (including motivation and use of learning strategies) were also focus of present study.

2.4 Summary

In the light of the related literature, it can be concluded that students have severe difficulties in understanding genetics concepts that may result from the abstract nature of genetics concepts and inadequacy in forming effective linkages among these concepts. This situation leads the students form misconceptions that are persistent to change and they inhibit further development of concepts. Mode of instruction is a key factor for eliminating students' misconceptions and facilitating conceptual change. Therefore, in the present study, the effects of prediction/discussion-based learning cycle (HDP-LC) instruction, conceptual change text (CCT) instruction, and traditional instruction in promoting conceptual change concerning genetics concepts were investigated. To further probe students' understanding about related genetics concepts a multidimensional interpretive framework of conceptual change was used from ontological, epistemological, and social/affective perspectives (Tyson, Venville, Harrison & Treagust, 1997). Apart from investigating the effects of different instructional strategies on students' genetic understanding, present study also interested in examining the effects of above-mentioned instructional strategies on students' ability to self-regulate their own learning due to the assumed relationship between self-regulation and academic achievement.

CHAPTER III

PROBLEMS AND HYPOTHESES

This chapter includes main problems, sub-problems, and the hypotheses of the study.

3.1 Main Problems

1. What are the relevant prior knowledge, motivation, and learning strategies of 8^{th} grade students?

2. What is the effect of prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction on 8^{th} grade students' understanding of genetics concepts?

3. What is the effect of prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction on 8^{th} grade students' retention of genetics concepts?

4. What is the effect of prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction on 8^{th} grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety)?

5. What is the effect of prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction on 8^{th} grade students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation)?

6. What is the effect of prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction on 8^{th} grade students' conceptual change about genetics concepts in terms of ontological, epistemological, and social/affective domains?

3.2 Sub-Problems

1. What is the relevant prior knowledge of 8^{th} grade students in genetics?

2. What are the 8^{th} grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety)?

3. What are the 8^{th} grade students' learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation)?

4. Is there a significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' understanding of genetics concepts?

5. Is there a significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' retention of genetics concepts?

6. Is there a significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety)?

7. Is there a significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation)?

3.3 Hypotheses

1. There is no statistically significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' understanding of genetics concepts.

2. There is no statistically significant mean difference among the groups exposed to prediction/discussion-based learning cycle

instruction, conceptual change text instruction, and traditional instruction with respect to students' retention of genetics concepts.

3. There is no statistically significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety).

4. There is no statistically significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation).

CHAPTER IV

METHOD

This chapter includes information about the variables, sample of the study, design of the study, instruments used, description of the treatment, methods used to analyze the data, and the assumptions and the limitations of the study.

4.1 Design of the Study

In this study, the nonequivalent control group design as a type of quasi-experimental design was used (Fraenkel & Wallen, 2006) because it was not possible to assign the students to classes randomly due to the consideration of time and administrative rules. The already formed classes were randomly assigned as experimental group I, experimental group II, and control group. The research design of the study is represented in Table 4.1.

Table 4.1 Research Design of the Study

Groups	Pretest	Treatment	Posttest	Delayed Posttest
EG I	GCT MSLQ	HPD-LCI	GCT MSLQ	GCT
EG II	GCT MSLQ	CCTI	GCT MSLQ	GCT
CG	GCT MSLQ	TI	GCT MSLQ	GCT

In this table, EG I represents the experimental group I instructed by the prediction/discussion-based learning cycle instruction. EG II represents the experimental group II instructed by the conceptual change text instruction. CG represents the control group receiving traditional instruction. GCT is the Genetics Concept Test and MSLQ is the Motivated Strategies for Learning Questionnaire. HPD-LCI represents prediction/ discussion-based learning cycle instruction, CCTI represents the conceptual change text instruction, and TI is the traditional instruction.

In this study GCT was administered to all the groups before the treatment in order to determine their prior understanding of genetics. The MSLQ was also administered to all the groups before the treatment to compare their motivation, and their use of cognitive and metacognitive strategy. After the instruction on genetics, GCT and MSLQ were re-administered to all the groups to determine the effects of HPD-LC instruction, CCT instruction and traditional instruction on students' understanding and their motivation and learning strategies, respectively. The GCT was also administered one month later as a delayed posttest to assess the continuous effects of the HPD-LCI, CCTI, and TI on students' understanding of genetics concepts. To obtain quantitative data six students (two from each group) were interviewed before and after the treatment.

4.2 Subjects of the Study

The target population of this study was all 8th grade students in Ankara. The accessible population of the study was all the 8th grade elementary students in the public schools of Yenimahalle district. Three intact classes from one of the 80 public elementary schools in Yenimahalle district was randomly selected as a representative sample.

This study includes a quantitative and a qualitative part. The subjects of the quantitative part of this study consisted of 81 eight-grade (32 boys and 49 girls) students, having a mean age of 13.11 years, from an elementary school in Yenimahalle district of Ankara. For qualitative part of the study, 6 students (2 boys and 4 girls) were chosen among the 81 students purposively to obtain the data needed. These 6 students were recommended by their science teacher considering that they would express their knowledge and ideas clearly during interviews.

This study was conducted over a five-week period during 2006-2007 fall semester. Subjects of the present study attended three intact classes and were exposed to the same content taught by the same science teacher who had a 25-years teaching experience. Three instructional methods (HPD-LCI, CCTI, and TI) were randomly assigned to the experimental and control groups. Students in the first experimental group (n=30) received prediction/discussion-based learning cycle instruction, the second experimental group (n=25) received conceptual change text instruction, and the students in control group (n=26) received traditional instruction. The science grades of the students among groups were comparable: about 4 over 5. The distribution of subjects in the groups is given in Table 4.2.

Table 4.2 Distribution of the Subjects of the Study

Group	Girls	Boys	Total
HPD-LC	15	15	30
CCTI	14	11	25
TI	20	6	26
Total	49	32	81

All the students in the groups were familiar with the related concepts like cell structure and function and some basic information about DNA and chromosome from their sixth grade science lessons.

4.3 Variables

The variables of this study were categorized in two groups as dependent variables (DV) and independent variables (IV).

4.3.1 Dependent Variables

The dependent variables of this study were; (a) students' understanding in the unit of genetics measured by GCT, (b) students' intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety, rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation measured by MSLQ. Intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety were included in the motivation section of MSLQ, whereas rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation were included in the learning strategies section of MSLQ. These variables were considered as continuous variables and measured on interval scale. Motivation section scales used in this study measure students' goals and value beliefs for science, their beliefs about their skills to succeed in science, and their anxiety about tests in science. On the other hand, learning strategies section scales used in this study measure students' use of different cognitive and metacognitive strategies. In order to prevent confusion due to the high number of variables in each section, in this study, names of the sections were mentioned as dependent variables, i.e. students' motivation, and learning strategies.

4.3.2 Independent Variables

The independent variables of this study were time; time 1, time 2, and time 3, and mode of instruction. At Time 1, the students were at the beginning of genetics unit and pre-GCT and pre-MSLQ were administered and pre-instructional interviews were held. At Time 2, participants finished studying the related genetics concepts and post-GCT and post-MSLQ were administered and post-instructional interviews were held. At time 3, one month period was passed after the students studied the related genetics concepts and delayed post-GCT was administered. The other independent variable was mode of instruction; namely prediction/discussion-based learning cycle instruction, conceptual change text instruction and traditional instruction.

4.4 Instruments

The instruments used in this study were Genetics Concept Test (GCT), the Motivated Strategies for Learning Questionnaire (MSLQ), and interviews.

4.4.1 The Genetics Concept Test (GCT)

To evaluate students' understanding of genetics the GCT was developed by the researcher by examining the related literature and the objectives related to genetics unit determined by the national science curriculum (Appendix A). The test mainly assessed students' understanding of basic concepts in genetics; namely, basic terminology of genetics, Mendelian genetics, inheritance, and genetics crosses. It consists of 15 multiple choice questions with one correct answer and three distracters. The distracters of some questions reflected students misconceptions identified from related literature. Among these 15 questions, 5 of them were knowledge level, 6 of them were comprehension level, and 4 of them were application level questions according to Bloom's Taxonomy of educational objectives. Table of specification was presented in Appendix B. Content validity of each item in the test was determined by experts in biology education. The Genetics Concept Test (GCT) was administered to students in each group as a pretest to control their understanding of genetics before the instructions begin. The same test was re-administered to students in each group as a posttest immediately after the treatment and one month later as a delayed posttest to assess the continuous effects of the HPD-LC instruction, CCT instruction and TI on students' understanding of genetics concepts.

While computing the scores on the test, each correct and incorrect answer was given one and zero points, respectively, and each student's total score was equal to the sum of the correct answers. Therefore, students' total scores ranged from 0 to 15. The reliability coefficient was found to be 0.73 by using Kuder-Richardson Formula 20.

4.4.2 The Motivated Strategies for Learning Questionnaire (MSLQ)

In the current study to investigate the effects of HPD-LCI, CCTI, and TI on students' motivation and learning strategies, the MSLQ was used. It is a self-reported questionnaire developed by Pintrich, Smith, Garcia, and McKeachie (1991). It consists of two sections; a motivation section (6 scales) and a learning strategies section (9 scales). There are 81 items scored on a 7 point Likert scale from 1(not at all true for me) to 7 (very true for me). The modular nature of the MSLQ allows researchers use the scales together or individually depending on their needs. Although developed for college students, MSLQ has been used successfully with elementary level students (Pintrich, Anderman, & Klobucar, 1994; Garcia & de Caso, 2006). The MSLQ was translated and adapted into Turkish by Sungur (2004). The wording of related items was modified by adding 'science' to each of them. For the purposes of this study, intrinsic goal orientation (4 items; α=0.55), extrinsic goal orientation (4 items; α=0.65), task value (6 items; α= 0.81), control of learning beliefs (4 items; α=0.81), self-efficacy for learning and performance (8 items; α=0.91) and test anxiety (5 items; α=0.72) scales of motivation section and rehearsal (4 items; α=0.68), elaboration (6 items; α=0.78), organization (4 items; α=0.72), critical thinking (5 items; α=0.79) and metacognitive self-regulation (12 items; α=0.76) scales of learning strategies section were used (Appendix C).

4.4.3 Interview

The interviews conducted at the beginning and at the end of the study, served as the main source of data to further probe students' understanding about related genetics concepts and were analyzed by using a multidimensional interpretive framework of conceptual change from ontological, epistemological, and social/affective perspectives (Tyson, Venville, Harrison & Treagust, 1997). These dimensions were investigated in order to determine how they facilitate or impede the conceptual change process. Moreover, for a holistic picture of the effects of the treatment on conceptual change, these dimensions of conceptual change were considered in this study. Semi-structured interviews were held with 6 students (2 from each class) individually that each lasted approximately 20 minutes duration and all interviews were tape recorded. Interview questions covered basic concepts of genetics; namely, basic terminology of genetics, Mendelian genetics, inheritance, and genetics crosses (Appendix D). The interviews were fully transcribed and the transcripts were used to analyze students' conceptual change from ontological dimension; as matter-based or process-based (Chi, Slotta, & de Leeuw, 1994), from epistemological dimension; as intelligibility, plausibility, and fruitfulness (Posner, Strike, Hewson, & Gertzog, 1982) and from social/affective perspective (Pintrich, Marx, & Boyle, 1993).

4.5 Treatment

This study was carried out over 5 weeks during 2006-2007 fall semester at a public elementary school in Ankara. A total of 81 students from three intact classes of the same science teacher were involved in the study. The classes were randomly assigned as experimental and control groups. Students in the first experimental group received HPD-LC instruction, the second experimental group received CCT instruction, and the students in control group received traditional instruction. The topics related to genetics were covered as part of the regular curriculum in 8^{th} grade science course. Students in all groups were exposed to the same content for the same duration. The classroom instruction was three 40-min sessions per week. Instructions in all classes were observed by the researcher to verify the treatment.

Before the study, in a one-month period, the researcher administered the questionnaires, hold interviews with the selected six students and hold meetings with the teacher. Although the teacher had experience on learning cycle instruction and conceptual change text instruction, meetings with the teacher were held before the study begins in order to discuss the implementation of the treatments and introduce the materials that would be used during the treatments. The GCT and the MSLQ were administered at the beginning of the study to measure students' prior knowledge about genetics concepts and their motivation and learning strategies, respectively. The researcher informed the students about the purposes of the questionnaires and procedures for completing them. They were explained that the results of the questionnaires would not be used as grades and would not be used by anybody other than the researcher. After the explanations, the students were asked to complete the questions on their own. The questionnaires were administered separately and on different times. It took approximately one hour for each questionnaire to be completed by the students. The interviews were also held before the instructions begin. Six students (2 from each class) were interviewed individually in a quite room and each interview took approximately 20 minutes. In these interviews students were asked several questions which they answered both verbally and written.

4.5.1 Prediction/discussion-based Learning Cycle Instruction

Students in the first experimental group were instructed by prediction/discussion-based learning cycle (HPD-LC) instruction. In this study, two separate HPD-LC lessons, one for the basic terminology of genetics and passing of traits, and the other for Mendelian Genetics and genetics crosses were developed by focusing on objectives of the lesson. Lesson plans including the objectives and detailed explanation of each phase of the HPD-LC were prepared to be a guide for the teacher. The HPD-LC lesson was presented in Appendix E. In the prediction/discussion phase of the first learning cycle, hypothetico-predictive problem sheets were administered which required students individually make predictions about passage of traits from parents to offspring. For this purpose, in the first question students were asked to use the photographs of different species of dogs and puppies and predict which dogs were the members of the same family and in the second question they were asked to predict the reason why puppies look similar to their parents (adapted from Venville, Gribble & Donovan, 2005). The aim of this question was to determine the students' prior understanding about how and why offspring resemble their parents. Once they had completed the hypothetico-predictive problem sheet, the teacher initiated a whole class discussion in which students were encouraged to discuss their predictions and reasons. In the exploration phase, students explored and tested their own predictions that they made in the prediction/discussion phase. They worked in groups to visualize the passage of traits from parents to offspring while performing a hands-on activity (adapted from http://learn.genetics.utah.edu/units/activities/print-and-go/traits_generations.pdf). In the term introduction phase, the teacher introduced basic terminology of genetics; gene, dominant allele, recessive allele, homozygous, heterozygous, genotype, phenotype, and discussed the results collected in exploration phase. In the concept application phase, students worked in groups and participated in another hands-on activity in which they extended the concepts that were identified in the previous phase (adapted from Atay, 2006). Each group was provided a worksheet and a coin. In the first part of the activity, students tried to predict the genotype and phenotype of a baby whose parents' traits were given. In the second part of the activity students tried to find out the baby's genotype and phenotype by using a coin. In the worksheet it was explained that the heads of the coin represented dominant allele of the related trait, and the tails of the coin represented recessive allele of that trait. Students flipped the coin for each of the trait. After obtaining relevant data, students filled the table provided on the worksheet and discussed their results with the whole class.

The second learning cycle lesson plan was developed about Mendelian Genetics and genetics crosses. In the prediction/discussion phase, hypothetico-predictive problem sheets were administered which required students make predictions about the probability of the parents who have both heterozygous brown eyes to have a child having blue eyes. It was written on the sheet that the allele for brown eyes was dominant to the allele for blue eyes. Students were also needed to write explanatory reasons to support their predictions. Once they had completed the hypothetico-predictive problem sheet, the teacher initiated a whole class discussion in which students were encouraged to discuss their predictions and reasons. In the exploration phase, students were engaged in an inquiry activity in which they explored and tested their own predictions while working in small groups (adapted from http://www.iit.edu/~smile/bi8602.html). In this activity, each group were given two black plastic bags containing equal amount of red and white beans that represented alleles of heterozygous brown-eyed parents. The aim of using black plastic bags was to prevent the students from seeing inside them and manipulating the results. Students were explained that white beans symbolized brown eye allele, red beans symbolized blue eye allele and each plastic bag containing the beans symbolized the mother and the father. Each group was provided with a worksheet including necessary information and tables that were used to record data. In the first part of the activity, only one of the plastic bags containing equal number and sized red and white beans was used to explore Mendel's Law of Segregation which states that each pair of alleles separate randomly and each gamete receives one or the other with equal probability. Each time one of the students in the groups pulled one bean from the plastic bags and recorded its color (red or white) on the table and returned that bean into the bag again. This process was repeated for 50 times. In the second part of the activity, students used both of the plastic bags and two students in each group pulled two beans at a time and recorded their colors (white & white, red & white, or red & red) on the second table. They returned the beans into their own bags after each pull and repeated this process 50 times. After the observations, students answered the questions on the worksheet with their group members and tried to find out the probability of the parents who have both heterozygous brown eyes to have a child having blue eyes by using their observation results. Once students in the groups discussed their findings, the teacher initiated a whole class discussion in order to make the groups share their findings with each other. Students were also directed to interpret and relate their findings with the target concepts. In the term introduction phase, the teacher explained that in the first part of the activity the expected ratio of white beans to red beans was 1:1, and in the second part of the activity the expected ratio of white & white, red & white, and red & red was 1:2:1. Students compared expected ratios with observed group ratios and tried to make sense from their observations. After reaching to a conclusion about the activity results, the teacher introduced related concepts; namely, Mendel's Genetics Laws, using Punnett square for monohybrid crosses, and analyzing pedigrees. In the concept application phase, students were provided a worksheet with two problems which helped them extend newly learned concepts. In the first problem, students were asked to predict the possible genotypic and phenotypic ratios of crossing two heterozygous yellow-seeded pea plants by using Punnett square. In the second problem, students were asked to predict the genotype and phenotype of an individual from a given pedigree.

4.5.2 Conceptual Change Text Instruction

Students in the second experimental group were instructed with conceptual change text (CCT) instruction. A conceptual change text covering basic concepts of genetics; namely, basic terminology about genetics, Mendelian genetics, inheritance, and genetics crosses was prepared by the researcher with considering four conditions proposed by Posner et al. (1982); dissatisfaction, intelligibility, plausibility, and fruitfulness. It was presented in Appendix F. The science teacher examined the conceptual change text to decide if the content is suitable for that grade level and matches with the objectives of the unit. Before the treatment, meetings were held with the teacher to explain the procedure of using conceptual change text for the instruction. The teacher distributed the texts to the students before the instruction. He directed the students to read it before the class hour and bring it to the class. Students were informed about the new instruction, the nature of the conceptual change text, and how they would use it during the instruction. Students read a paragraph in which a question was posed to arouse students' interest on the subject and to analyze their preconceptions. Students shared their ideas about the answer with the class. The teacher did not intervene and did not give any feedback during this process. It was expected that students were dissatisfied with their existing conceptions. Then, typical misconceptions about the concept that were provided on the text were read aloud by one of the students. Students were asked to compare their conceptions with these misconceptions. The purpose was to create conceptual conflict. Scientifically correct explanation of concept was provided to guide students why the misconceptions could be wrong. The teacher then asked whether anything related with the explanation surprised them to help the students reconstruct the concepts. Images, figures, and pictures were used to help students visualize the concepts while reading the text. In addition, history of science, such as Mendel's life and his studies with pea plants, and history of Punnett Square, was used as a motivational tool to enhance students' motivation.

4.5.3 Traditional Instruction

Students in the control group received traditional instruction which was based on lecture and questioning methods. Teaching strategy relied on teacher explanation. The teacher used the chalkboard to write notes about the definitions of the concepts like; phenotype, genotype, heterozygous homozygous, and to draw figures related with genetic crosses. After teacher explanation, concepts were discussed by teacher-directed questions. The focus of the instruction was on problems related with Mendelian genetics. No experiments or hands on activities were performed by the students related with the topics. Therefore, they did not actively participate in the learning process and reveal their preconceptions. In short, the majority of instruction time was devoted to teacher explanation and answering teacher-directed questions.

After the treatment, the GCT and MSLQ were administered as post-test to evaluate students' understanding of genetics concepts and their motivation and learning strategies, respectively. The GCT was re-administered one month later as a delayed posttest to assess the continuous effects of the HPD-LC instruction, CCT instruction and traditional instruction on students' understanding of genetics concepts. In addition, individual interviews were conducted with students after the treatment in order to obtain relevant data for the analyses of ontological, epistemological, and social/affective dimensions of conceptual change.

4.6 Analysis of Data

The general characteristics of the sample were analyzed as descriptive statistics. Means, standard deviations, histograms, and skewness and kurtosis values were also presented for the related research questions.

Mixed between-within subjects ANOVA was used to investigate the effects of the HPD-LC instruction, CCT instruction and TI on students' genetics understanding and continuous effects of HPD-LC instruction, CCT instruction and TI on students' genetics understanding. Independent variables were time; time 1, time 2, and time 3, and mode of instruction; namely prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction. Dependent variable was students' understanding in the unit of genetics measured by GCT before the treatment, after the treatment, and one month after the treatment.

Four separate MANOVAs were conducted to investigate whether there was a significant mean difference among groups with respect to student' motivation and learning strategies prior to treatment and to investigate the effects of the treatments on students' motivation and learning strategies. Independent variable was mode of instruction; namely prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction. Dependent variables for the first and third MANOVA were students' Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety measured by MSLQ.

Dependent variables for the second and fourth MANOVA were Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation measured by the MSLQ.

While analyzing the interviews, interview transcripts and students written responses to some interview questions were used. For the ontological analysis, matter and process categories were used (Chi et al., 1994). For the epistemological analysis, Thorley's (1990) status analysis categories; intelligibility (intelligibility analogy, image, exemplar, language), plausibility (past experience, metaphysics, plausibility analogy, real mechanism), fruitfulness (power, promise) were used for the purposes of this study. Factors such as interest and classroom context and their influence on conceptual change were examined for the analysis of social/affective dimension of conceptual change.

4.7 Assumptions and Limitations

4.7.1 Assumptions

1. The teacher who applied this study was not biased during the treatment.
2. Tests were administered under standard conditions.
3. All students' responses to the test items were sincere.
4. Students in control and experimental groups did not interact with each other.

4.7.2 Limitations

1. The subjects of this study were limited to 81 eight grade students.
2. The research findings were limited to genetics concepts.
3. This study was limited to public schools.
4. The study was limited by its reliance on self-reported data.

CHAPTER V

RESULTS

This chapter presents the results of the analyses which were conducted to describe the data and to answer research questions. The results were divided into two sections. In the first section analyses of the quantitative data (GCT and MSLQ scores) were presented, and in the second section analyses of the qualitative data (interview transcripts) were presented.

5.1 Analyses of Quantitative Data

This section is divided into two parts. In Part I, problems regarding general characteristics of the sample were addressed. In Part II, statistical analysis of GCT scores, and statistical analyses of MSLQ scores were presented. Statistical analyses were performed at 0.05 significance level using Statistical Package for Social Sciences (SPSS).

PART I

5.1.1 General characteristics of the sample

In this part, main problem 1 and related sub-problems (1-3) were answered.

Main problem 1:

What are the relevant prior knowledge, motivation, and learning strategies of 8^{th} grade students?

The mean, median, mode, standard deviation, skewness, kurtosis and histograms were presented for all the three groups. Skewness and kurtosis values were examined in order to check normality. Skewness and kurtosis values provided in Table 5.1 were in acceptable range being between -2 and +2 for all variables indicating normality. Table 5.1 presents the descriptive statistics for the variables of the study. The findings presented in Table 5.1 were interpreted in depth under the following sub-problems.

Sub-problem 1:

What is the relevant prior knowledge of 8th grade students in genetics?

The Genetics Concept Test (GCT) was used as a pretest in order to determine students' relevant prior knowledge about genetics concepts before the treatment. Of a possible 15 correct answers, a relatively low mean score of 4.80 was obtained by the eighty one students indicating low level of prior knowledge (Table 5.1). The right skewed distribution of the data attained from pre-GCT also indicated that most of the students had low scores on this pretest (Figure 5.1).

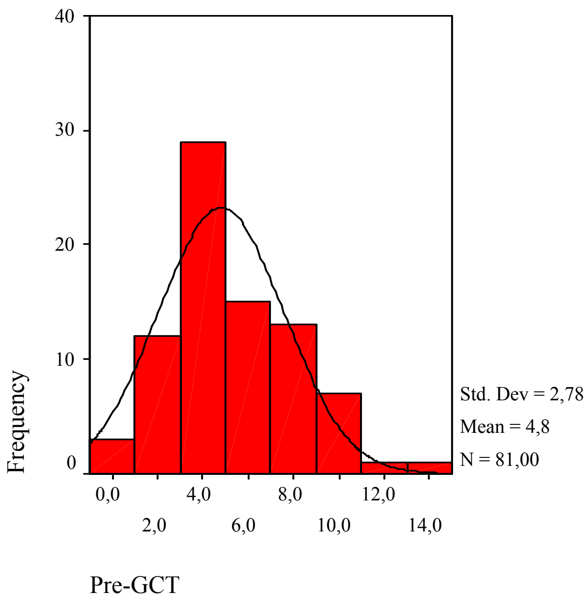


Figure 5.1 Range of pre-GCT scores

Table 5.1 Descriptive statistics for the Variables of the Study

Variable		Instrument	Mean	SD	Possible range	Actual range	Skewness	Kurtosis
Prior knowledge		Pre-GCT	4.80	2.78	0-15	0-14	0.64	0.33
Conceptual understanding		Post-GCT	8.10	3.03	0-15	3-14	0.03	-1.19
Retention		Delayed post-GCT	8.40	3.36	0-15	1-15	-0.15	-0.93
Prior Motivation	IGO	Pre-MSLQ	20.35	3.65	4-28	13-27	-0.10	-0.85
	EGO		22.58	4.25	4-28	7-28	-1.04	1.09
	TV		32.35	6.09	6-42	12-42	-0.85	0.62
	CLB		22.30	3.36	4-28	12-28	-0.39	0.29
	SELP		40.10	9.21	8-56	20-56	-0.25	-0.68
	TA		19.83	6.58	5-35	7-34	0.07	-0.63
Prior Learning strategies	R	Pre-MSLQ	18.46	5.03	4-28	8-28	-0.19	-0.59
	E		26.41	6.74	6-42	9-39	-0.25	0.01
	O		17.56	5.08	4-28	6-28	-0.14	-0.54
	CT		20.48	5.69	5-35	7-33	0.15	0.33
	MSR		56.31	10.01	12-84	27-79	-0.27	0.34
Post Motivation	IGO	Post-MSLQ	20.58	3.54	4-28	12-26	-0.09	-0.78
	EGO		22.15	4.06	4-28	10-28	-0.79	0.27
	TV		32.70	5.70	6-42	20-42	-0.53	-0.75
	CLB		23.21	3.15	4-28	17-28	-0.11	-1.01
	SELP		41.79	8.16	8-56	21-56	-0.55	-0.04
	TA		20.46	6.20	5-35	8-35	0.13	-0.68
Post Learning strategies	R	Post-MSLQ	18.23	4.69	4-28	5-28	-0.36	0.20
	E		26.94	6.84	6-42	11-40	-0.12	-0.56
	O		18.05	4.72	4-28	5-28	-0.10.	-0.20
	CT		20.58	5.42	5-35	9-32	0.15	-0.56
	MSR		55.43	9.41	12-84	32-74	-0.05	-0.26

Sub-problem 2:

What are the 8th grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety)?

The first section of MSLQ was used as a pretest in order to determine students' perceived motivation in science prior to treatment. Intrinsic goal orientation (IGO) and extrinsic goal orientation (EGO) scales assessed students' goals in science course. Table 5.1 summarizes means and standard deviations of these two scales. Possible ranges of IGO and EGO are both 4-28. The actual ranges were 13-27 for IGO and 7-28 for EGO. The mean of IGO scores (*M*=20.35) was lower than EGO sores (*M*=22.58) indicating that students generally focused on grades and approval from others than focusing on learning and mastery. Figure 5.2 presents a clear picture of the results.

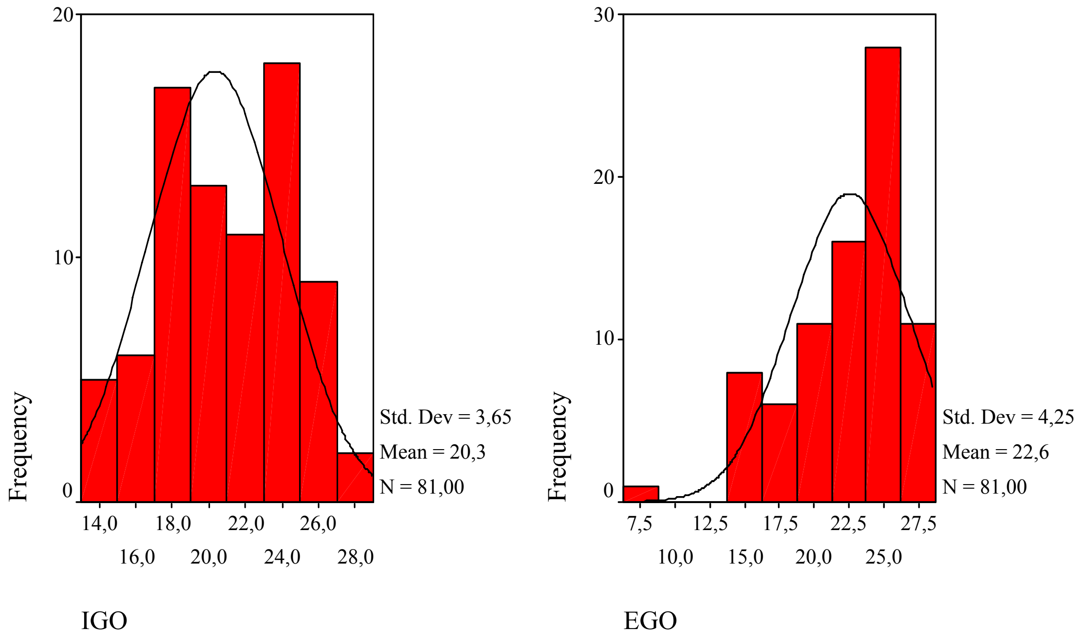


Figure 5.2 Range on IGO and EGO scales

Task value (TV) scale assessed students' value beliefs for science lesson. As presented in Table 5.1, the possible range for TV is 6-42 and the actual range was 12-42. The mean of this scale was 32.35. The left-skewed diagram also shows that most of the students have high scores on task value scale (Figure 5.3). This means that most students found science content interesting, useful, and important.

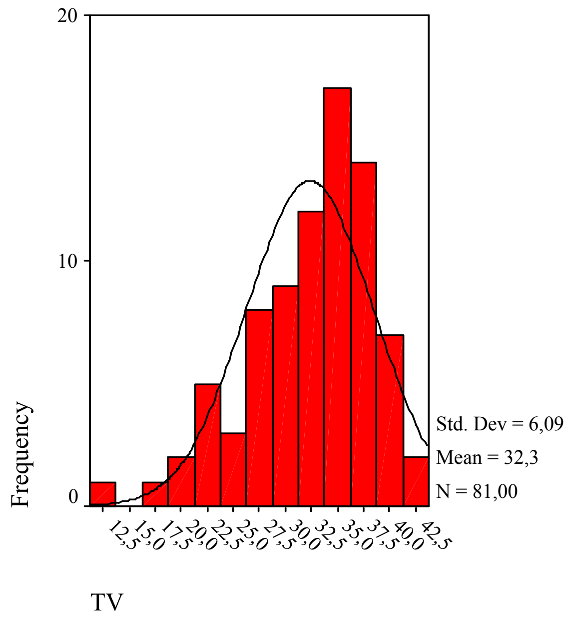


Figure 5.3 Range of TV scores

Control of learning beliefs (CLB) scale is related with students' expectations about being successful in school without relating it with specific issues (Pintrich & Schunk, 2002). Possible and actual ranges of CLB were 4-28 and 12-28, respectively. As it was presented in Table 5.1 the mean score of CLB was 22.30. The left-skewed diagram also shows that most of the students had high scores on this scale (Figure 5.4).

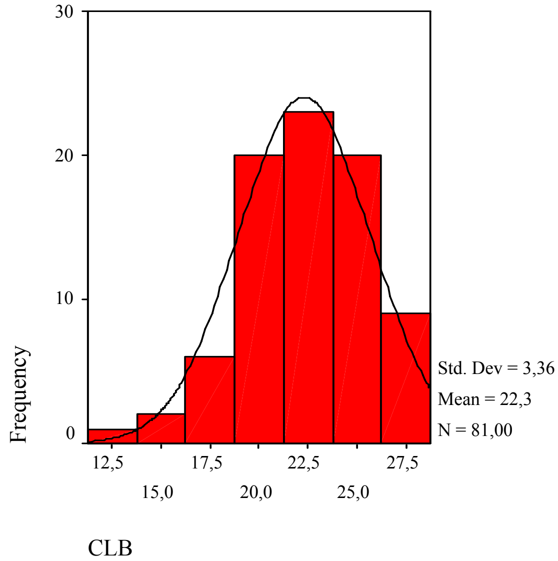


Figure 5.4 Range of CLB scores

Another scale is self-efficacy for learning and performance (SELP) which focuses on students' beliefs that they can accomplish a task. Possible and actual ranges of SELP were 8-56 and 20-56, respectively. The mean score for this scale was 40.10. The distribution in Figure 5.5 indicated that moderate number of the students believe in themselves about being successful in science lesson.

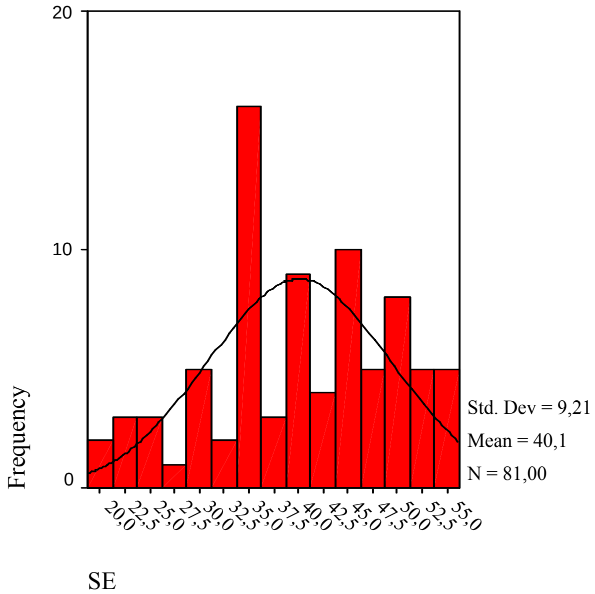


Figure 5.5 Range on SE scale

The last scale of motivation section is task anxiety (TA) related with students' worries and concerns about taking examinations. Possible and actual ranges of TA were 5-35 and 7-34, respectively. The mean score for this scale was 19.83. The diagram shown in Figure 5.6 indicated that students had high scores in this scale.

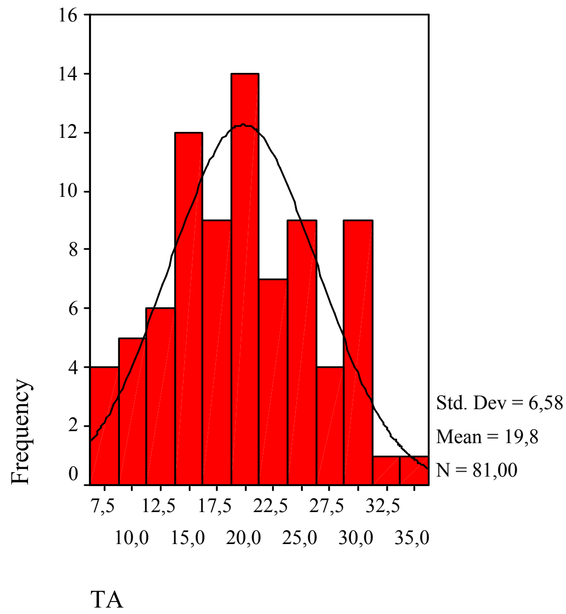


Figure 5.6 Range of TA scores

Sub-problem 3:

What are the 8th grade students' learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation)?

The second section of MSLQ was used as a pretest in order to determine students' use of learning strategies prior to treatment. The first scale is rehearsal (R). Possible and actual ranges of this scale were 4-28 and 8-28, respectively. The mean score as given in Table 5.1 was 18.46. The left-skewed diagram also indicated that moderate students use repetition and memorization of concepts as a learning strategy (Figure 5.7).

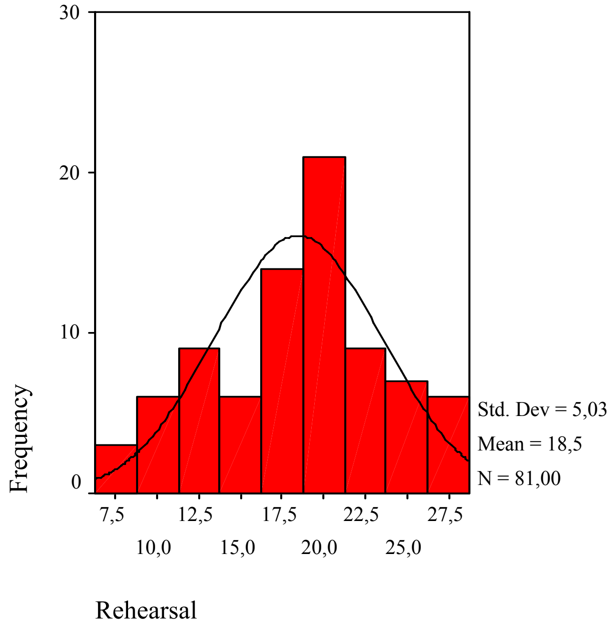


Figure 5.7 Range of Rehearsal scores

Elaboration (E) is another scale of learning strategies section. Possible and actual ranges of this scale were 6-42 and 9-39, respectively. The mean score was 26.41 (see Table 5.1). The left-skewed diagram also indicated that moderate students use paraphrasing and summarizing as a learning strategy (Figure 5.8).

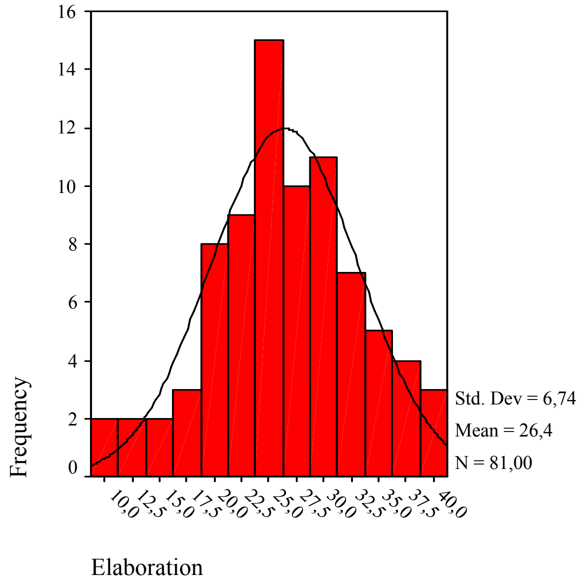


Figure 5.8 Range of Elaboration scores

Organization scale (O) is related with organizing the learning material, like outlining, as a learning strategy. It has possible range of 4-28 and actual range of 6-28. The mean score of this scale was 17.56. The left-skewed diagram in Figure 5.9 indicated that moderate number of students had high scores on this scale.

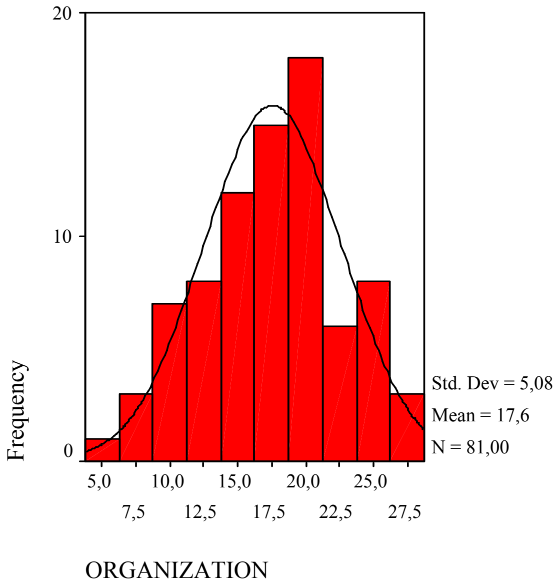


Figure 5.9 Range on Organization scale

Critical thinking (CT) scale is another one related with students' critical evaluations about ideas. Possible and actual ranges of this scale were 5-35 and 7-33, respectively. The mean score was 20.48. The left-skewed diagram indicated that moderate number of students had high scores on this scale (Figure 5.10).

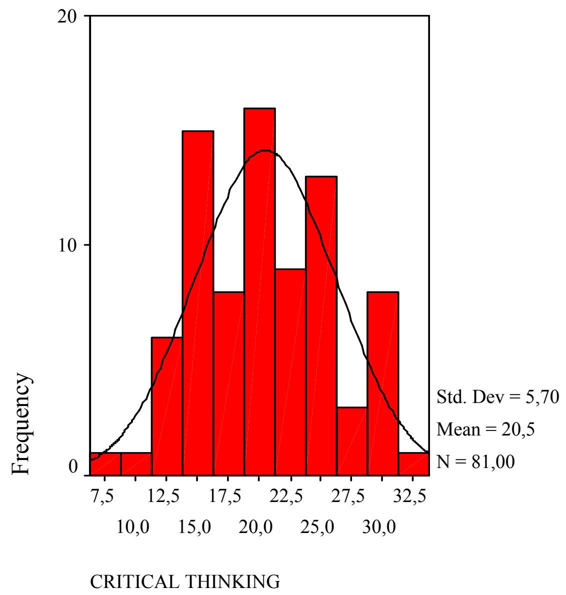


Figure 5.10 Range on CT scale

The last scale is metacognitive self-regulation (MSR) which is related with students' use of strategies like planning and monitoring that help control and regulate their own learning. Possible and actual ranges of this scale were 12-84 and 27-79, respectively. The mean score was 56.31. The left-skewed diagram indicated that moderate number of students had high scores on this scale (Figure 5.11).

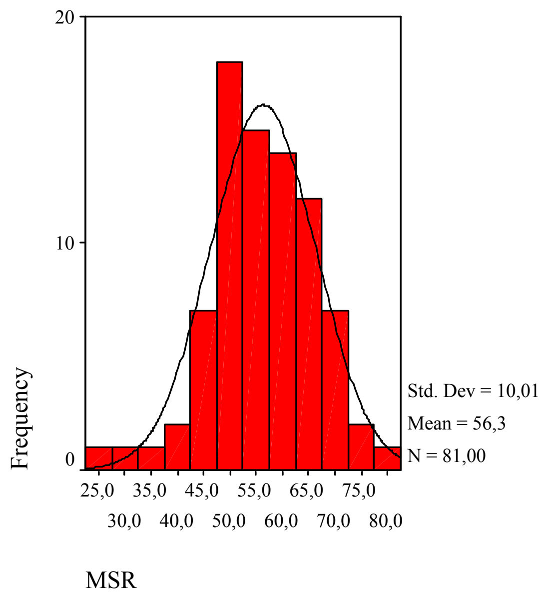


Figure 5.11 Range on MSR scale

PART II

5.1.2 Statistical Analysis of the Genetics Concept Test Scores

First and second hypotheses stated in Chapter 3 were tested by Mixed between-within subjects ANOVA.

Hypothesis 1:

There is no statistically significant mean difference among the groups exposed to prediction-discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' understanding of genetics concepts.

Hypothesis 2:

There is no statistically significant mean difference among the groups exposed to prediction/discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' retention of genetics concepts.

Mixed between-within subjects ANOVA was performed to determine whether there was significant mean difference among students' genetics understanding who participated three groups that received HPD-LC instruction, CCT instruction and TI. In addition, the continuous effects of HPD-LC instruction, CCT instruction and TI on students' genetics understanding were analyzed. Descriptive statistics for the mixed between-within ANOVA were presented in Table 5.2. In this table, EG I represents the experimental group I instructed by the prediction/discussion-based learning cycle instruction, EG II represents the experimental group II instructed by the conceptual change texts instruction, and CG represents the control group receiving traditional instruction. Pre-GCT, Post-GCT, and Delayed post-GCT represents, the Genetics Concept Test administered before, after, and one month later the treatment, respectively.

Table 5.2 Descriptive Statistics

		N	Mean	SD	Skewness	Kurtosis
Pre-GCT	HPD-LC	30	6.77	2.49	0.70	1.21
	CCT	25	3.76	2.54	0.73	-0.17
	TI	26	3.54	2.00	0.97	1.92
Post-GCT	HPD-LC	30	9.60	3.20	-0.79	-0.39
	CCT	25	8.32	2.56	-0.23	-1.36
	TI	26	6.15	2.13	0.67	-0.03
Delayed post-GCT	HPD-LC	30	9.90	3.17	-0.48	-0.13
	CCT	25	9.32	2.73	-0.79	-0.13
	TI	26	5.77	2.57	0.45	-0.78

Assumptions of mixed between-within subjects ANOVA were checked before conducting the analysis. Histograms and skewness and kurtosis values were examined in order to check normality. Histograms for all groups indicated that the scores appeared to be normally distributed. In addition, skewness and kurtosis values provided in Table 5.2 were in acceptable range being between -2 and +2 for all the dependent variables indicating normality. The result of Box's M test, $F(12, 27922)=1.85$, $p=0.035$ ($p>0.001$), indicated that homogeneity of intercorrelations assumption was met. The result of Mauchly's Test of Sphericity, $p=0.42$ ($p>0.05$), indicated that sphericity assumption was met. The results of Levene's Test of Equality of Error Variances, presented in Table 5.3, indicated that error variance of the dependent variable was equal across groups.

Table 5.3 Levene's Test for Equality of Error Variances

	F	df1	df2	Sig. (*p*)
Pre-GCT	1.41	2	78	0.25
Post-GCT	2.81	2	78	0.07
Delayed post-GCT	0.18	2	78	0.84

After meeting the assumptions, mixed between-within subjects ANOVA was run to determine whether there was significant mean difference among students' genetics understanding who participated three groups that received HPD-LC instruction, CCT instruction and TI and the continuous effects of HPD-LC instruction, CCT instruction and TI on students' genetics understanding. Results were displayed in Table 5.4.

Table 5.4 Mixed between-within subjects ANOVA results

Source	df	SS	MS	F	Sig. (*p*)
Time	2	657.00	328.50	60.31	0.00
Treatment	2	180.73	90.36	26.08	0.00
Time*treatment	4	78.05	19.51	3.19	0.01

The results given in the table above indicated that there was a statistically significant interaction effect between time and treatment $F(4,154)=3.19$, $p=0.01$.

Although there was a significant interaction effect between time and treatment, following tables and figures were presented for information about the results of mixed between-within subjects ANOVA.

Table 5.5 Test of within-subjects contrasts

Source		Type III SS	df	MS	*F*	Sig. (*p*)	Eta Squared	Observed Power
Time	1 vs. 2	896.06	1	896.06	96.47	0.00	0.44	1.00
	2 vs. 3	7.50	1	7.50	0.73	0.39	0.09	0.88
	1 vs. 3	1067.46	1	1067.46	88.93	0.00	0.53	1.00

Table 5.6 Means for the main effect of time

Time period	N	Mean	Std. Error
Time 1	81	4.69	0.26
Time 2	81	8.03	0.30
Time 3	81	8.33	0.32

At Time 1, the students were at the beginning of genetics unit and pre-GCT was administered. At Time 2, participants finished studying related genetics concepts and post-GCT was administered. At time 3, one month period was passed after the students studied the related genetics concepts and delayed post-GCT was administered.

Table 5.7 Means with respect to mode of instruction

Group	Mean	Std. Error
EG I	8.76	0.34
EG II	7.13	0.37
CG	5.15	0.37

Table 5.8 Multiple comparisons

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig. (*p*)
EG I	CG	3.60	0.49	0.00
	EG II	1.62	0.50	0.01
EG II	EG I	-1.62	0.50	0.01
	CG	1.98	0.52	0.00
CG	EG I	-3.60	0.49	0.00
	EG II	-1.98	0.52	0.00

The results presented in the Table 5.4 indicated that there was significant interaction effect between time and treatment $F(4,154)=3.19$, $p=0.01$. Table 5.9 presents test of within-subjects contrasts of interaction between time and treatment. The results indicated that interaction effect was significant at Time 1 and Time 2, and Time 1 and Time 3, but not at Time 2 and Time 3.

Table 5.9 Test of within-subjects contrasts

Source		Type III SS	df	MS	*F*	Sig. (*p*)	Eta Squared	Observed Power
Time* treatment	1 vs. 2	58.408	2	29.204	3.14	0.04	0.08	0.59
	2 vs. 3	24.435	2	12.218	1.18	0.31	0.29	0.25
	1 vs. 3	151.314	2	75.657	6.30	0.00	0.14	0.89

Table 5.10 presents the means and Figure 5.12 presents estimated marginal means of students' understanding of genetics.

Table 5.10 Means with respect to students' understanding of genetics

Treatment	Time	Mean	Std. Error
EG I	1	6.77	0.43
	2	9.60	0.49
	3	9.90	0.52
EG II	1	3.76	0.47
	2	8.32	0.54
	3	9.32	0.57
CG	1	3.54	0.46
	2	6.15	0.53
	3	5.77	0.56

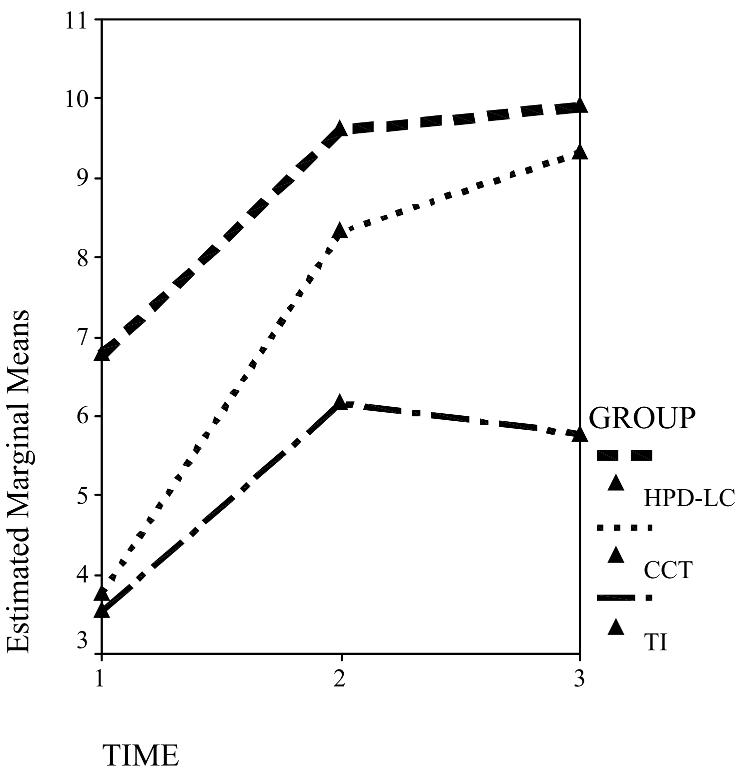


Figure 5.12 Estimated marginal means of students' understanding of genetics.

As it can be inferred from Table 5.10 and Figure 5.12, students' mean scores in EG I and EG II increased across two time periods. CG students' mean scores increased at the end of instruction, however, after one-month later the mean scores decreased. At time 2 and time 3, EG I students had the highest mean score, and CG students had the lowest mean score.

In order to give detailed information about the differences among the groups, the proportions of correct responses of post-GCT questions were presented in Figure 5.13. As it can be inferred from this figure, there were differences among the item responses of EG I, EGII, and CG.

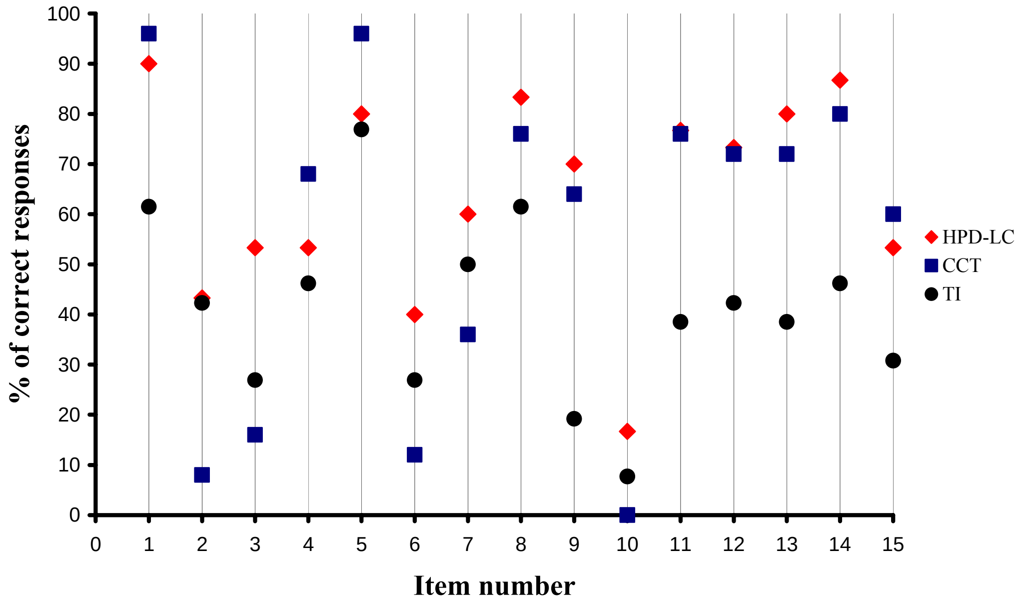


Figure 5.13 Comparison of HPD-LCI, CCTI, and TI with respect to correct responses to the items of post-GCT

This graph indicated that, in general, students instructed with HPD-LC gave more correct answers to the questions than students who received CCT instruction and TI. Students instructed with CCT answered more questions correctly than students received TI. It was also seen that, for all the items, students who received TI gave less correct answers than students instructed with HPD-LC.

Specifically, percentages of the correct responses of items 2, 9, 10, 11, 13, and 14 differed strikingly among groups. Item 2 was a knowledge level question and it was about the relation between allele and gene. The proportions of correct responses of students who received HPD-LCI, CCTI, and TI for question 2 were 43.3%, 42.3%, and 8.0%, respectively. As it can be inferred from the results, the number of students in both experimental groups who gave correct response to this item was higher than the students in CG.

In item 10, another knowledge level question, students were asked to find the wrong distracter about Mendel's genetic crosses. The proportions of correct responses of students who received HPD-LCI, CCTI, and TI for this question were 16.7%, 0%, and 7.7%, respectively. It is necessary to note that, the proportions of correct responses of students for item 10 were very low. Most of the students could not identify the wrong distracter which was stating that the gametes contain both of the alleles of a gene. This result further supports the evidence that gene and alleles are among the most difficult concepts of genetics for students to understand.

Items 11, 13 and 14 were comprehension level questions in which students were asked to use a Punnett square to answer the items. In item 11 students were asked to find parent's genotypes by using children's genotypes given in a Punnett square. The proportions of correct responses of the students in HPD-LC, CCT, and TI classrooms for this item were 76.7%, 76.0%, and 38.5%, respectively. Students who received HPD-LCI and CCTI gave more correct answer to this question than the students in the CG.

In item 13 students were asked to calculate the probability of offspring's having black hair. The proportions of correct responses of students' who received HPD-LCI, CCTI, and TI for this question were 80.0%, 72.0%, and 38.5%, respectively. This result also indicated that experimental group students were more successful in giving the correct answer for this item than the students in the control group.

Similarly, in item 14 student were asked the number of offspring which are heterozygous for hair color. The proportions of correct responses of students who received HPD-LCI, CCTI, and TI for this question were 86.7%, 80.0%, and 46.2%, respectively. Once again the results indicted that the number of students in both experimental groups who gave correct response to this item was higher than the students in control group.

Item 9, dealing with monohybrid crosses and pedigrees, was an application level of question and students were asked to make judgments of the distracters to find the wrong one. The proportions of correct responses of students instructed with HPD-LC, CCT, and TI for question 9 were 70%, 64.0%, and 19.2%, respectively. The results also indicated that the number of students in both experimental groups who gave correct response to this item were higher than the students in the control group.

In general, students' improved in understanding knowledge, comprehension, and application levels of items. However, both experimental group students were more successful in answering comprehension and application level of items than the control group students.

5.1.3 Statistical Analysis of MSLQ Scores

Prior to treatment, two separate One-Way Multivariate Analysis of Variance (MANOVA) were conducted in order to determine whether there was a significant mean difference among groups with respect to student' motivation and learning strategies, respectively. After the treatment, another two separate MANOVAs, third and fourth, were conducted to determine whether there was a significant mean difference among groups with respect to student' motivation and learning strategies, respectively.

5.1.3.1 Statistical Analysis of pre-MSLQ Scores

The first MANOVA was run before the treatment in order to determine whether there was a significant mean difference among groups with respect to students' Intrinsic Goal Orientation (IGO), Extrinsic Goal Orientation (EGO), Task Value (TV), Control of Learning Beliefs (CLB), Self-Efficacy for Learning and Performance (SELP), and Test Anxiety (TA) that constitute motivation collective dependent variable. The second MANOVA was run before the treatment in order to determine whether there was a significant mean difference among groups with respect to Rehearsal (R), Elaboration (E), Organization (O), Critical Thinking (CT), and Metacognitive Self-Regulation (MSR) that constitute learning strategies collective dependent variable. Descriptive statistics for the dependent variables of the first MANOVA were presented in Table 5.11.

Table 5.11 Descriptive Statistics of the first MANOVA

		IGO	EGO	TV	CLB	SELP	TA
EG I	M	20.93	22.73	32.27	22.57	42.37	18.23
	SD	4.11	3.79	6.99	2.70	9.32	6.96
	Skewness	-0.38	-0.94	-1.15	-0.37	-0.57	0.02
	Kurtosis	-1.13	0.00	1.16	0.43	-0.29	-0.76
EG II	M	19.28	22.28	31.32	21.88	39.28	19.28
	SD	3.16	4.69	5.65	2.89	9.63	6.33
	Skewness	0.02	-0.23	0.11	0.38	0.13	0.32
	Kurtosis	0.10	-1.24	-0.55	0.22	-0.86	-0.65
CG	M	20.69	22.69	33.42	22.38	38.27	22.19
	SD	3.44	4.46	5.39	4.39	8.44	5.89
	Skewness	-0.07	-2.04	-1.26	-0.62	-0.51	0.31
	Kurtosis	-0.67	5.28	1.49	-0.21	-0.43	-0.91

Table 5.11 presents mean, standard deviation, skewness, and kurtosis values for the collective dependent variables of motivation. As it can be deduced from the table all the three groups had more or less similar mean scores on each of the dependent variables. Additionally, all the skewness and kurtosis values indicated univariate normality as being between -2 and +2.

Table 5.12 Descriptive Statistics of the second MANOVA

		R	E	O	CT	MSR
EG I	M	18.07	27.67	17.67	18.07	52.17
	SD	4.28	6.57	4.28	5.90	4.28
	Skewness	-0.20	-0.49	-0.20	0.00	0.00
	Kurtosis	0.35	0.07	-0.68	-0.54	-0.21
EG II	M	18.64	25.68	17.36	20.40	51.36
	SD	4.96	5.95	5.39	4.96	8.89
	Skewness	-0.44	0.36	0.14	-0.44	0.92
	Kurtosis	-0.23	0.32	-0.55	-0.23	1.73
CG	M	18.73	25.65	17.62	21.50	52.31
	SD	5.97	7.62	5.15	5.96	11.15
	Skewness	-0.16	-0.36	-0.45	0.01	-0.14
	Kurtosis	-1.16	0.13	-0.09	-1.16	-0.64

Similarly, Table 5.12 presents the descriptive statistics for the dependent variables of the second MANOVA. The mean, standard deviation, skewness, and kurtosis values were presented for the each of the collective dependent variable of learning strategies. The table shows that all the three groups had more or less similar mean scores on each of the dependent variable. Once again all the skewness and kurtosis values lie within the acceptable range; -2 and +2.

5.1.3.1.1 Assumptions of Multivariate Analysis of Variance

1. Sample Size

The cases in each cell were greater than the number of the dependent variables; therefore, the sample size was appropriate to conduct both first and second MANOVA.

2. Normality and Outliers

Univariate and multivariate normalities were checked for both MANOVAs. Histograms and skewness and kurtosis values were examined in order to check univariate normality. Histograms for all groups indicated that the scores appeared to be normally distributed. In addition, skewness and kurtosis values provided in tables 5.11 and 5.12 were in acceptable range being between -2 and +2 for all the dependent variables indicating univariate normality. To check multivariate normality Mahalanobis distances were calculated as 20.11 and 13.44 for first and second MANOVAs, respectively. These values were compared with critical values given in the Chi-square table (Pallant, 2001). The critical value for six dependent variables was 22.46. Since, 20.11 is smaller than 22.46, it was concluded that there were no substantial multivariate outliers for the first MANOVA. The critical value for five dependent variables was 20.52. Since, 13.44 is smaller than 20.52, it was concluded that there were no substantial multivariate outliers for the second MANOVA.

3. Linearity

In order to check linearity assumption, scatterplots were generated for each pairs of the dependent variables. These scatterplots indicated that there was no violation of this assumption for both the first and the second MANOVAs.

4. Multicollinearity and Singularity

Correlation coefficients between dependent variables varied from -0.329 to 0.467 for the first MANOVA, and from 0.420 to 0.689 for the second MANOVA. These values showed that dependent variables were moderately correlated.

5. Homogeneity of Variance-Covariance Matrices

Results of the Box's M Test of Equality of Covariance Matrices indicated that there was no violation of the assumption of homogeneity of variance-covariance matrices for both of the MANOVAs (p=0.41 for the first MANOVA, p=0.64 for the second MANOVA).

Having met the assumptions of MANOVA, first and second MANOVAs were conducted. MANOVA results with respect to collective dependent variables of IGO, EGO, TV, CLB, SELP, and TA were displayed in Table 5.13 and MANOVA results with respect to collective dependent variables R, E, O, CT, and MSR were displayed in Table 5.14.

Table 5.13 Results of MANOVA

Source	Wilks' Lambda	F	Sig. (p)
Treatment	0.39	1.07	0.39

Results given in the table 5.13 revealed that there was no statistically significant mean difference among students in the first experimental group, second experimental group and in the control group with respect to collective dependent variables IGO, EGO, TV, CLB, SELP, and TA before the treatment. Therefore, it was concluded that prior to treatment, students' attending three groups were similar in terms of their motivation in science.

Table 5.14 Results of MANOVA

Source	Wilks' Lambda	*F*	Sig. (*p*)
Treatment	0.89	0.92	0.52

Results given in the table above revealed that there was no statistically significant mean difference among students in the first experimental group, second experimental group and in the control group with respect to collective dependent variables R, E, O, CT, and MSR. Therefore, it was concluded that prior to treatment, students' attending three groups were similar in terms of their use of learning strategies.

5.1.3.2 Statistical Analysis of post-MSLQ Scores

Third and fourth hypotheses stated in Chapter 3 were tested by two separate MANOVAs, third and fourth, respectively.

Hypothesis 3:

There is no statistically mean difference among the groups exposed to prediction-discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, and Test Anxiety).

Descriptive statistics for the third MANOVA were presented in Table 5.15.

Table 5.15 Descriptive Statistics with respect to IGO, EGO, TV, CLB, SELP, TA

		IGO	EGO	TV	CLB	SELP	TA
EG I	M	21.00	22.23	32.53	23.02	43.50	20.07
	SD	3.39	3.72	5.56	3.37	6.94	6.36
	Skewness	-0.31	-1.13	-0.64	0.14	0.04	0.31
	Kurtosis	0.25	2.84	-0.27	-1.36	-0.27	-0.39
EG II	M	20.08	22.16	32.40	22.96	41.76	19.48
	SD	3.33	3.84	6.51	12.04	9.74	5.95
	Skewness	0.01	-0.88	-0.31	-0.15	-0.56	0.37
	Kurtosis	-0.90	-0.08	-1.17	-0.92	-0.84	-0.14
CG	M	20.58	22.04	33.19	23.65	39.85	21.85
	SD	3.97	4.74	5.21	2.59	7.66	6.24
	Skewness	-0.02	-0.57	-0.75	-0.26	-1.02	-0.29
	Kurtosis	-1.29	-0.72	-0.67	-0.65	0.58	-0.76

Assumptions of MANOVA were checked before conducting the third MANOVA (Pallant, 2001). The first assumption is related with the sample size. The cases in each cell were greater than the number of the dependent variables; therefore, the sample size was appropriate to conduct third MANOVA. The second assumption is related with normality and outliers. Histograms and skewness and kurtosis values were examined in order to check univariate normality. Histograms for all groups indicated that the scores appeared to be normally distributed. In addition, skewness and kurtosis values provided in Table 5.15 were in acceptable range being between -2 and +2 for all the dependent variables indicating univariate normality. To check multivariate normality Mahalanobis distance was calculated as 17.97. This value was compared with critical value given in the Chi-square table (Pallant, 2001). The critical value for six dependent variables was 22.46. Since, 17.97 is smaller than 22.46, it was concluded that there were no substantial multivariate outliers for the third MANOVA. The third assumption is related with linearity. In order to check linearity assumption, scatterplots were generated for each pairs of the dependent variables. These scatterplots indicated that there was no violation of this assumption for the third MANOVA. The fourth assumption is related with multicollinearity and singularity. Correlation coefficients between dependent variables varied from 0.225 to 0.536. These values showed that dependent variables were moderately correlated. The fifth assumption is related with homogeneity of variance-covariance matrices. Results of the Box's M Test of Equality of Covariance Matrices indicated that there was no violation of the assumption of homogeneity of variance-covariance matrices for the third MANOVA; $F(42,17253)=1.04$, $p=0.41$. For the equality of variances assumption Levene's Test of Equality of Error Variances was used. Table 5.16 indicted that each dependent variable has the same variance across groups.

Table 5.16 Levene's Test for Equality of Error Variances

	F	df1	df2	Sig. (*p*)
IGO	1.52	2	78	0.22
EGO	1.95	2	78	0.15
TV	1.42	2	78	0.25
CLB	1.88	2	78	0.16
SELP	2.82	2	78	0.07
TA	0.04	2	78	0.96

After checking the assumptions, third MANOVA was conducted. Results of the analysis were shown in Table 5.17.

Table 5.17 MANOVA results for null hypothesis 3

Source	Wilks' Lambda	*F*	Hypothesis df	Error df	Sig. (*p*)	Eta Squared	Observed Power
Treatment	0.90	0.63	12	146	0.82	0.05	0.35

The results showed that there was no significant mean difference among the groups with respect to collective dependent variables of motivation after the treatment.

Fourth MANOVA was conducted to test the fourth hypothesis stated in Chapter 3.

Hypothesis 4:

There is no statistically mean difference among the groups exposed to prediction-discussion-based learning cycle instruction, conceptual change text instruction, and traditional instruction with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, and Metacognitive Self-Regulation).

Descriptive statistics for the fourth MANOVA were presented in Table 5.18.

Table 5.18 Descriptive Statistics with respect to R, E, O, CT, MSR

		R	E	O	CT	MSR
EG I	M	18.77	29.57	18.93	21.80	56.03
	SD	4.90	6.82	5.00	6.21	9.93
	Skewness	0.02	-0.23	-0.09	0.05	-0.54
	Kurtosis	-0.39	-0.41	-0.80	-1.30	0.43
EG II	M	17.92	24.04	18.16	19.32	50.56
	SD	4.49	6.49	4.49	4.69	9.37
	Skewness	-0.76	0.45	-0.25	-0.16	-0.01
	Kurtosis	0.52	-0.76	-0.02	-0.38	-0.30
CG	M	17.92	26.69	16.92	20.38	51.65
	SD	4.77	6.22	4.53	4.50	10.85
	Skewness	-0.63	-0.85	-0.24	0.06	0.38
	Kurtosis	0.89	0.55	0.85	0.42	0.06

Assumptions of MANOVA were checked before conducting the fourth MANOVA. The first assumption is related with the sample size. The cases in each cell were greater than the number of the dependent variables; therefore, the sample size was appropriate to conduct fourth MANOVA. The second assumption is related with normality and outliers. Histograms and skewness and kurtosis values were examined in order to check univariate normality. Histograms for all groups indicated that the scores appeared to be normally distributed. In addition, skewness and kurtosis values provided in Table 5.18 were in acceptable range being between -2 and +2 for all the dependent variables indicating univariate normality. To check multivariate normality Mahalanobis distance was calculated as 15.64. This value was compared with critical value given in the Chi-square table (Pallant, 2001). The critical value for five dependent variables was 20.52. Since, 15.64 is smaller than 20.52, it was concluded that there were no substantial multivariate outliers for the fourth MANOVA. The third assumption is related with linearity. In order to check linearity assumption, scatterplots were generated for each pairs of the dependent variables. These scatterplots indicated that there was no violation of this assumption for the fourth MANOVA. The fourth assumption is related with multicollinearity and singularity. Correlation coefficients between dependent variables varied from 0.457 to 0.746. These values showed that dependent variables were moderately correlated. The fifth assumption is related with homogeneity of variance-covariance matrices. Results of the Box's M Test of Equality of Covariance Matrices indicated that there was no violation of the assumption of homogeneity of variance-covariance matrices for the fourth MANOVA; $F(30,18399)=1.54$, $p=0.03$. For the equality of variances assumption Levene's Test of Equality of Error Variances was used. Table 5.19 indicted that each dependent variable has the same variance across groups.

Table 5.19 Levene's Test for Equality of Error Variances

	F	df1	df2	Sig. (*p*)
R	0.12	2	78	0.89
E	0.30	2	78	0.74
O	0.81	2	78	0.45
CT	2.28	2	78	0.11
MSR	0.06	2	78	0.94

After checking the assumptions, fourth MANOVA was conducted. Results of the analysis were shown in Table 5.20.

Table 5.20 MANOVA results for null hypothesis 4

Source	Wilks' Lambda	*F*	Hypothesis df	Error df	Sig. (*p*)	Eta Squared	Observed Power
Treatment	0.75	2.24	10	148	0.02	0.13	0.91

The results showed that there was a significant mean difference among the experimental group I, experimental group II and control group with respect to collective dependent variables as indicated in Table 5.20; $F(10,148)=2.24$, $p<0.05$. The multivariate η^2 based on Wilks' λ was strong, 0.13. This value indicted that 13% of multivariate variance of the dependent variables was explained by the treatment. In addition, power was found to be 0.91. Therefore, these findings indicated that the difference among the groups originated from the treatment effect and this difference had practical value.

In order to determine the effect of treatment on each dependent variable, univariate ANOVAs were run. The results were presented in Table 5.21.

Table 5.21 Follow-up results for null hypothesis 4

Source	DV	df	*F*	Sig. (*p*)	Eta Squared	Observed Power
Treatment	R	2	0.30	0.74	0.01	0.10
	E	2	4.91	0.01	0.10	0.79
	O	2	1.29	0.28	0.03	0.27
	CT	2	1.47	0.24	0.04	0.31
	MSR	2	2.33	0.10	0.06	0.46

Each ANOVA was evaluated at 0.01 (0.05/5) significance level after using the Bonferroni adjustment. As it can be inferred from the table, only the univariate ANOVA for elaboration scale was significant, indicating that there was a significant mean difference among the groups with respect to this dependent variable. Post-hoc test was conducted for multiple comparisons of groups with respect to use of elaboration strategies. According to the post-hoc test results, there was a significant mean difference between the students instructed with HPD-LC and CCT with respect to use of elaboration strategies. When the mean scores given in Table 5.18 were examined, students in the first experimental group who received HPD-LC instruction had higher mean score on elaboration scale than students in the experimental group II who received CCT instruction. Therefore, students in EG I appeared to use elaboration strategies more than students in EG II. For instance, 76.7% of the students in the first experimental group rated themselves on the item (item no: 55) “When I study for this course, I write brief summaries of the main ideas from the readings and my class notes” as 5, 6, and 7. Students in the control group had a percentage of 46.1% for the same item. Percentages of responses to items of elaboration scale were presented in Table 5.22.

Table 5.22 Percentages of responses to items of Elaboration scale

Item number	Group	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
44	EG I	0	13.3	6.7	26.7	13.3	23.3	16.7
	EG II	4.0	4.0	20.0	24.0	44.0	4.0	0
	CG	3.8	11.5	11.5	11.5	30.8	19.2	11.5
51	EG I	3.3	13.3	10.0	16.7	20.0	23.3	13.3
	EG II	8.0	28.0	8.0	16.0	20.0	12.0	8.0
	CG	7.7	19.2	11.5	7.7	26.9	23.1	3.8
53	EG I	0	6.7	0	10.0	23.3	43.3	16.7
	EG II	4.0	4.0	32.0	16.0	20.0	20.0	4.0
	CG	0	3.8	3.8	30.8	34.6	23.1	3.8
55	EG I	6.7	6.7	3.3	6.7	36.7	13.3	26.7
	EG II	12.0	16.0	8.0	20.0	32.0	4.0	8.0
	CG	11.5	7.7	15.4	19.2	19.2	11.5	15.4
56	EG I	0	3.3	10.0	10.0	36.7	20.0	20.0
	EG II	0	8.0	20.0	16.0	36.0	4.0	16.0
	CG	3.8	3.8	11.5	19.2	26.9	26.9	7.7
62	EG I	10.0	10.0	6.7	10.0	30.0	26.7	6.7
	EG II	16.0	28.0	16.0	4.0	16.0	8.0	12.0
	CG	11.5	7.7	3.8	23.1	38.5	7.7	7.7

There was no significant mean difference between students in the first experimental group and students in the control group who received traditional instruction with respect to use elaboration strategies. When the mean scores were examined, it was found that students in the EG I had higher scores than students in the CG. Therefore, students in the EG I appeared to use rehearsal strategies more than the control group students. However, it should be mentioned that this difference in the mean scores was not statistically significant. In addition, there was no significant mean difference between the students in the second experimental group and students in the control group with respect to use of elaboration strategies. When the mean scores were examined, it was found that students in the CG had higher scores than students in the EG II. Therefore, students in the CG appeared to use rehearsal strategies more than the students in EG II. However, it should again be mentioned that this difference in the mean scores was not statistically significant.

5.2 Analyses of Qualitative Data

This section is divided into three parts. The interviews conducted with the 6 students at the beginning and at the end of the study were analyzed by using a multidimensional interpretive framework of conceptual change from ontological, epistemological, and social/affective perspectives. Descriptive information of the 6 interviewees was presented in Table 5.23.

Table 5.23 Descriptive information

	Group	Gender	Age	Science Grade
Student 1	EG I	Male	13	5
Student 2	EG I	Female	14	4
Student 3	EG II	Female	14	5
Student 4	EG II	Female	13	5
Student 5	CG	Female	13	4
Student 6	CG	Male	14	4

5.2.1 Ontological Perspective

This part focuses on the changes in students' conceptions of gene, DNA, and chromosome concepts from an ontological perspective of conceptual change (see Figure 2.2).

In order to determine students' prior understandings of various genetics concepts, both verbal and written responses were analyzed. Selected student pre-instructional responses about gene, DNA, and chromosome concepts were presented as follows;

> Researcher: *What do you think genes are? What are their functions?*
> Student 1: Genes make up DNA.
> Student 2: I don't know.
> Student 3: Genes are something carried on chromosomes.
> Student 4: Genes are made up of DNA and provide variation in human beings.
> Student 5: Genes are inherited characteristics passed from parents to child.
> Student 6: Genes are something passed from parents to child.
>
> Researcher: W*here is a gene located?*
> Student 1: It is in the nucleus I guess.
> Student 2: I don't know.
> Student 3: I guess it is in the cells.
> Student 4: In the nucleus.
> Student 5: I don't know.
> Student 6: I don't know.

Researcher: *What do you think DNA is? What is its function?*

Student 1: DNA is a nucleic acid found in the nucleus that carries inherited information.

Student 2: DNA is something related with human structure.

Student 3: DNA is a helix shaped thing that forms chromosomes.

Student 4: DNA makes up genes and provides variation in humans.

Student 5: DNA is a structure that carries inherited characteristic of humans.

Student 6: DNA is inherited information which determines human's characteristics, like; shape of a person's nose and eye color.

Researcher: *What do you think chromosome is? What is its function?*

Student 1: It is something located in the nucleus and related with genes.

Student 2: Chromosome is something in the cell.

Student 3: Chromosome holds genetic information of humans which has a function in the cell.

Student 4: It is something in the cell and related with DNA.

Student 5: I don't know.

Student 6: It is something found in gametes, actually it is found in all the cells but in the gametes its number is half of the normal cells.

Students' comments related with gene, DNA, and chromosome suggest that prior to instruction they viewed these concepts as particles belonging to "matter" category as described by Chi et al. (1994). For example, students' conceptions like "genes pass from parents to child", "genes are something carried on chromosomes" or "DNA is something related with human structure" indicated that they viewed gene and DNA concepts as 'things' belonging to "matter" category (Chi et al., 1994).

Pre-instructional interview results were presented in Table 5.24.

Table 5.24 Pre-instructional interview results

Treatment	Student	Gene			DNA			Chromosome		
		No conception	Matter	Process	No conception	Matter	Process	No conception	Matter	Process
HPD-LCI	Student 1		1			1			1	
	Student 2	1				1			1	
CCTI	Student 3		1			1			1	
	Student 4		1			1			1	
TI	Student 5		1			1		1		
	Student 6		1			1			1	

After the instruction, post-instructional interviews were held in order to determine students' understandings of various genetics concepts. Students described gene, DNA, and chromosome concepts as follows;

> Researcher: *What do you think is the function of a gene?*
>
> Student 1: Gene determines a cell's inherited characters and its function. Cells with different functions synthesize different proteins, and a gene determines which proteins should be synthesized. [HPD-LC, male]
>
> Student 2: Gene is something that carries genetic information. [HPD-LC, female]
>
> Student 3: Gene holds inherited information and passes from parent to child. [CCT, female]
>
> Student 4: Gene holds characters that pass from parents to child; like hair color, eye color, and height of the child. It determines inherited characteristics of humans. [CCT, female]
>
> Student 5: Genes pass from parents to child and consist of codes and these codes determine characteristics of humans. [TI, female]
>
> Student 6: Since genes make up DNA and DNA controls cells, therefore, genes control cells.
>
> Researcher: *What do you mean by controlling cells?*
>
> Student 6: The nucleus controls cell and DNA is located in nucleus. DNA forms messenger RNA and determines its [messenger RNA] function. Messenger RNA goes to ribosome and protein synthesis occurs. [TI, male]

> Researcher: *What is the function of DNA?*
>
> Student 1: DNA is responsible from protein synthesis. [HPD-LC, male]

Student 2: DNA directs protein synthesis and transfers inherited characters to offspring. [HPD-LC, female]
Student 3: DNA assists nucleus for cell division, I mean, DNA caries the inherited information in the old cell to the new cell. [CCT, female]
Student 4: DNA carries genetic information of humans and it passes from parents to child. It determines variation in human beings. [CCT, female]
Student 5: DNA is a structure that determines humans' I mean living things' characters. [TI, female]
Student 6: DNA forms messenger RNA and determines its function. Messenger RNA goes to ribosome and protein synthesis occurs. So, it is responsible for protein synthesis. [TI, male]

Researcher: *What is chromosome? What is its function?*
Student 1: Chromosome is located in nucleus and carries DNA. [HPD-LC, male]
Student 2: Chromosome is something that carries genes. [HPD-LC, female]
Student 3: Chromosome is related with inheritance, like DNA and genes. [CCT, female]
Student 4: Chromatin condenses and forms chromosome where DNA is located. [CCT, female]
Student 5: Chromosome is a structure found in the nucleus. [TI, female]
Student 6: Chromosome is something that determines things like sex. [TI, male]

Post-instructional interview results were presented in Table 5.25.

Table 5.25 Post-instructional interview results

Treatment	Student	Gene			DNA			Chromosome		
		No conception	Matter	Process	No conception	Matter	Process	No conception	Matter	Process
HPD-LCI	Student 1			1			1		1	
	Student 2		1				1		1	
CCTI	Student 3		1			1			1	
	Student 4		1			1			1	
TI	Student 5		1			1			1	
	Student 6			1			1		1	

Students' comments related with genes and DNA concepts indicated that there were ontological changes in the way they interpret these concepts after the instruction. For instance, prior to instruction student 1 perceived genes as particles forming DNA, suggesting a gene conception in the ontological category of "matter". However, after the instruction, he understood the relation between genes and protein synthesis, which suggests a gene conception in the ontological category of "process". This ontological change across distinct categories indicated *radical conceptual change* (Chi et al., 1994). Similarly, prior to instruction student 2 perceived DNA as a structure that includes humans' genetic information, suggesting a gene conception in the ontological category of "matter". After the instruction, she explained the connection between DNA and protein synthesis, which suggests a DNA conception in the ontological category of "process". This also indicated *radical conceptual change*. These two students were instructed with HPD-LC.

Student 6, who attended TI classroom, mentioned about the relation between genes and protein synthesis after the instruction suggesting gene conception in the ontological category of "process". His prior conception about gene was as something related with characters which suggests a gene conception in the ontological category of "matter". This change also indicated *radical conceptual change*. However, he mentioned during the interviews that he was attending a "dershane" in Turkish, and he studied this unit in there.

There were also changes in some students' conceptions related with gene, DNA, and chromosome concepts within the category of "matter" indicating *gradual conceptual change* (Chi, 1992). For instance, prior to instruction student 5 perceived genes as inherited characteristics passed from parents to child, however, after the instruction, she mentioned the role of the codes in genes in determining characteristics of humans. Her gene conception changed from being a passive particle to being an active particle (Venville & Treagust, 1998). This change in her conception about gene indicated that she still perceived gene as “matter”. Another example is the change in student 3’s conception about DNA concept. Prior to instruction she perceived DNA as a helix shaped thing that forms chromosomes suggesting a passive particle model, however after the instruction, she mentioned the role of DNA in carrying the inherited information in the old cell to the new cell. This change was also within “matter” category indicating *gradual conceptual change*.

5.2.2 Epistemological Perspective

This part focuses on the students' conceptual status of basic concepts in genetics. Both verbal and written data from the interviews were used as sources of information about students' conceptions. Thorley's (1990) status analysis categories were used in order to determine each student's conceptions as no status, intelligible, intelligible-plausible, or intelligible-plausible-fruitful as Tsui and Treagust (2007) used in their study. Table 5.26 presents Thorley's status analysis categories.

Table 5.26 Thorley's status analysis categories (1990, pp. 191-193)

Status of Conceptions	Status Elements
Intelligibility	*Representational models:* Intelligibility analogy (analogy or metaphor used as primary representation) Image (use of pictures, diagrams) Exemplar (real-world exemplar of conception) Attribute (description of significant features of conception) Language (linguistic or symbolic representation of conception)
Plausibility	*Consistency factors:* Other knowledge ('reasoned' consistency with other knowledge) Past experience (particular events cited as consistent with conception) Epistemology (consistency with epistemological commitments)

Table 5.26 Continued

	Transient categories: Metaphysics (reference to ontological status of objects, or metaphysical beliefs about science) Plausibility analogy (another conception or phenomenon is invoked as analogous to first conception or phenomenon) Lab experience (consistency with laboratory data or observations) Thought experience (consistency with features of thought experiment) Hypothesis (consistency with laboratory experience) *Other factors:* Real mechanism (casual mechanism invoked) Neotheory ("embryonic" theory) Anomaly (conception resolves an anomaly)
Fruitfulness	Power (conception has wide applicability) Promise (looking forward to what new conception might do) Compete (two competing conceptions are explicitly compared) Extrinsic (recognition of conception as important in discipline or associated with some "expert")

5.2.2.1 Intelligibility

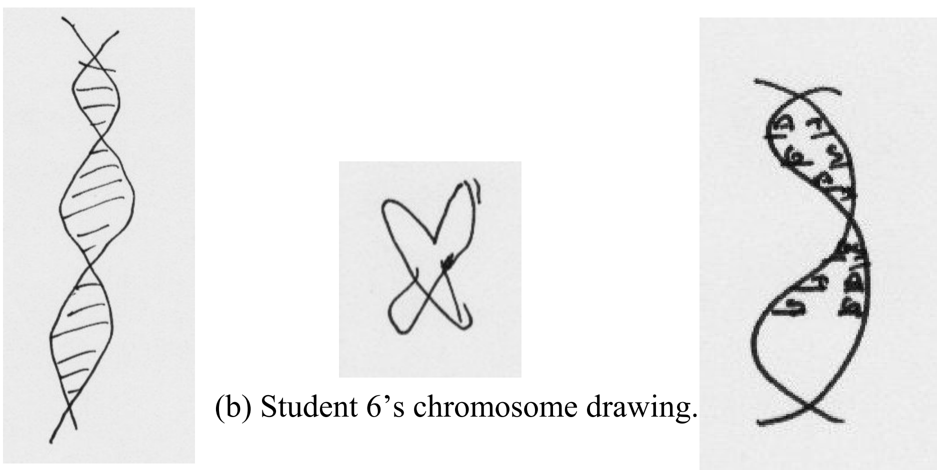
As it was presented in Table 5.26, there are five status elements about intelligibility. However, four of them; intelligibility analogy, image, exemplar, and language were used for the analysis of interviews in this study.

Intelligibility Analogy

Student 1 and student 6 included this status element in their interviews. Student 1 expressed his ideas in the post-instructional interview as “Different sequences of the bases form different genes, and these genes code for different characters, like a different language”. Student 6 said “DNA is like a helix shape ladder”. The usage of “a different language” and “helix shape ladder” analogies while describing conceptions about gene and DNA showed that these students’ gene and DNA conceptions were intelligible.

Image

While representing their conceptions about DNA all of the six students were able to make a drawing. However, when the shape of gene was asked only student 1 mentioned that a short length of DNA is called the gene and when the shape of chromosome was asked only student 6 made a drawing about it. The visual representations of students indicated that gene, DNA, and chromosome concepts were intelligible to them. Figure 5.14 represents sample drawings of students’ DNA and chromosome conceptions.



(b) Student 6’s chromosome drawing.

(a) Student 1’s DNA drawing.

(c) Student 3’s DNA drawing.

Figure 5.14 Students’ drawings concerning DNA and chromosome concepts.

Exemplar

Three students among the six interviewees, student 1, student 3, and student 4, used examples like hair color, hair style, and eye color while expressing their conceptions about gene. For instance, student 3 expressed her ideas as "Genes make up us, that is our hair type, eye color, like this" and students 4 said "Genes hold information from parents like hair color, eye color, body height".

Language

All of the six students used genetic terminology while representing their conceptions about gene, DNA, and chromosome. For instance, student 5 said "Genes hold some codes that determine characteristics of humans" and student 4 stated that "Genes make up DNA and passed from parents …".

Results of the analysis of conceptual status for intelligibility, which were presented in Table 5.27, indicated that all the six students had intelligible conceptions about basic concepts in genetics.

Table 5.27 Analysis of conceptual status: Intelligibility

Status Elements	Intelligibility of Student Conceptions					
	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Intelligibility Analogy	+					+
Image	+	+	+	+	+	+
Exemplar	+		+	+		
Language	+	+	+	+	+	+

5.2.2.2 Plausibility

Among the status elements of plausibility presented in Table 5.26, only past experience, epistemology, plausibility analogy, and real mechanism were used for the analysis of interviews in this study.

Past experience

Three students among the six interviewees, student 1, student 2, and student 5, compared their new conceptions with their old conceptions about basic concepts of genetics. For instance, student 2 expressed her conception about genes and chromosome as "Before the instruction, I thought gene as a cell; however, it is not a cell. It holds inherited characteristics and is found in chromosomes. Chromosomes are located in cells" which is a metaconceptual statement.

Metaphysics

This status element is related with the ontological status of objects or beliefs (Thorley, 1990). It was identified in three interviewees' post instructional interview transcript. For instance, student 1 expressed his ideas about the function of genes as "Gene determines a cell's inherited characters and its function. Cells with different functions synthesize different proteins, and a gene determines which proteins should be synthesized". Prior to instruction, student 1 perceived genes as passive particles forming DNA, suggesting a gene conception in the ontological category of "matter". However, after the instruction, he understood the relation between genes and protein synthesis, which suggests a gene conception in the ontological category of "process". This ontological change across distinct categories indicated *radical conceptual change* (Chi et al., 1994). Student 6's conceptions about genes and DNA also belonged to "process" category as he mentioned in his post instructional interview that "Since genes make up DNA and DNA controls cells, therefore, genes control cells. The nucleus controls cell and DNA is located in nucleus, and DNA form messenger RNA and determines its [messenger RNA] function. Messenger RNA goes to ribosome and protein synthesis occurs". This also indicated *radical conceptual change*.

Plausibility analogy

This status element is related with invoking a conception by using another analogous conception. All the six students included this status element in their interview discourse. For instance, student 1 mentioned in his post-instructional interview "Gene determines a cell's inherited characters and its function. Cells with different functions synthesize different proteins, and a gene determines which proteins should be synthesized". Student 1's gene conception as determining cells' function invoked the conception of how the functions of cells' are determined by protein synthesis. Another example is student 5's conception about gene as "Gene consists of codes and these codes determine characteristics of humans". Her conception was also plausible to her, since it invoked the role of the codes in genes in determining characteristics.

Real mechanism

This status element is related with invoking the casual mechanism of an event. Thorley (1990) mentioned its importance as "potentially powerful aspect of 'reality' dimension, which was left unanalyzed by the authors of the CCM [conceptual change model]" (p. 175). Four of the six interviewees' conceptions indicated high plausibility status. For instance, student 1 solved the pedigree problem related with attached and free earlobe inheritance as shown in Figure 5.15. He provided a plausible explanation for his answer in his interview.

> Researcher: The mother has homozygous attached earlobes, Tuğçe has heterozygous free earlobes, and Deniz has homozygous attached earlobes. Would it be possible for the father to have homozygous

earlobes?

Student 1: Tuğçe has heterozygous free earlobes therefore Aa. Deniz has homozygous attached earlobes. Would it be possible for the father to have homozygous earlobes? No, I don't think so, because here is a dominant chromosome. If both parents had recessive things, Tuğçe should not have a dominant thing.

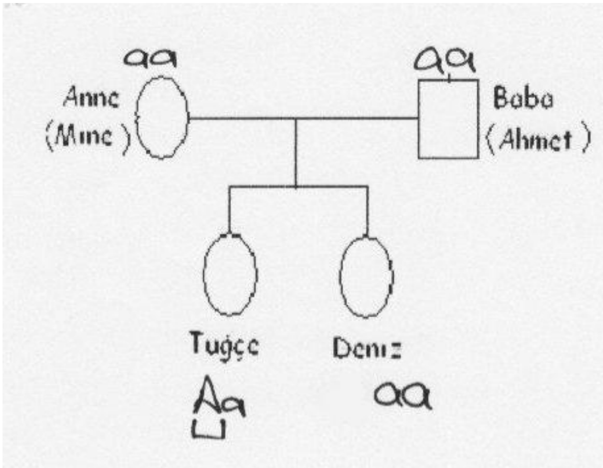


Figure 5.15 Student 1's post instructional interview problem sheet.

Student 4 also solved the pedigree problem as shown in Figure 5.16 and provided a plausible explanation for her answer.

Researcher: The mother has homozygous attached earlobes, Tuğçe has heterozygous free earlobes, and Deniz has homozygous attached earlobes. Would it be possible for the father to have homozygous earlobes?

Student 4: The mother should have homozygous earlobes in order to have attached earlobes, it is mentioned in here. If I symbolize it with letter y, there should be two small y's. Deniz has homozygous attached earlobes and Tuğçe has heterozygous free earlobes. First of all, if Tuğçe has heterozygous free earlobes, the father should have a gene for free earlobes. If Deniz has homozygous attached earlobes, she should get small y's from both parents. Therefore, the father could not have homozygous earlobes. He should have heterozygous free earlobes.

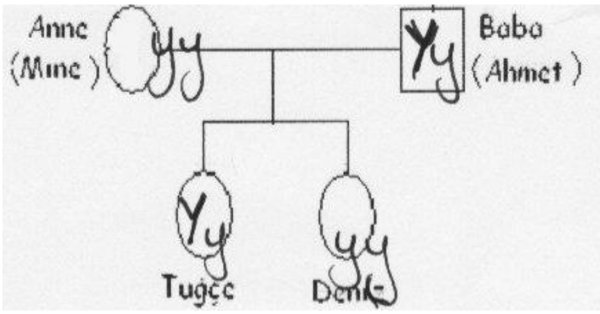


Figure 5.16 Student 4's post instructional interview problem sheet.

Results of the analysis of conceptual status for plausibility were presented in Table 5.28.

Table 5.28 Analysis of conceptual status: Plausibility

Status Elements	Plausibility Case Student Conceptions					
	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Past experience	+	+			+	
Metaphysics	+	+				+
P Analogy	+	+	+	+	+	+
Real Mechanism	+		+	+	+	

5.2.2.3 Fruitfulness

It is suggested in Tsui and Treagust (2007) that for a conception to become fruitful, it should be intelligible and plausible. Two status elements of fruitfulness, power and promise, were used for the analysis of interviews in this study.

Power

Power is related with the wide applicability of the conception (Thorley, 1990). Four students included this status element in their interview discourse. Student 4 expressed her ideas as "It [genetics] helped me understand why my hair is brown color and for example; a child can have blonde hair although his parents have brown hair. It explains these things". Student 5 also mentioned in her post instructional interview that "I can now understand the inheritance of eye color, hair color, and hair type of humans".

Promise

This status element is related with looking forward to what the new conception might do (Thorley, 1990). Two students included this status element in their interview discourse. Student 1 mentioned that "I had always considered being a medical doctor, but now becoming a genetic engineer attracts my attention. After learning the genetics concepts, this idea became clearer". Student 5 mentioned that "I definitely want to learn more about genetics, analyzing humans' genetic structure really attracts my attention".

Results of the analysis of conceptual status for fruitfulness were presented in Table 5.29.

Table 5.29 Analysis of conceptual status: Fruitfulness

Status Elements	Fruitfulness of Student Conceptions					
	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Power	+		+	+	+	
Promise	+				+	

The results of the status analysis of the six interviewees' conceptions of basic concepts of genetics indicated that four students had intelligible-plausible-fruitful conceptions after instruction. The other two students', student 2 and student 6, conceptions were intelligible-plausible.

5.2.3 Social / Affective Perspective

This part focuses on the influences of interest and classroom context on conceptual change.

All of the six students mentioned that they enjoyed studying genetics and only student 3 mentioned about the point that she did not like during the course. Followings are the students' comments about the reasons why they interested in this topic:

> Student 1: With the activities, the lessons were very enjoyable. I sometimes got board while studying previous units, because, we were studying lots of things and we were always writing questions. However, while studying genetics unit we did not write much and we learnt the concepts by hands on activities and visualize them, I liked that. It is hard to understand from written materials. The activities made it easier to understand the concepts because you work with the materials. Also, the concept was related with one's own structure which was much more interesting than that of physics concepts.

> Student 2: I liked studying genetics units since we made several activities which were different from other lessons. The topic was interesting. I was always wondering about the probabilities like having brown eyes and stuff like that. And the activities with colored pencils and beans made the concept attractive since we made them ourselves.

> Student 3: The point that I did not like about the unit is probability problems. I sometimes get confused about them. However, there were enjoyable points like learning one's own inheritance pattern. The text [conceptual change text] also helped me understand the concept, especially the misconceptions. I started to think more deeply about the concept.
>
> Student 4: I liked the genetics unit because you learn about your own characteristics. The text helped me understand the concept easily because there were many examples related with the topic. If we had not used the text, we would only write down the concepts and pass them. I believe that it made easier for the other people to learn the topic.
>
> Student 5: I have always interested in human structure. Therefore, I liked this unit.
>
> Student 6: I liked this unit because it was understandable. Also, it was related with humans, like DNA and the things happening inside our body.

Student 1 and student 2 who received HPD-LC instruction mentioned about the activities and their role in making the lesson more enjoyable and understandable. They also mentioned that they enjoyed working in groups during the activities. Student 2 stated that "We gave names to our groups and working in groups enables us to share our knowledge with our friends. It was fun.". In addition, Student 3 and student 4 who received CCT instruction mentioned the role of conceptual change text in making the concept clearer.

One important point is, all the students mentioned that they found the unit interesting because it was related with human characteristics. The relation of personal interest as a motivational factor and conceptual change was mentioned by Pintrich et al. (1993).

Interview analysis by considering ontological, epistemological, and social/affective perspectives of conceptual change contributed to deeper examination of students' understanding of various genetics concepts. By using an ontological perspective, changes in the views of students about related genetics concepts were determined. The initial gene, DNA, and chromosome conceptions of the students belonged to matter category (Chi et al., 1994). However, three students could comprehend the process nature of gene and DNA after the instruction. From an epistemological perspective, it can be concluded that conceptual change had taken place in four of the students' minds; student 1, student 3, student 4, and student 5, since their related gene conceptions were fruitful. However, conceptual change had not taken place in two of the students' minds; student 2 and student 6, since their related gene conceptions were only plausible but not fruitful. From social/affective perspective, all the interviewees expressed that they were interested in studying the unit. Specifically, student 1 and student 2 mentioned the role of the activities and working in groups in making the lesson more enjoyable and understandable. Student 3 and student 4 stated the role of CCT in making the lesson clearer.

5.3 Conclusions

The results of the current study revealed that there was a statistically significant interaction effect between time and treatment. Students who received HPD-LC instruction and CCT instruction understood the genetics concepts and retained their knowledge significantly better than the students in the control group.

The results also underlined that HPD-LC students had higher levels of use of elaboration learning strategies compared with CCT students. Therefore, it appeared that, HPD-LC students focus on extracting meaning, summarizing, or paraphrasing more than CCT students.

Interview analysis by considering ontological, epistemological, and social/affective perspectives of conceptual change indicated while some students underwent conceptual change concerning the genetics concepts, the others could not.

CHAPTER VI

DISCUSSION

This chapter includes discussion, validity threats of the study, implications of the study, and recommendations for further research.

6.1 Discussion

This study was conducted in order to reveal the effects of prediction/discussion-based learning cycle instruction (HPD-LC), conceptual change text instruction (CCT), and traditional instruction (TI) on eight grade Turkish students' understanding of basic concepts of genetics, perceived motivation (i.e. intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety), and perceived learning strategies (i.e. rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation).

Before the treatment, the Genetics Concept Test and the Motivated Strategies for Learning Questionnaire were administered to students in all the groups in order to determine students' prior understanding of genetics and to compare their motivation and use of learning strategy, respectively. Additionally, selected students were interviewed before the treatment to obtain relevant data for the analysis of conceptual change by using a multidimensional interpretive framework. MANOVA results revealed that there were no preexisting differences among the groups with respect to students' motivation and learning strategies. During the treatment, students in the first experimental group instructed with HPD-LC, students in the second experimental group instructed with CCT, and students in the control group received traditional instruction while learning the genetics concepts. After the treatment, GCT and MSLQ were re-administered to all the groups to determine the effects of above mentioned instructional strategies on students' understanding and their motivation and learning strategies, respectively. Post interviews were also conducted to detect whether conceptual change occurred in students' minds. To assess the continuous effects of the HPD-LCI, CCTI, and TI on students' understanding of genetics concepts, the GCT was re-administered one month later after the treatment as a delayed posttest.

In the light of the results of the current, it can be concluded that HPD-LC instruction promoted better understanding and retention of the genetics concepts than the traditional instruction. This result shows consistency with other research on learning cycle in the literature. The role of learning cycle instruction in facilitating better understanding and retention of scientific concepts than traditional approaches was mentioned by several research (e.g. Atay, 2006; Barman, Barman & Miller, 1996; Balci, Cakiroglu & Tekkaya, 2005; Marek, Cowan, and Cavallo, 1994; Schneider & Renner, 1980; Wilke & Granger, 1987). For example, Balci et al. compared the effects of 5E learning cycle instruction, conceptual change text instruction, and traditional instruction on students' understanding of photosynthesis and respiration concepts. Results of that study showed that 5E learning cycle instruction and conceptual change text instruction were more effective in improving students' understanding of related concepts than traditional instruction. The authors mentioned that students' reevaluation of their existing ideas during exploration creates disequilibrium which lead to accommodation to reach equilibrium. Therefore, students may correct their misconceptions more easily than traditionally instructed students. The effectiveness of learning cycle in eliminating students' misconceptions was also mentioned by Guzzetti, Synder, Glass, and Gamas (1993). In another study, Marek et al. (1994) investigated the role of the learning cycle instruction and expository instruction in students' understanding of diffusion concepts. The findings of that study indicated that learning cycle instruction was more effective in promoting students to make linkages between concepts therefore facilitating better understanding than the expository instruction. Hands-on experiences and classroom discussions are shown as the important parts of the learning cycles in creating better achievement (Allard & Barman, 1994).

Lavoie (1999) also investigated the effects of HPD-LC and traditional learning cycle on conceptual understanding. This was the only study that investigated the role of HPD-LC on students' conceptual understanding in the literature. Results showed that HPD-LC instruction was more effective than the traditional learning cycle in improving conceptual understanding. Similar to the present study it was shown that by integrating prediction/discussion phase, students tested their own predictions and this made them aware of the changes in their own conceptions and made the teacher aware of students' preconceptions. Additionally, the relation between Piaget's model of mental functioning and the learning cycle was emphasized by prior research (e.g. Abraham & Renner, 1986; Marek & Cavallo, 1997). For example, the exploration phase of learning cycle used in the present study promoted assimilation while students were experiencing the new concept. During assimilation, disequilibrium might occur since students used their existing conceptions while exploring the new concept. Moreover, Marek and Cavallo (1997) mentioned that assimilation and disequilibrium can be fostered by exploration phase. When the disequilibrium occurs, students needed to construct new mental structures to reach equilibrium during the second phase, term introduction, and this corresponds to accommodation. During the last phase of learning cycle, concept application, students extended their new concepts by applying them in other situations and this phase matches with process of organization. In this phase, students organized the relation between new mental structure and prior mental structures (Marek & Cavallo, 1997). Additionally, whole-class and small-group discussions made students aware of other students' conceptions and promote students verify whether their own conceptions were correct. The importance of student interaction during group works was also important in developing common knowledge. One another important point was the students' physically and mentally active participation in the learning process which facilitates deeper understanding and conceptual change.

Therefore, the significant difference of the students' genetics understanding who received HPD-LC instruction and traditional instruction could be attributed to several reasons. First, students' preexisting conceptions and misconceptions were revealed by the hypothetico-predictive problem sheets in HPD-LC group while they were forming their own hypothesis, which is an important step for further construction of the new knowledge. However, students and the teacher did not focus on students' preexisting conceptions and misconceptions in the traditional instruction group. Second, students who received HPD-LC were actively involved in the learning process and constructed their own knowledge while manipulating, observing, and recording the data and testing their own hypothesis during exploration phase, which led to meaningful learning. Third, as it was mentioned in the literature review part, in order for the students to understand genetics concepts coherently, they should form effective linkages among these concepts. Because of the interrelated phases of the HPD-LC, students could easily manage to relate the newly learned concepts with each other and with the existing ones. Therefore, these students were able to think about their existing knowledge and decided their appropriateness while understanding the new knowledge. However, students who received traditional instruction were passive listeners in the learning process and the teacher was responsible for making the connections among the concepts and presenting them to the students. Therefore, students in the control group could not form a coherent understanding of the genetics concepts. Forth, during the concept application phase, students who received HPD-LC instruction were able to extent their newly constructed information by applying them to new situations. Lastly, teacher guided whole-class and small-group discussions after the prediction/discussion phase and during the exploration phase, made students who received HPD-LC instruction be aware of other students' conceptions and promote students verify whether their own conceptions were correct.

Conceptual change text instruction also caused a better understanding and retention of the genetics concepts when compared with the traditional instruction. This result shows consistency with other research on conceptual change text in the literature (e.g. Alparslan et al. 2003; Chambers & Andre, 1997; Pınarbaşı, Canpolat, Bayrakçeken & Geban 2006; Sungur, Tekkaya & Geban, 2001; Wang & Andre, 1991; Yenilmez & Tekkaya, 2006) Different from the traditional instruction, the questions presented in conceptual change text aided to activate students existing conceptions and misconceptions. Pınarbaşı et al. (2006) mentioned that the difference between the effects of conceptual change text instruction and traditional instruction mainly arise from explicitly dealing with students' alternative conceptions in conceptual change text instruction. Conceptual change texts are designed according to Posner et al.'s (1982) four conditions; dissatisfaction, intelligibility, plausibility, and fruitfulness. The conceptual change text that was used in this study was also designed according to these four conditions. During this study, the students who received CCT instruction firstly dissatisfied with their existing conceptions by posing a question and then presenting the identified misconceptions. Once the students were dissatisfied with their existing conceptions scientific explanations and examples were presented. Yenilmez and Tekkaya (2006) mentioned that dissatisfaction of the students with their existing conceptions lead them to accept scientific explanations. Another important point in CCT instruction was mentioned by Balci et al. (2006) as the social interactions during discussions in CCT instruction. According to the authors, discussions help students gaining insights, intrinsic interest, and self-efficacy, and help them focusing on learning, understanding, and mastering the task. The role of the discussions on convincing the students that the new conception was more meaningful than their existing conceptions was also mentioned by Yenilmez and Tekkaya (2006). Therefore, students who received CCT instruction believed that the new conception was true, which is actually plausibility, by the teacher directed discussions. Finally, while they were answering the questions, they realized that the new concept help them solve other problems, which showed the fruitfulness of the new concept. Because of the above-mentioned reasons, students who received traditional instruction could not acquire genetics concepts and retain them as the students who received CCT instruction did.

When investigated in detail, it was seen that students in the both experimental groups were more successful in answering and retaining comprehension and application level of items, which indicates meaningful learning, than students in the control group. As understood from their low mean score in delayed post-test, control group students could not retain the concepts indicating rote learning. As it is discussed in the results part in detail percentages of the correct responses of some items differed among the groups. For instance, in item 8, which is an application level question, students were asked to predict the genotypes of pea plants having half wrinkled and half round progeny. The proportions of correct responses of students who received HPD-LCI, CCTI, and TI for this question in the pre-GCT were 40.7%, 13.6%, and 22.7%, respectively. However, after the treatments the proportions of correct responses of students who received HPD-LCI, CCTI, and TI were changed as 83.3%, 76.0%, and 61.5%, respectively. In the delayed post-GCT the proportions of these students receiving HPD-LCI, CCTI, and TI were became 86.7%, 96.0%, and 30.8%, respectively. Similarly, in item 15, a comprehension level question, students were asked to find the proportions of offspring having black hair to offspring having blond hair by using a given Punnett square. The proportions of correct responses of students who received HPD-LCI, CCTI, and TI for this question in the pre-GCT were 34.5%, 35.7%, and 34.6%, respectively. However, after the treatments the proportions of correct responses of students who received HPD-LCI, CCTI, and TI were changed as 53.3%, 60.0%, and 30.8%, respectively. In the delayed post-GCT the proportions of these students receiving HPD-LCI, CCTI, and TI were became 70.0%, 76.0%, and 34.6%, respectively. As these proportions indicate, students in both experimental groups were managed to improve their understanding in both post-GCT and delayed post-GCT, however, students in the control group could not.

Analysis of the qualitative data by using a multidimensional interpretive framework for conceptual change provided a holistic approach for examining conceptual change. The ontological perspective of conceptual change analysis, which was proposed by Chi et al. (1994), identified students' mental models about genetics concepts. It was revealed that majority of the students viewed related concepts belonging to "matter" category. After the treatments, most of the students still failed to comprehend "process" nature of the concepts. These results are consistent with the findings of previous research (Tsui & Treagust, 2004; Venville & Treagust, 1998). For instance, most of the students comprehend that genes determine characteristics, but could not explain how this process occurs. Saka et al. (2006) also found similar results that majority of the students in their study understand that genes determine characteristics, but they could not explain how genes are related with DNA and chromosome. One of the probable reasons for these results of the present study may be the teacher's emphasis on Mendel's genetics and crosses which lead most of the students comprehend gene, DNA and chromosome concepts as particles belonging to "matter" category, since the students enter the high school entrance examinations at the end of the year which the study was conducted and questions in that examination are related with Mendel' genetics and crosses. One another reason may be the teacher's less emphasis on the relationship among gene, DNA, chromosome, protein synthesis and phenotype of an organism. Venville and Treagust (1998) mentioned that students can solve genetics problems without understanding the process nature of genes, since, while solving these problems students do not need to understand the structure and function of genes.

In the current study, the epistemological perspective of conceptual change identified the status of students' genetics conceptions. Thorley's (1990) status analysis categories aid the categorization of students' conceptions as no status, intelligible, intelligible-plausible, or intelligible-plausible-fruitful. The results revealed that conceptual change had taken place in four students' minds since their conceptions of basic concepts of genetics were intelligible-plausible-fruitful after instruction. Two of these four students were instructed with CCT which was based on Posner et al.'s (1982) four conditions; dissatisfaction, intelligibility, plausibility, and fruitfulness. Similar results were obtained by Tsui and Treagust (2007) who used Thorley's (1990) status analysis categories to investigate the effects of multiple representations on conceptual change. The results of their study indicated that multiple representations improved students understanding of genetics. The authors also mentioned the importance of status in enabling researchers to identify students' conceptual change.

Another perspective of conceptual change analysis is the social/affective perspective, proposed by Pintrich et al. (1993), emphasizes the role of the motivational beliefs and classroom context on conceptual change. All the students that were interviewed in the present study mentioned that they found the unit interesting because it was related with human characteristics. The relation of personal interest as a motivational factor and conceptual change was mentioned by Pintrich et al. (1993). However, most of them mentioned that they were not interested in microscopic level of concepts. This may explain why they were good at understanding concepts like Mendelian genetics and solving probability problems, but had difficulty in relating basic concepts like gene, DNA, and chromosome. Students who received HPD-LC instruction mentioned about the activities and their role in making the lesson more enjoyable and understandable. They also mentioned that they enjoyed working in groups during the activities. The importance of peer group discussion in making the students aware of other students' opinions (Lavoie, 1999) and providing the social and motivational context for conceptual change (Pintrich et al., 1993) was mentioned in the literature.

Another focus of the present study was to explore the effects of HPD-LC, CCT, and traditional instruction on student' self-reported motivation (intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety) and self-reported use of learning strategies (rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation). Results of the present study revealed no statistically significant differences among the groups with respect to students' perceived motivation after the treatment. This finding can be attributed to the duration of treatment. The time period of the study may not be enough to improve students' motivation. Further research, however, is necessary to clarify this finding.

Regarding learning strategies, results indicated that the only difference among the groups was the use of elaboration strategies. Students who received HPD-LC instruction appeared to use elaboration strategies more than students who received CCT instruction. Elaboration is defined as "a kind of deeper processing strategy where students focus on extracting meaning, summarizing, or paraphrasing" (Zusho, Pintrich, Arbor & Coppola, 2003, p.1084). Pintrich et al. (1993) mentioned that the students should use elaboration strategies to encode and make the new concepts understandable and plausible. Active participation of students, who received HPD-LC instruction, while testing their own predictions during exploration phase, facilitates extracting meaning from the new knowledge and summarizing their findings. Therefore, these students frequently used the elaboration strategies. Weinstein (1982) showed that use of elaboration enhance learning. Also, Weinstein and Mayer (1986) mentioned the role of elaboration strategies in aiding students to connect new information with prior knowledge, therefore, storing new information into long-term memory. This may also contribute to the explanation of the higher performance of students who received HPD-LC instruction when compared with students who received CCT instruction and traditional instruction.

There are no existing studies in the literature that investigated the role of HPD-LC and CCT instructions on students' self-reported motivation and use of learning strategies. However, the effects of other instructional strategies, like problem-based learning, on self-regulated learning were investigated. For example, Sungur and Tekkaya (2006) investigated the effectiveness of problem-based learning and traditional instruction on students' self-regulated learning. They showed that problem-based learning was more effective than traditional instruction in positively influencing students' intrinsic goal orientation and task value. Additionally, results revealed that problem-based learning enhances students' use of elaboration strategies, critical thinking, metacognitive self-regulation, effort regulation, and peer learning. Lan (1998) suggested that in order to increase learning teachers should implement instruction on self-regulated learning strategies into their teaching as an instructional component. He also mentioned that traditional instruction is not efficient in helping students to develop learning strategies, since it does not assist learners to involve in self-regulation. The main idea that he claimed is that in order to help the students to become life long learners, the instructions should be designed according to helping them improve their learning skills and cognitive strategies for self-monitoring, self-reflection, self-motivation, and self-instruction. By this way they can initiate and maintain their learning process without relying on external sources for motivation, instruction, and evaluation.

To conclude, results of the present study revealed that HPD-LC and CCT are effective teaching strategies in aiding students acquire and retain genetics concepts better than traditional instruction and in facilitating conceptual change. Additionally, HPD-LC instruction is effective in enhancing the use of elaboration strategies. Therefore, it is suggested that using HPD-LC and CCT strategies should be preferred to using traditional instruction in order to help students to become more successful not only in their educational life but also for their whole life.

6.2 Validity Threats of the Study

6.2.1 Threats to internal validity

Some of the subject characteristics such as age, intelligence, socioeconomic status, prior knowledge, and gender were possible threats for this study. Since it was not possible to randomly assign each student to experimental and control groups due to the consideration of time and administrative issues, equalizing the groups in terms of some of these threats was not possible. However, by using an appropriate statistical technique, student' prior knowledge was not considered as a potential threat.

Loss of subjects and location were not considered as potential threats for this study since none of the subjects left the study during treatment and the implementations were made in similar conditions.

The instrumentation threat was handled by administration of the questionnaires only by the researcher and the researcher treated all the groups equally during the administrations.

Implementation could not be a threat, since the same teacher implemented the treatments.

Lastly, confidentiality could also not be a threat, since the names of the participants were not used in anywhere.

6.2.2 Threat for external validity

Purposive sampling was used while selecting the subjects of this study, since students' science teacher was experienced about learning cycle and conceptual change text instructions and teaching three intact classes. Eighty-one 8^{th} grade students who were attending an elementary school involved in this study. Generalizability can be a potential threat for this study. The findings of the study may be generalized to the schools having the similar conditions with the one in this study.

6.3 Implications of the Study

The findings of the present study had some implications for science teachers, researchers, and curriculum developers. Presents study revealed that HPD-LC instruction and CCT instruction were more effective in helping students acquire and retain genetics concepts and facilitating conceptual change better than traditional instruction. Moreover, it was shown that HPD-LC promotes the use of elaboration strategies. Therefore, it is suggested that instructional strategies that considers students' pre-existing knowledge, encourages students to be active participants in the learning process, and promotes their use of self-regulatory strategies should be integrated into curriculum. Additionally, students should given opportunities to test their own hypothesis and work collaboratively with peers in order to increase achievement and motivation.

Teachers should be trained about the integration of HPD-LC and CCT instructions in their lessons. Moreover, they should develop new lesson plans according to implementation of these teaching strategies for not only increasing students' achievement but also for their motivation and learning strategies. These lesson plans should include not only the genetics concept but also other science concepts. School administrators should inform the teachers about the usage and importance of HPD-LC and CCT instructions. Curriculum developers should also consider these two teaching strategies in order to increase students' achievement in science learning. Moreover, researchers should consider using a multidimensional interpretive framework while analyzing conceptual change in order to obtain a whole picture.

6.4 Recommendations for Further Research

1. The effects of HPD-LC and CCT instructions on students' acquisition and retention on science topics other than genetics concepts can be investigated.

2. The effects of HPD-LC and CCT instructions on students' motivation and use of learning strategies in other science concepts can be investigated.

3. The effects of HPD-LC and CCT instructions on different variables like reasoning ability and learning approach can be investigated.

4. The effects of HPD-LC and CCT instructions on different grade levels of students can be investigated.

5. The duration of the study can be extended to whole semester.

6. The effects of other instructional methods on conceptual change can be investigated by using a multidimensional interpretive framework.

7. This study can be replicated with larger sample size and different types of schools.

8. The interviews could be held with higher number of students.

9. The results of the concept test can be used for analyzing conceptual change from ontological and epistemological perspectives.

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APPENDICES

APPENDIX A

DEFINITION OF IMPORTANT TERMS

In order to make the reader familiar with some of the important terms used in this thesis, following definitions were provided.

Prediction/discussion-based learning cycle instruction

It is an activity-oriented teaching strategy which includes a prediction/discussion phase added at the beginning of three-phase Karplus learning cycle involving exploration, term introduction, and concept application phases (Lavoie, 1999). In prediction/discussion phase, students make predictions about the related problem and form hypothesis followed by whole-class and small-group discussions. In the exploration phase, students explore and test their own predictions. In the term introduction phase, the teacher explains related terms. In the concept application phase students extend the new concept by applying it to new situations.

Conceptual change text instruction

It is a teaching strategy that aims to activate students' misconceptions by posing questions and presenting common misconceptions. Once students' misconceptions are activated, disequilibrium between students' existing conceptions and the scientific conception is created. Afterwards, scientific explanations that are supported by examples are provided.

Traditional instruction

It is a teacher-centered instructional strategy in which the students are passive listeners during the learning process. New information is introduced and transferred to the students by the teacher, textbooks, or other media.

Self-regulation

Self-regulation is “an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment” (Pintrich, 2000, p. 453).

Goal orientation

Goal orientation is related with the purposes of individuals’ when approaching, engaging in, and responding to achievement situations (Zusho, Pintrich, Arbor & Coppola, 2003). Two primary achievement goals are; intrinsic goal orientation and extrinsic goal orientation. Intrinsic goal oriented students focus on learning, understanding, and mastering the task, whereas, extrinsic goal oriented students focus on obtaining a good grade or being more successful than others (Pintrich, Marx & Boyle, 1993).

Task value

Task value beliefs are students’ beliefs about the importance of a course (Zusho et al., 2003).

Control of learning beliefs

Student’s beliefs about the outcomes of a performance and attributing them with his/her own efforts, not to external factors like the teacher.

Self-efficacy

Self-efficacy refers students’ judgments of their capabilities to perform a task and their beliefs about their capacity to perform a course (Zusho et al., 2003).

Test anxiety

Test anxiety refers worrying or having negative feelings about doing well in a test.

Rehearsal

Rehearsal is “a surface level strategy, where students focus on memorizing and recall of facts” (Zusho et al., 2003, p.1084).

Elaboration

Elaboration is defined as “a kind of deeper processing strategy where students focus on extracting meaning, summarizing, or paraphrasing” (Zusho et al., 2003, p.1084).

Organization

Organization is another deeper processing strategy related with students' organization of learning materials by outlining important parts or by drawing graphs and tables (Zusho et al., 2003).

Critical Thinking

Critical thinking is related with students' making critical evaluations of ideas.

Metacognitive self-regulation

Metacognitive self-regulatory strategies can be defined as those strategies that help students planning, monitoring, and controlling their cognition (Zusho et al., 2003, p.1083).

APPENDIX B

GENETICS CONCEPT TEST

Adınız-Soyadınız:

Cinsiyetiniz: Kız☐ Erkek☐

Doğum tarihiniz:

Geçen seneki Fen bilgisi dersi karne notunuz:

Sevgili öğrenciler,

15 sorudan oluşan bu test sizlerin genetik konusu hakkındaki bilgilerinizi ölçmek amacı ile hazırlanmıştır. Bu testteki bütün sorular çoktan seçmelidir. Vereceğiniz bilgiler kesinlikle gizli tutulacaktır.

Katılımınız için teşekkürler.

Diba Yılmaz

ODTÜ – Eğitim Fakültesi

1. Canlı vücudunda genler nerede bulunur?

a) Üreme sisteminde
b) Hücrede
c) Çekirdekte
d) Kromozomlarda

2. Aşağıdaki alel ve gen terimlerine ait açıklamalardan hangisi doğrudur?

a) Alellerin yapısında genler bulunur.
b) Alel gen çeşididir.
c) Gen ile alel aynı şeydir.
d) Genlerin yapısında aleller bulunur.

3. Canlıların yapısını belirleyen her özellik için aşağıdakilerden hangisi söylenebilir?

a) Bir gen çifti tarafından kontrol edilir.
b) Bir gen tarafından kontrol edilir.
c) 23 gen tarafından kontrol edilir.
d) 46 gen tarafından kontrol edilir.

4. Bir ailenin arka arkaya üç çocuğu kız olmuştur. Dördüncü çocuğun erkek olma olasılığı nedir?

a) 1/2 b) 1/3 c) 1/4 d) 2/3

5. Bezelyelerde mor çiçek rengi, beyaz çiçek rengine baskındır. Heterozigot (melez; Bb) mor çiçek renkli bezelye bitkisi ile homozigot (arı döl; bb) beyaz çiçek renkli bezelye bitkisinin çaprazlanmasından oluşacak döldeki bitkilerin fenotiplerinin (dış görünüş) nasıl olması beklenir? (B: mor çiçek rengi, b: beyaz çiçek rengi)

a) %100' ü mor çiçek
b) %75' i mor çiçek, %25' i beyaz çiçek
c) %50' si mor çiçek, %50' si beyaz çiçek
d) %25' i mor çiçek, %75' i beyaz çiçek

6. Aynı canlıda bulunan deri, kas ve kemik hücre çeşitleri için aşağıda verilen açıklamalardan hangisi doğrudur?

a) Hepsi aynı genleri taşır.
b) Hepsi farklı genleri taşır.
c) Deri hücresi diğerlerinden farklı genleri taşır.
d) Deri ve kemik hücreleri aynı genetik yapıya, kas hücresi ise bunlardan farklı bir genetik yapıya sahiptir.

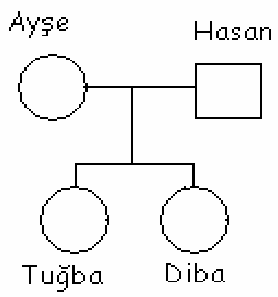
7. Genotipleri; 1. Aa 2. AA 3. aa
olan bireylerden fenotipleri aynı olanlar, aşağıdakiler-den hangisinde verilmiştir?

a) 1, 2 ve 3 b) 2 ve 3 c) 1 ve 3 d) 1 ve 2

8. Bezelyelerde yuvarlak tohum şekli buruşuk tohum şekline baskındır. Hangi genotipteki bireyler çaprazlanırsa oluşan bezelyelerin yarısı yuvarlak tohumlu, yarısı ise buruşuk tohumlu olur? (H: yuvarlak tohum, h: buruşuk tohum).

a) HH x hh b) Hh x hh c) Hh x Hh d) hh x hh

9. Aşağıda verilen soyağacında gösterildiği gibi Ayşe ile Hasan'ın, Tuğba ve Diba adında iki kızları vardır. Ayşe mavi gözlü, Diba ise siyah gözlüdür. Verilen bu bilgilere göre aşağıdakilerden hangisi **kesinlikle yanlıştır**? (Siyah göz rengi, mavi göz rengine baskındır.)



a) Ayşe homozigot mavi gözlüdür.
b) Hasan siyah gözlüdür.
c) Tuğba mavi gözlü olabilir.
d) Diba homozigot siyah gözlüdür

10. Mendel'in çaprazlamalarından elde edilen sonuçlar dikkate alındığında aşağıdakilerden hangisi **söylenemez**?

a) Her karakter bir gen çifti tarafından kontrol edilmiştir.
b) Gametler oluşurken aleller birbirinden ayrılır.
c) Gametler alellerin her ikisini de taşır.
d) Gametlerin birleşmesi rasgeledir.

11.

♂ BABA \ ♀ ANNE	?	?
?	Ee	ee
?	Ee	ee

Yukarıda verilen Punnett karesine göre anne ve babanın genotipleri aşağıdakilerden hangisi olabilir?

a) Ee x ee   b) EE x EE   c) Ee x Ee   d) EE x ee

12. Melez sarı tohumlu bir bezelyeyi, kendi genotipindeki bir bezelyeyle çaprazladığımızda elde edilen 112 bireyin kaç tanesinin yeşil tohumlu olması beklenir? (Sarı renkli tohum, yeşil renkli tohuma baskındır).

a) 0   b) 28   c) 84   d) 112

Yönerge: 13., 14. ve 15. soruları aşağıda verilen Punnett karesine göre cevaplandırınız.

♂ \ ♀	B	b
B	BB	Bb
b	Bb	bb

İnsanda siyah saç rengi karakteri (B), sarı saç rengi karakterine (b) baskındır. Heterozigot (melez) siyah saçlı kadın (Bb) ve erkeğin (Bb) çaprazlanması sonucu oluşan döllerin genotipi yandaki Punnet karesinde verilmiştir.

13. Döllerin yüzde kaçı siyah saç rengi karakterine sahip olur?

a) %0   b) %25   c) %50   d) %75

14. Döllerin kaç tanesi saç rengi karakteri bakımından heterozigottur?

a) 1   b) 2   c) 3   d) 4

15. Siyah saç rengi karakterine sahip olan döllerin, sarı saç rengi karakterine sahip olan döllere oranı nedir?

a) 1/1   b) 1/3   c) 3/1   d) 4/1

APPENDIX C

TABLE OF SPECIFICATION

Subject content	**Knowledge**	**Comprehension**	**Application**	**Analysis**	**Synthesis**	**Evaluation**	**Total**
Basic terminology	3 (20.0%)	4 (26.7%)					7 (46.7%)
Mendelian genetics	1 (6.7%)						1 (6.7%)
Inheritance	1 (6.7%)		1 (6.7%)				2 (13.3%)
Genetic crosses		2 (13.3%)	3 (20.0%)				5 (33.3%)
Total	5 (33.3%)	6 (40.0%)	4 (26.7%)				15 (100%)

APPENDIX D

MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE

Adı-Soyadı:
Cinsiyet: Kız ☐ Erkek ☐
Sınıf:

Bu anket 62 maddeden oluşmaktadır. Bu ankette fen bilgisi dersine karşı tutumunuzu, motivasyonunuzu ve fen bilgisi dersinde kullandığınız öğrenme stratejilerini belirlemeye yönelik ifadeler yer almaktadır. Cevap verirken aşağıda verilen ölçeği göz önüne alınız. **Eğer ifadenin sizi tam olarak yansıttığını düşünüyorsanız, 7' yi yuvarlak içine alınız. Eğer ifadenin sizi hiç yansıtmadığını düşünüyorsanız, 1' i yuvarlak içine alınız. Bu iki durum dışında ise 1 ve 7 arasında sizi en iyi tanımladığını düşündüğünüz numarayı yuvarlak içine alınız.** Unutmayın doğru ya da yanlış cevap yoktur. Yapmanız gereken sizi en iyi tanımlayacak numarayı yuvarlak içine almanızdır.

1 --- 2 --- 3 --- 4 --- 5 --- 6 -- 7

beni hiç yansıtmıyor — beni tam olarak yansıtıyor

	beni hiç yansıtmıyor						beni tam olarak yansıtıyor
1. Fen bilgisi dersinde yeni bilgiler öğrenebilmek için, büyük bir çaba gerektiren sınıf çalışmalarını tercih ederim.	1	2	3	4	5	6	7
2. Eğer uygun şekilde çalışırsam, fen bilgisi dersindeki konuları öğrenebilirim.	1	2	3	4	5	6	7
3. Fen bilgisi sınavları sırasında, diğer arkadaşlarıma göre soruları ne kadar iyi yanıtlayıp yanıtlayamadığımı düşünürüm.	1	2	3	4	5	6	7
4. Fen bilgisi dersinde öğrendiklerimi başka derslerde de kullanabileceğimi düşünüyorum.	1	2	3	4	5	6	7
5. Fen bilgisi dersinden çok iyi bir not alacağımı düşünüyorum.	1	2	3	4	5	6	7
6. Fen bilgisi dersi ile ilgili okumalarda yer alan en zor konuyu bile anlayabileceğimden eminim.	1	2	3	4	5	6	7
7. Benim için şu an fen bilgisi dersi ile ilgili en tatmin edici şey iyi bir not getirmektir.	1	2	3	4	5	6	7
8. Fen bilgisi sınavları sırasında bir soru üzerinde uğraşırken, aklım sınavın diğer kısımlarında yer alan cevaplayamadığım sorularda olur.	1	2	3	4	5	6	7
9. Fen bilgisi dersindeki konuları **öğrenemezsem** bu benim hatamdır.	1	2	3	4	5	6	7
10.Fen bilgisi dersindeki konuları öğrenmek benim için önemlidir.	1	2	3	4	5	6	7
11. Genel not ortalamamı yükseltmek şu an benim için en önemli şeydir, bu nedenle fen bilgisi dersindeki temel amacım iyi bir not getirmektir.	1	2	3	4	5	6	7
12. Fen bilgisi dersinde öğretilen temel kavramları öğrenebileceğimden eminim.	1	2	3	4	5	6	7
13. Eğer başarabilirsem, fen bilgisi dersinde sınıftaki pek çok öğrenciden daha iyi bir not getirmek isterim.	1	2	3	4	5	6	7
14. Fen bilgisi sınavları sırasında bu dersten başarısız olmanın sonuçlarını aklımdan geçiririm.	1	2	3	4	5	6	7

	beni hiç yansıtmıyor						beni tam olarak yansıtıyor
15. Fen bilgisi dersinde, öğretmenin anlattığı en karmaşık konuyu anlayabileceğimden eminim.	1	2	3	4	5	6	7
16. Fen bilgisi derslerinde öğrenmesi zor olsa bile, bende merak uyandıran sınıf çalışmalarını tercih ederim.	1	2	3	4	5	6	7
17. Fen bilgisi dersinin kapsamında yer alan konular çok ilgimi çekiyor.	1	2	3	4	5	6	7
18. Yeterince sıkı çalışırsam fen bilgisi dersinde başarılı olurum.	1	2	3	4	5	6	7
19. Fen bilgisi sınavlarında kendimi mutsuz ve huzursuz hissederim.	1	2	3	4	5	6	7
20. Fen bilgisi dersinde verilen sınav ve ödevleri en iyi şekilde yapabileceğimden eminim.	1	2	3	4	5	6	7
21. Fen bilgisi dersinde çok başarılı olacağımı umuyorum.	1	2	3	4	5	6	7
22. Fen bilgisi dersinde beni en çok tatmin eden şey, konuları mümkün olduğunca iyi öğrenmeye çalışmaktır.	1	2	3	4	5	6	7
23. Fen bilgisi dersinde öğrendiklerimin benim için faydalı olduğunu düşünüyorum.	1	2	3	4	5	6	7
24. Fen bilgisi dersinde, iyi bir not getireceğimden emin **olmasam** bile öğrenmeme olanak sağlayacak ödevleri seçerim.	1	2	3	4	5	6	7
25. Fen bilgisi dersinde bir konuyu **anlayamazsam** bu yeterince sıkı çalışmadığım içindir.	1	2	3	4	5	6	7
26. Fen bilgisi dersindeki konulardan hoşlanıyorum.	1	2	3	4	5	6	7
27. Fen bilgisi dersindeki konuları anlamak benim için önemlidir.	1	2	3	4	5	6	7
28. Fen bilgisi sınavlarında kalbimin hızla attığını hissederim.	1	2	3	4	5	6	7
29. Fen bilgisi dersinde öğretilen becerileri iyice öğrenebileceğimden eminim.	1	2	3	4	5	6	7
30. Fen bilgisi dersinde başarılı olmak istiyorum çünkü yeteneğimi aileme, arkadaşlarıma göstermek benim için önemlidir.	1	2	3	4	5	6	7

	beni hiç yansıtmıyor						beni tam olarak yansıtıyor
31. Dersin zorluğu, öğretmen ve benim becerilerim göz önüne alındığında, fen bilgisi dersinde başarılı olacağımı düşünüyorum.	1	2	3	4	5	6	7
32. Fen bilgisi dersi ile ilgili bir şeyler okurken, düşüncelerimi organize etmek için konuların ana başlıklarını çıkarırım.	1	2	3	4	5	6	7
33. Fen bilgisi dersi sırasında başka şeyler düşündüğüm için önemli kısımları sıklıkla kaçırırım.	1	2	3	4	5	6	7
34. Fen bilgisi dersi ile ilgili bir şeyler okurken, okuduklarıma odaklanabilmek için sorular oluştururum.	1	2	3	4	5	6	7
35. Fen bilgisi dersiyle ilgili duyduklarımı ya da okuduklarımı ne kadar gerçekçi olduklarına karar vermek için sıklıkla sorgularım.	1	2	3	4	5	6	7
36. Fen bilgisi dersine çalışırken, önemli bilgileri içimden defalarca tekrar ederim.	1	2	3	4	5	6	7
37. Fen bilgisi dersi ile ilgili bir şeyler okurken bir konuda kafam karışırsa, başa döner ve anlamak için çaba gösteririm.	1	2	3	4	5	6	7
38. Fen bilgisi dersine çalışırken, daha önce okuduklarımı ve aldığım notları gözden geçirir ve en önemli noktaları belirlemeye çalışırım.	1	2	3	4	5	6	7
39.Eğer fen bilgisi dersi ile ilgili okumam gereken konuları anlamakta zorlanıyorsam, okuma stratejimi değiştiririm.	1	2	3	4	5	6	7
40. Fen bilgisi dersine çalışırken, dersle ilgili okumaları ve ders sırasında aldığım notları defalarca okurum.	1	2	3	4	5	6	7
41. Ders sırasında veya ders için okuduğum bir kaynakta bir teori, yorum ya da sonuç ifade edilmiş ise, bunları destekleyen bir bulgunun var olup olmadığını sorgulamaya çalışırım.	1	2	3	4	5	6	7
42. Dersle ilgili konuları organize etmek için basit grafik, şema ya da tablolar hazırlarım.	1	2	3	4	5	6	7
43. Fen bilgisi dersinde işlenen konuları bir başlangıç noktası olarak görür ve ilgili konular üzerinde kendi fikirlerimi oluşturmaya çalışırım.	1	2	3	4	5	6	7

	beni hiç yansıtmıyor						beni tam olarak yansıtıyor
44. Fen bilgisi dersine çalışırken, dersten, okuduklarımdan, sınıf içi tartışmalardan ve diğer kaynaklardan edindiğim bilgileri bir araya getiririm.	1	2	3	4	5	6	7
45. Yeni bir konuyu detaylı bir şekilde çalışmaya başlamadan önce çoğu kez konunun nasıl organize edildiğini anlamak için ilk olarak konuyu hızlıca gözden geçiririm.	1	2	3	4	5	6	7
46. Fen bilgisi dersinde işlenen konuları anladığımdan emin olabilmek için kendi kendime sorular sorarım.	1	2	3	4	5	6	7
47. Çalışma tarzımı, dersin gereklilikleri ve öğretmenin öğretme stiline uygun olacak tarzda değiştirmeye çalışırım.	1	2	3	4	5	6	7
48. Genelde derse gelmeden önce konuyla ilgili bir şeyler okurum fakat okuduklarımı çoğunlukla anlamam.	1	2	3	4	5	6	7
49. Fen bilgisi dersindeki önemli kavramları hatırlamak için anahtar kelimeleri ezberlerim.	1	2	3	4	5	6	7
50. Fen bilgisi dersine çalışırken, konuları sadece okuyup geçmek yerine ne öğrenmem gerektiği konusunda düşünmeye çalışırım.	1	2	3	4	5	6	7
51. Mümkün olduğunca fen bilgisi dersinde öğrendiklerimle diğer derslerde öğrendiklerim arasında bağlantı kurmaya çalışırım.	1	2	3	4	5	6	7
52. Fen bilgisi dersine çalışırken notlarımı gözden geçirir ve önemli kavramların bir listesini çıkarırım.	1	2	3	4	5	6	7
53. Fen bilgisi dersi için bir şeyler okurken, o anda okuduklarımla daha önceki bilgilerim arasında bağlantı kurmaya çalışırım.	1	2	3	4	5	6	7
54. Fen bilgisi dersinde öğrendiklerimle ilgili ortaya çıkan fikirlerimi sürekli olarak gözden geçiremeye çalışırım.	1	2	3	4	5	6	7
55. Fen bilgisi dersine çalışırken, dersle ilgili okuduklarımı ve derste aldığım notları inceleyerek önemli noktaların özetini çıkarırım.	1	2	3	4	5	6	7

	beni hiç yansıtmıyor						beni tam olarak yansıtıyor
56. Fen bilgisi dersiyle ilgili konuları, ders sırasında öğrendiklerim ve okuduklarım arasında bağlantılar kurarak anlamaya çalışırım.	1	2	3	4	5	6	7
57. Fen bilgisi dersindeki konularla ilgili bir iddia ya da varılan bir sonucu her okuduğumda veya duyduğumda olası alternatifler üzerinde düşünürüm.	1	2	3	4	5	6	7
58. Fen bilgisi dersinde önemli kavramların listesini çıkarır ve bu listeyi ezberlerim.	1	2	3	4	5	6	7
59. Fen bilgisi dersine çalışırken iyi anlamadığım kavramları belirlemeye çalışırım.	1	2	3	4	5	6	7
60. Fen bilgisi dersine çalışırken, çalışmalarımı yönlendirebilmek için kendime hedefler belirlerim.	1	2	3	4	5	6	7
61. Ders sırasında not alırken kafam karışırsa, notlarımı dersten sonra düzenlerim.	1	2	3	4	5	6	7
62. Fen bilgisi dersinde, okuduklarımdan edindiğim fikirleri sınıf içi tartışma gibi çeşitli faaliyetlerde kullanmaya çalışırım.	1	2	3	4	5	6	7

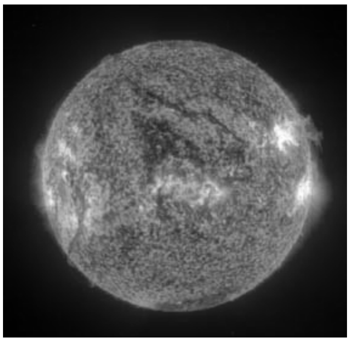
APPENDIX E

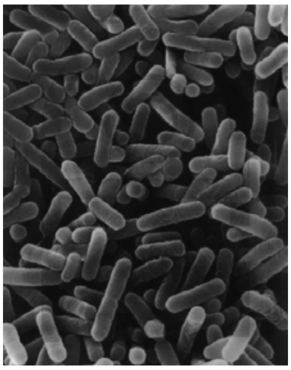
INTERVIEW QUESTIONS

1. Kromozom nedir? Nerede bulunur? Bu bilgiyi nereden öğrendin?
2. DNA nedir? Nerede bulunur? Bu bilgiyi nereden öğrendin?
3. Gen nedir? Nerede bulunur? Bu bilgiyi nereden öğrendin?
4. Alel nedir? Bu bilgiyi nereden öğrendin?
5. Bu kavramların arasında bir ilişki var mı? Bu bilgiyi nereden öğrendin?
6. Organizma, hücre, çekirdek, kromozom, DNA, gen kavramlarını büyükten küçüğe doğru sıralayabilir misin? Bu bilgiyi nereden öğrendin?
7. Şekillerini çizebilir misin?
8. Aşağıdaki şekillerin kromozomları, DNA'ları veya genleri var mıdır?







9. Aynı canlıda bulunan farklı çeşit vücut hücrelerinde (sinir, deri ve kas gibi) farklı genler mi bulunur?
10. Baskın (dominant) alel nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
11. Çekinik (resesif) alel nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
12. Homozigot (arı döl) nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
13. Heterozigot (melez) nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
14. Genotip nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
15. Fenotip nedir? Örnek verebilir misin? Bu bilgiyi nereden öğrendin?
16. Mendel kimdir? Ne yapmıştır?
17. Afrika'da doğan bir bebeği 3 aylıkken bir Türk aile evlat edinmiştir. Afrikalı bu bebek büyüyünce fiziksel özellikleri bakımından Afrikalı anne ve babasına mı yoksa onu evlat edinen Türk anne ve babasına mı benzer? Afrika yemeklerini mi yoksa Türk yemeklerini mi yemeği tercih eder?

18. Bir anne ve babanın iki çocukları vardır. Çocuklardan biri babaya çok benzerken diğeri annesine benzemektedir. Bu durum nasıl açıklanabilir?

19. Kahverengi göz rengine sahip olan anne ve babanın mavi gözlü çocukları olabilir mi?

20. Neden çoğu insan anne ve babasına benzer?

21. Genler anne ve babadan çocuklara nasıl geçer?

22. Genin yapısında ne vardır?

23. DNA'nın yapısında ne vardır?

24. Kromozomun yapısında ne vardır?

25. Genin görevi nedir? Ne yapar? Nasıl yapar?

26. DNA'nın görevi nedir?

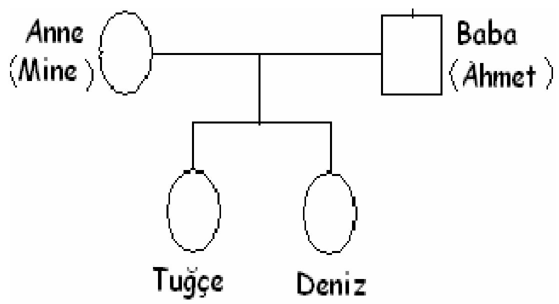
27. Kromozomun görevi nedir?

28. Genlerin arasında dolaşabilecek kadar boyun küçültülseydi ne görmeyi beklerdin? Sence gen neye benzer?

29. Genetik konusunu işledikten sonra, bu konuları anlamanı nasıl değerlendiriyorsun?

30. Genetik konusundan ve dersten hoşlandın mı? Neden?

31.



Mine homozigot yapışık kulak memeli, Tuğçe heterozigot ayrık kulak memeli, Deniz ise homozigot yapışık kulak memelidir. Buna göre Ahmet homozigot yapışık kulak memeli olabilir mi? (ayrık kulak memesi, yapışık kulak memesine baskındır)

32. Genetik konusunu yararlı buldun mu? Neden?

33. Gelecekte genetik konusuyla ilgili daha fazla bilgi öğrenmek ister misin?

APPENDIX F

GENETICS LESSON PLAN

DERS: Fen Bilgisi

KONU: Kalıtımla ilgili temel kavramlar ve Mendel yasaları

SEVİYE: 8. sınıf

DERSİN HEDEFLERİ:

HEDEF 1:

- Kalıtımın temellerini, kalıtım ile ilgili temel terimleri, kalıtımın ve canlılarda çeşitliliğin kalıtsal nedenlerini kavrayabilme.

DAVRANIŞLAR:

- Gen ve alel kavramlarını açıklar.
- Hücre, çekirdek, kromozom, DNA, gen ve alel kavramları arasındaki ilişkiyi açıklar.
- Baskın (dominant) alel ve çekinik (resesif) alel kavramlarını açıklar.
- Baskın (dominant) alel ve çekinik (resesif) alel kavramlarına örnekler verir.
- Homozigot (arı döl) ve heterozigot (melez=hibrit) kavramlarını açıklar.
- Homozigot (arı döl) ve heterozigot (melez=hibrit) kavramlarına örnekler verir.
- Genotip ve fenotip kavramlarına örnekler verir.
- Mendel ilkelerine, bir özelliğin kalıtımı ile ilgili örnekler verir.
- Bir kalıtsal özellikle ilgili çaprazlamalar yaparak problem çözer.
- Punnett karesini kullanarak çaprazlamayla ilgili problem çözer.
- İnsanda cinsiyeti belirleyen kalıtımı açıklar.

- Soyağacını kullanarak çaprazlamayla ilgili problem çözer.

ÖĞRENME EVRESİ I

KALITIMLA İLGİLİ TEMEL KAVRAMLAR

ARAÇ VE GEREÇLER:

- Plastik bardak
- Renkli çubuk
- Renkli kuru kalem
- Metal para

DERSİN İŞLENİŞİ:

<u>Tahmin yürütme</u>

1) Öğrencilere köpeklerle ilgili tahmin yürütecekleri "Etkinlik Kağıdı-1a" çalışma kağıtları dağıtılır. Bu çalışma kağıdında farklı cins köpek ailelerine ait resimler bulunmaktadır.
2) Öğrenciler bu çalışma kağıtlarını aldıktan sonra onlardan birinci soruyu cevaplamaları istenir. Bu soruda öğrenciler hangi köpeklerin aynı aileye ait olduklarını tahmin ederler ve aynı ailedeki köpeklerin birbirlerine benzedikleri sonucuna varırlar.
3) Öğrencilerden ikinci soruyu cevaplamaları istenir. Bu soruda öğrencilerden köpeklerin anne ve babalarına benzemelerinin nedenini tahmin etmeleri istenir. Bu soruyla öğrencilerin kalıtsal karakterlerin nesilden nesile aktarıldığı konusu hakkında bilgi sahibi olup olmadıkları ortaya çıkar.
4) Öğrenciler bireysel olarak soruları yanıtladıktan sonra bu sorular hakkında sınıf içi tartışma yapılır.

<u>Keşfetme</u>

1) Öğrenciler bu evrede kalıtsal karakterlerin nesilden nesile nasıl aktarıldıklarını keşfederler. Öğrencilere neden anne ve babamıza benzediğimiz sorulur.
2) Öğrencilerin bu sorunun cevabını keşfetmeleri için 5 öğrenciden oluşan gruplar oluşturulur. Her bir gruba "Etkinlik Kağıdı-1b" çalışma kağıtları dağıtılır.
3) Her bir gruba üzerinde "anneanne (Mine), dede (Mehmet), babaanne (Serpil), büyükbaba (Mustafa), anne (Nalan), baba (Ahmet), Ayşe, Hasan, Zeynep ve Burak" yazan plastik bardaklar dağıtılır. Üzerinde "anneanne (Mine), dede (Mehmet), babaanne (Serpil), büyükbaba (Mustafa)" yazan plastik bardakların içinde kalıtsal karakterleri temsil eden renkli çubuklar vardır.
4) Öğrencilerden grup halinde "Etkinlik Kağıdı -1b" çalışma kağıtlarındaki maddeleri tek tek okuyup yapmaları istenir.
5) Öğrencilere çubukları seçerken gözlerini kapatmalarını ve karıştırarak çekmeleri söylenir.

<u>Kavramı Tanıtma</u>

1) Öğrencilere gen ve alel kavramları açıklanır. Yaptıkları etkinlikteki çubukların neyi temsil ettikleri sorulur.
2) Kalıtımın tanımı yapılır. Hücre, DNA, gen, alel, organizma, kromozom, çekirdek kavramları arasındaki ilişki açıklanır.
3) Öğrencilere canlılarda gözlemlediğimiz özelliklerin genler tarafından belirlendiği söylenir. Öğrencilerin köpek resimlerinde de gözlemledikleri gibi aile bireyleri arasındaki benzerliklerin kalıtım sayesinde anneden ve babadan oğul döllere aktarıldığı söylenir. Saç rengi, göz rengi, kan grubu ya da sahip olduğumuz herhangi bir genetik hastalık gibi birçok özelliğimizin **genlerimiz** tarafından

belirlendiği söylenir.Sadece insanlarda değil eşeyli üreyen bütün canlılarda canlının görünüşünün genin **alel** adı verilen farklı şekilleriyle belirlendiği söylenir ve örnekler verilir.

4) Baskın (dominant) alel, çekinik (resesif) alel, homozigot (arı döl), heterozigot (melez=hibrit), genotip ve fenotip kavramları açıklanır ve bu kavramlarla ilgili örnekler verilir.

<u>Kavramı Uygulama</u>

1) Beş öğrenciden oluşan gruplar oluşturulur. Her gruba bir adet metal para ve "Etkinlik Kağıdı-1c" çalışma kağıtları verilir. Bu etkinlikte öğrenciler öğrenmiş oldukları baskın alel, çekinik alel, genotip ve fenotip gibi kavramları kullanacaklardır. Öğrenciler, anne ve babasının dört kalıtsal özelliği belli olan bir bebeğin genotip ve fenotipini tahmin etmeye çalışacaklardır.
2) Öğrencilere anne ve babanın her özellik için heterozigot oldukları söylenir.
3) Öğrencilerden anne ve babanın her özellik için genotip ve fenotiplerini yazmaları istenir.
4) Öğrencilerden metal paralar atılmadan önce bebeğin sahip olabileceği genotip ve fenotipleri tahmin etmeleri istenir.
5) Öğrencilerden etkinlik kağıdında bulunan her bir özellik için metal paraları atmaları ve anne ve babanın gametlerindeki alelleri belirlemeleri istenir. Öğrencilere metal paranın tura yüzünün baskın özelliği, yazı yüzünün ise çekinik özelliği temsil ettiği belirtilir.
6) Sonuçta her öğrenci bebeğin verilen dört özellik için sahip olacağı genotip ve fenotipleri belirleyip tabloya yazar.
7) Sınıf içi tartışma yapılarak öğrencilerin bulduğu sonuçlar tartışılır.

ÖĞRENME EVRESİ II

MENDEL İLKELERİ VE UYGULAMALARI

ARAÇ VE GEREÇLER:

- İki torba
- 50 kuru fasulye
- 50 barbunya fasulyesi

DERSİN İŞLENİŞİ:

Tahmin yürütme

1) Öğrencilere "Etkinlik Kağıdı-2a" çalışma kağıtları dağıtılır. Bu etkinlikte öğrenciler soyağacı verilen ailenin çocuğunun mavi gözlü olma olasılığını tahmin ederler.
2) Bu etkinlikte öğrenciler iki melez karakterli bireyden, çekinik karakterli bireyler olup olamayacağını sorgularlar.
3) Öğrenciler bireysel olarak soruyu yanıtladıktan sonra bu soru hakkında sınıf içi tartışma yapılır.

Keşfetme

1) Beş öğrenciden oluşan gruplar oluşturulur. Öğrencilere "Etkinlik Kağıdı-2b" çalışma kağıtları dağıtılır. Bu etkinlikte öğrenciler "Etkinlik Kağıdı-2a"da sorulan sorunun cevabını bulmaya çalışırlar.
2) Bu etkinlikte öğrencilere kuru fasulyelerin kahverengi göz rengini, barbunya fasulyelerinin ise mavi göz rengini temsil ettikleri söylenir.
3) Her gruba 25 barbunya fasulyesi, 25 kuru fasulye bulunan torbalar verilir. Öğrencilerden torbalara bakmamaları ve içindeki fasulye sayılarını değiştirmemeleri istenir.
4) Etkinliğin birinci bölümünde öğrenciler bir torbadan 1 tane fasulye çekerler ve rengini Tablo I'e not ederler. Daha sonra bu fasulye torbaya geri atılır ve bir tane daha çekilir. Bu fasulyenin de rengi not

edilir. Öğrencilerden 50 fasulye çekimi için tahminde bulunmaları istenir.

5) Öğrencilerin aktiviteyi yapmaları istenir. Her grup birinci bölümü tamamladıktan sonra tahtaya bulduğu sonuçları yazar.
6) Etkinliğin ikinci bölümünde her gruba ikişer tane torba verilir. Bu torbaların her ikisinin içinde de 25 kuru fasulye ve 25 barbunya fasulyesi bulunur. Öğrenciler her iki torbadan da aynı anda fasulye çekerler ve buldukları sonuçları Tablo II'ye not ederler. Daha sonra bu fasulyeler çekildikleri torbalara geri atılır ve birer tane daha çekilir.Gruplardan toplam 50 deneme sonunda olası sonuçları tahmin etmeleri istenir.
7) Öğrencilere aynı anda her iki torbadan da barbunya fasulyesi, her iki torbadan da kuru fasulye ya da bir torbadan barbunya fasulyesi diğer torbadan kuru fasulye çekebilecekleri söylenir.
8) Daha sonra her grup aktiviteyi yapar. Her grup ikinci bölümü tamamladıktan sonra tahtaya bulduğu sonuçları yazar.
9) Öğrencilerden buldukları bu sayısal değerleri kullanarak doğacak çocuğun mavi gözlü olma olasılığını hesaplamaları istenir.
10) Her grup çalışmasını bitirdiğinde tahminlerini ve buldukları sonuçları tartışırlar. Öğrencilerin buldukları sonuçlar sınıf içinde tartışılır.

Kavramı Tanıtma

1) Öğretmen eşliğinde sınıf olarak her ebeveynin oğul döllere sahip olduğu özellikleri belirleyen iki alelden sadece bir tanesini aktarabileceği tartışılır. Yapılan aktivitenin ilk bölümünde torbadaki barbunya fasulyelerinin ve kuru fasulyelerin bir bireyin (annenin ya da babanın) sahip olduğu iki aleli temsil ettikleri söylenir. Etkinliğin ilk bölümünde barbunya fasulyelerinin kuru fasulyeye beklenen oranını 1:1 olduğu, deneme ne kadar fazla olursa oranın o kadar doğru çıkacağı söylenir.

2) Etkinliğin ikinci bölümünde barbunya fasulyesi ve barbunya fasulyesi; kuru fasulye ve barbunya fasulyesi; ya da kuru fasulye ve kuru fasulye çekme olasılığının 1:2:1 olarak beklendiği söylenir.
3) Mendel'in bezelyelerle ilgili yaptığı çalışmalar ve kanunları örnekler verilerek açıklanır.
4) Çaprazlamayla ilgili problemlerin çözümünde Punnett karesinin nasıl kullanılacağı açıklanır.
5) İnsanda cinsiyetin belirlenmesini nasıl olduğu açıklanır.
6) Soyağacını kullanarak bir ailedeki bireyin genotipinin ve fenotipini nasıl tahmin edilebileceği açıklanır.

Kavramı Uygulama

1) Öğrencilere "Etkinlik Kağıdı - 2c" çalışma kağıdı dağıtılır. Bu etkinlikte öğrencilere bezelyelerde sarı tohum renginin yeşil tohum rengine baskın olduğu söylenir. Buna göre öğrencilerden heterozigot sarı renkli tohuma sahip iki bezelyenin çaprazlanması ile oluşacak bireylerin genotiplerinin dağılım oranını Punnett karesini kullanarak belirlemeleri istenir. Fenotiplerinin oranını bulmaları istenir.
2) Öğrenciler, çalışma kağıdının ikinci sorusunda verilen soyağacını kullanarak problemi çözerler.
3) Sonuçlar sınıf içinde tartışılır.

APPENDIX G

ACTIVITY SHEET – 1a

Adınız-Soyadınız:

1. Aşağıda farklı köpek ailelerine ait resimler bulunmaktadır. Sizce aşağıda kaç tane köpek ailesi vardır? Bu resimlerden hangi bireylerin aynı aileye ait olduklarını tahmin ediniz ve aile bireylerine ait harfleri yazınız.









Aile sayısı:

Aile no **Bireyler**

2. Hangi köpeğin hangi aileye ait olduğunu nasıl tahmin ettiğinizi açıklayınız. Sizce yavru köpeklerin anne ve babalarına benzemelerinin nedeni nedir, tahmin ediniz ve açıklayınız.

APPENDIX H

ACTIVITY SHEET – 1b

KONU: Kalıtım

Amaç: Kalıtsal karakterlerin nesilden nesile nasıl aktarıldığını kavrayabilme.

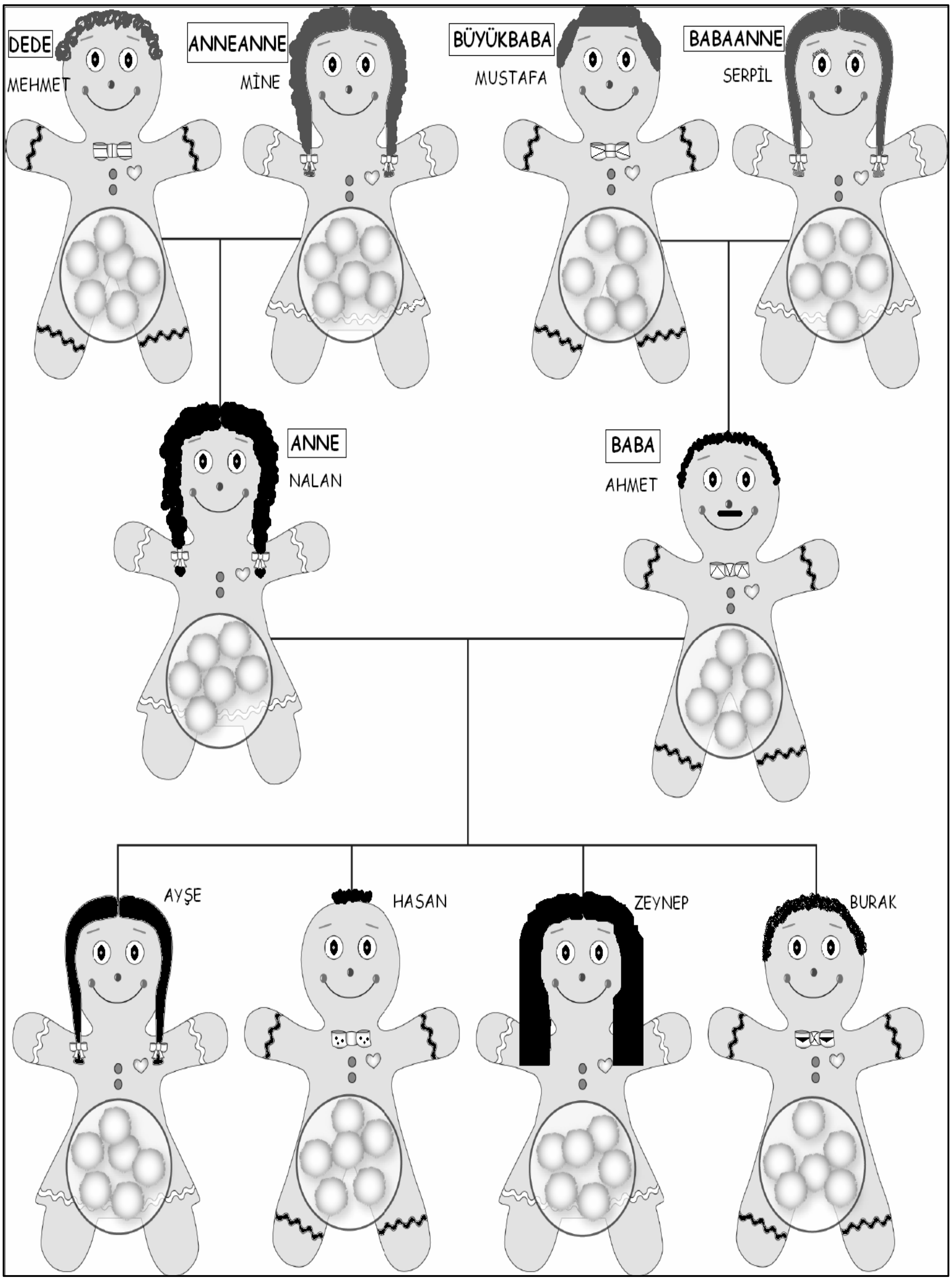
Soru: Neden anne ve babalarımıza benzeriz?

Araç-Gereçler:
10 adet plastik bardak
24 adet renkli çubuk
4 adet renkli kalem

1. Bu etkinlikte farklı kalıtsal karakterlerin nesilden nesile nasıl aktarıldığını inceleyeceksiniz. Grubunuza verilen renkli çubuklar, içinde bulundukları bardakların üzerinde yazan kişinin bazı kalıtsal karakterlerini temsil etmektedir.
2. Üzerinde aile fertlerinin resimleri bulunan kağıtlardaki anneanne (Mine), dede (Mehmet), babaanne (Serpil) ve büyükbabanın (Mustafa) kalıtsal karakterlerini, sizlere verilen bardaklardaki çubukların renkleriyle aynı olacak şekilde boyayın.
3. Gözlerinizi kapayın ve anneannenin (Mine) ve dedenin (Mehmet) bardağından 3'er tane çubuk çekerek annenin (Nalan) bardağının içine koyun. Bu çubuklar annenin, anneanne ve dededen aldığı kalıtsal karakterlerdir. Annenin kalıtsal karakterlerini göstermek için resmini boyayın.
4. Gözlerinizi kapayın ve babaannenin (Serpil) ve büyükbabanın (Mustafa) bardağından 3'er tane çubuk çekerek babanın (Ahmet) bardağının içine koyun. Bu çubuklar babanın babaanne ve büyükbabadan aldığı kalıtsal karakterlerdir. Babanın kalıtsal karakterlerini göstermek için resmini boyayın.
5. Anne (Nalan) ve baba (Ahmet)'in "Ayşe", "Hasan", "Zeynep" ve "Burak" adında 4 çocukları vardır. Ayşe'nin anne ve babasından alacağı kalıtsal karakterleri belirlemek için gözlerinizi kapatıp

anne ve babadan 3'er tane çubuk çekin. Ayşe'nin kalıtsal karakterlerini göstermek için resmini boyayın.

6. Anne ve babadan çekmiş olduğunuz 3'er çubuğu tekrar anne ve babanın bardaklarına koyunuz (eğer çubukların anneye mi yoksa babaya mı ait olduğunu unutursanız boyadığınız resimlerden yararlanabilirsiniz). Gözlerinizi kapayın ve Hasan'ın kalıtsal karakterlerini belirlemek için anne ve babadan 3'er tane çubuk çekin. Hasan'ın kalıtsal karakterlerini göstermek için resmini boyayın.
7. Anne ve babadan çekmiş olduğunuz 3'er çubuğu tekrar anne ve babanın bardaklarına koyunuz. 6. maddedeki işlemleri tekrarlayarak Zeynep ve Burak'ın kalıtsal özelliklerini belirleyin ve resimlerini boyayın.


DEDE
MEHMET
ANNEANNE
MİNE
BÜYÜKBABA
MUSTAFA
BABAANNE
SERPİL
ANNE
NALAN
BABA
AHMET
AYŞE
HASAN
ZEYNEP
BURAK

APPENDIX I

ACTIVITY SHEET – 1c

KONU: Kalıtım
Amaç: Kalıtsal karakterlerin nesilden nesile nasıl aktarıldığını kavrayabilme
Araç-Gereçler:
Madeni para

Yeni bir bebek doğdu ve sahip olduğu özellikleri anne ve babası belirliyor. Bebeğin anne ve babasının sahip oldukları özelliklerden dört tanesi aşağıda verilmiştir. Anne ve baba her özellik için heterozigottur (melez).

Özellikler:

Baskın	**Çekinik**
Siyah göz rengi (A)	Mavi göz rengi (a)
Kıvırcık saç (D)	Düz saç (d)
Siyah saç rengi (B)	Sarı saç rengi (b)
Ayrık kulak memesi (R)	Yapışık kulak memesi (r)

1) Annenin ve babanın her özellik için genotip ve fenotiplerini aşağıdaki tabloya yazınız.

	Göz rengi		Saç şekli		Saç rengi		Kulak memesi şekli	
	genotip	fenotip	genotip	fenotip	genotip	fenotip	genotip	fenotip
Anne								
Baba								

2) Bebeğin sahip olabileceği fenotip ve genotipleri tahmin ediniz ve yazınız.

3) Madeni paranızı anne ve babanın sahip olduğu her özellik için bir kere atarak anne ve babanın gametlerindeki alelleri belirleyin ve aşağıdaki tabloya yazın.

Not: Metal paranın tura yüzü baskın özelliği, yazı yüzü ise çekinik özelliği temsil etmektedir.

4) Anne ve babanın sahip oldukları alellere göre bebeğin genotip ve fenotipini belirleyin.

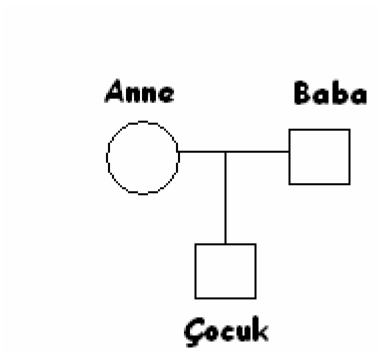
	Göz rengi	Saç şekli	Saç rengi	Kulak memesi şekli
Anneden gelen alel				
Babadan gelen alel				
Bebeğin genotipi				
Bebeğin fenotipi				

APPENDIX J

ACTIVITY SHEET – 2a

Adınız – Soyadınız:

İnsanda kahverengi göz rengi karakteri mavi göz rengi karakterine baskındır. Aşağıdaki soyağacında gösterilen anne ve baba heterozigot kahverengi gözlüdür. Buna göre doğacak çocuğun mavi gözlü olmasının olasılığını tahmin ediniz. Tahmininizi açıklayınız.



APPENDIX K

ACTIVITY SHEET – 2b

KONU: Kalıtım

Amaç: Kalıtsal karakterlerin nesilden nesile nasıl aktarıldığını kavrayabilme.

Soru: İnsanda kahverengi göz rengi karakteri mavi göz rengi karakterine baskındır. Heterozigot kahverengi gözlü anne ve babanın doğacak çocuğunun mavi gözlü olmasının olasılığını bulunuz.

Araç-Gereçler:
İki torba
50 kuru fasulye
50 barbunya fasulyesi

Açıklama: Kuru fasulyeler kahverengi göz rengini, barbunya fasulyeleri ise mavi göz rengini temsil etmektedir.

I. Bölüm

1. Torbadan 50 kere bir fasulye çekiniz, ancak her defasında çektiğiniz fasulyeyi torbaya geri atınız.
2. Her fasulyeyi çekişinizde I. tabloya hangi tür fasulye çektiğinizi işaretleyiniz.

II. Bölüm

1. 50 kere her iki torbadan da aynı anda birer fasulye çekiniz, ancak her defasında çektiğiniz fasulyeleri torbalarına geri atınız.
2. Her fasulye çekişinizde II. tabloya hangi tür fasulye çektiğinizi işaretleyiniz.

Değerlendirme:

1. I. tabloda toplam kuru fasulye sayısının toplam barbunya fasulye sayısına oranı nedir?

2. II. tabloda toplam kuru fasulye çekme sayısı, toplam barbunya fasulye çekme sayısı ve bir torbadan kuru fasulye diğerinden barbunya çekme sayısı nedir?
3. Bulduğunuz sayısal değerleri kullanarak heterozigot kahverengi gözlü anne ve babanın doğacak çocuğunun mavi gözlü olmasının olasılığını bulunuz.

Tablo I

Çekiliş no	Kuru fasulye	Barbunya fasulyesi	**Çekiliş no**	Kuru fasulye	Barbunya fasulyesi
1			**26**		
2			**27**		
3			**28**		
4			**29**		
5			**30**		
6			**31**		
7			**32**		
8			**33**		
9			**34**		
10			**35**		
11			**36**		
12			**37**		
13			**38**		
14			**39**		
15			**40**		
16			**41**		
17			**42**		
18			**43**		
19			**44**		
20			**45**		
21			**46**		
22			**47**		
23			**48**		
24			**49**		
25			**50**		

Tablo II

Çekiliş no	Kuru fasulye	Barbunya fasulyesi	Kuru fasulye ve Barbunya fasulyesi	**Çekiliş no**	Kuru fasulye	Barbunya fasulyesi	Kuru fasulye ve Barbunya fasulyesi
1				26			
2				27			
3				28			
4				29			
5				30			
6				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			

APPENDIX L

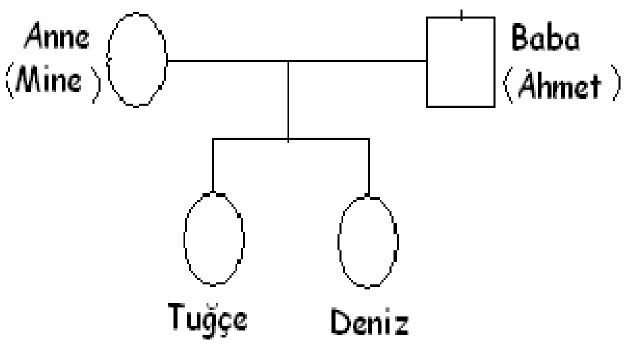
ACTIVITY SHEET – 2c

Adınız, soyadınız:

KONU: Kalıtım

1) Bezelyelerde sarı tohum rengi yeşil tohum rengine baskındır. Buna göre heterozigot sarı renkli tohuma sahip iki bezelyenin çaprazlanması ile oluşacak bireylerin genotiplerinin dağılım oranını Punnett karesini kullanarak belirleyiniz ve fenotiplerinin oranını bulunuz. (Sarı tohum rengi: A, yeşil tohum rengi: a).

2) Aşağıda verilen soyağacındaki bireylerden Mine homozigot düz saçlı, Tuğçe heterozigot kıvırcık saçlı, Deniz ise homozigot düz saçlıdır. Buna göre Ahmet'in sahip olabileceği genotip ve fenotipini bulunuz. (Kıvırcık saç: A, düz saç:a)



APPENDIX M

CONCEPTUAL CHANGE TEXT

MENDEL' İN KALITIMA KAZANDIRDIĞI BİLGİLER

Tarihsel Bilgi

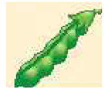
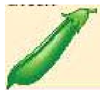
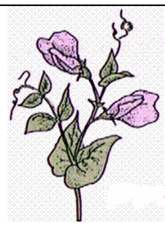
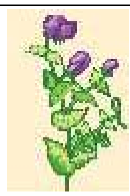
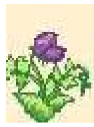
Avusturyalı bir bilim adamı ve papaz olan Gregor Mendel (1822-1884) genetik biliminin babası olarak kabul edilir. Mendel, çeşitli bezelye tohumlarını toplayarak onları manastır bahçesinde yetiştirir ve aralarındaki farkları inceler. Bu çalışmalarının sonucunda kalıtımın ana ilkelerini bulmuştur.

Peki Mendel çalışmalarında neden bezelyeleri kullanmıştır hiç düşündünüz mü?

- ✓ Bu bitkilerin yetiştirilmesi kolaydır
- ✓ Kısa sürede çok döl verirler
- ✓ Bir çok çeşidi vardır
- ✓ Bezelye bitkileri dışarıdan gelecek çiçek tozlarına kapalıdır

Mendel, çalışmalarında bir karakter bakımından farklılık gösteren bezelyeleri seçerek kullanmıştır. Mendel' in incelediği bezelyelerdeki 7 farklı karakter tablo 1' de gösterilmiştir.

Tablo 1- Bezelyelerde baskın ve çekinik karakterler

KARAKTERLER	Baskın karakter	Çekinik karakter
Tohum şekli	yuvarlak 	buruşuk 
Tohum kabuğunun rengi	sarı 	yeşil 
Meyve şekli	düzgün 	buruşuk 
Meyve rengi	yeşil 	sarı 
Çiçek rengi	pembe 	beyaz 
Çiçek durumu	yanda 	uçta 
Gövde uzunluğu	uzun 	kısa 

Peki bir bezelye bitkisinin gövdesinin uzun ya da kısa olmasını veya bir insanın göz renginin mavi ya da kahverengi olmasını ne kontrol eder hiç düşündünüz mü?

Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Hücrelerin içinde kromozomlar vardır ve kromozomlar göz rengini belirlemek için pigment taşırlar.

Gözler özel pigment taneciklerine sahiptirler ve bu pigment tanecikleri kan yoluyla dişi üreme hücresine taşınır.

Dişi ve erkek üreme hücreleri farklı materyallere sahiptirler ve anne ve babadan çocuğa farklı materyaller geçer.

Öğrencilerin bu cevaplarıyla bilim adamlarının kabul ettikleri düşünceler uyuşmamaktadır.

Saç rengi, göz rengi, kan grubu ya da sahip olduğumuz herhangi bir genetik hastalık gibi birçok özelliğimiz **genlerimiz** tarafından belirlenir.

Öğrencilere gen nedir sorusu yöneltildiğinde verdikleri cevaplar aşağıdaki gibidir.

Yapısında DNA bulunan bizi diğer canlılardan farklı kılan yapıdır.

Anneden ya da babadan çocuğa geçen kalıtsal hücrelerdir, yapısında kromozom vardır.

Anne ve babanın karışımıdır ve yapısında DNA ve RNA vardır.

İnsanların fiziki özelliklerinin oluşmasını sağlayan DNA ve RNA gendir.

Görüldüğü gibi sizler arasında yaygın olarak, DNA, gen, hücre ve kromozom kavramları birbirleriyle karıştırılmaktadır. Genetik konusunu daha iyi kavrayabilmemiz için bu kavramlar arasındaki ilişkileri bilmemiz gerekir.

Peki hücre, gen, kromozom, organizma, DNA ve çekirdek kavramları büyükten küçüğe doğru nasıl sıralanır?

Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Organizma DNA molekülünden daha büyüktür. DNA molekülü ise hücreden, hücre çekirdekten, çekirdek kromozomdan, kromozomlar ise genlerden daha büyüktür.

Organizma → DNA → Hücre → Çekirdek → Kromozom → Gen

Organizma DNA molekülünden daha büyüktür. DNA molekülü ise genlerden, genler hücreden, hücre çekirdekten, çekirdek ise kromozomlardan daha büyüktür.

Organizma → DNA → Gen → Hücre → Çekirdek → Kromozom

Organizma kromozomlardan daha büyüktür. Kromozomlar ise DNA molekülünden, DNA molekülü genlerden, genler hücreden, hücre ise çekirdekten daha büyüktür.

Organizma → Kromozom → DNA → Gen → Hücre → Çekirdek

Öğrencilerin birçoğu ise organizmanın hücrelerden oluştuğunu, hücrelerin ise çekirdeği olduğunu bilmektedirler; ancak sıralamayı aşağıdaki gibi yapmaktadırlar;

Organizma hücreden, hücre ise çekirdekten büyüktür. DNA molekülü ise genlerden, genler de kromozomlardan daha büyüktür.

Organizma → Hücre → Çekirdek → DNA → Gen → Kromozom

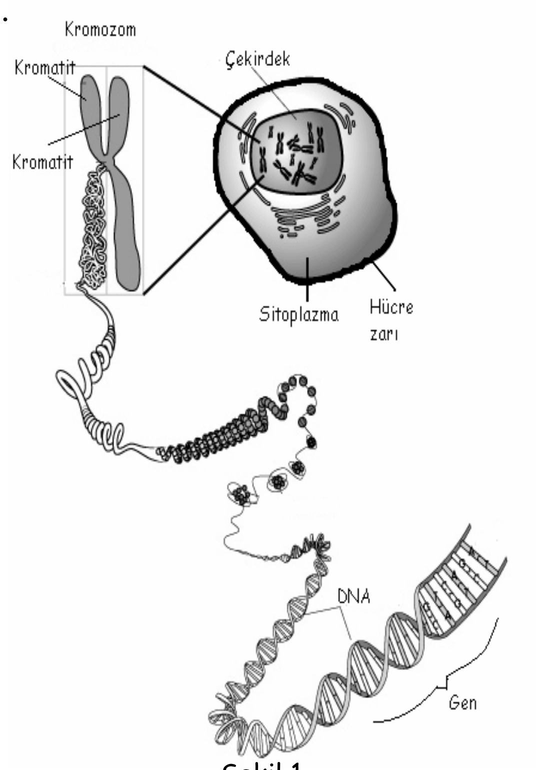
Ya da;

Organizma hücreden, hücre ise çekirdekten büyüktür. Çekirdek ise genlerden, genler DNA molekülünden, DNA molekülü ise kromozomlardan daha büyüktür.

Organizma → Hücre → Çekirdek → Gen → DNA → Kromozom

Öğrencilerin bu cevapları bilimsellikten uzaktır. Bu öğrenciler nerelerde hata yapıyor hep birlikte görelim.

Yeryüzünde yaşayan ve solunum, boşaltım, üreme ve benzeri yaşamsal faaliyetleri geçekleştiren hayvan, bitki gibi canlılara organizma denir. Organizmanın canlılık özelliği gösteren en küçük yapı birimi ise hücredir. Hücrenin çekirdeğinde bulunan kromatin ipliğin yapısında DNA denilen yönetici moleküller bulunur. DNA canlının bütün genetik bilgilerini taşır. Hücre bölünmesi sırasında DNA kendisini eşler ve bu sayede anne ve babanın karakterleri çocuklara iletilir. Kromozomların yapısında bulunan ve belirli bir özelliğin gelecek kuşaklara aktarılmasını sağlayan DNA parçasına **gen** denir. (Şekil 1)



Şekil 1

Bu bilgilere göre hücre, gen, kromozom, organizma, DNA ve çekirdek kavramlarının büyükten küçüğe doğru sıralanması aşağıdaki gibi olacaktır;

Organizma → Hücre → Çekirdek → Kromozom → DNA → Gen

Birçok öğrenci alel kelimesinin ne anlama geldiğini tam olarak bilmemekte veya alel ve gen terimlerini karıştırmaktadırlar. Peki sizce alel nedir?

Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Genlerin yapısında aleller bulunur.

Alellerin yapısında genler bulunur.

Gen ve alel aynı şeydir.

Bu cevapların hepsi bilimsellikten uzaktır. Şimdi bu öğrencilerin nerede yanlış yaptıklarını bulalım. Önce aşağıda verilen tablo 2' yi inceleyelim.

Tablo 2

GEN	ALEL	ALEL
Göz rengi geni	Mavi	Kahverengi
Kulak memesi şekli	Yapışık	Ayrık
Saç rengi geni	Siyah	Sarı
Saç şekli geni	Düz	Kıvırcık
Boy geni	Uzun	Kısa
Ten rengi geni	Beyaz	Siyah

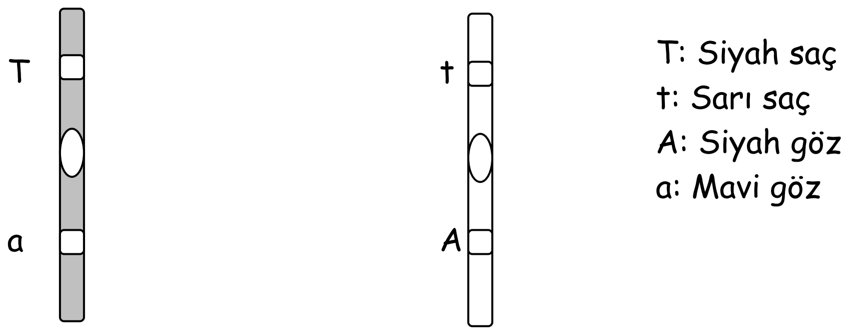
Bu tablo insan türüne ait bazı gen ve alelleri göstermektedir. Sadece insanlarda değil eşeyli üreyen bütün canlılarda canlının görünüşü genin **alel** adı verilen farklı şekilleriyle belirlenir. Örneğin; sarı ve yeşil, bezelye bitkisinin tohumunun renginin alelleridir. Tablo 2' de de gösterildiği gibi, düz saç ya da kıvırcık saç bir genin alelleridir.

Bir gene ait birçok alelin olabileceğini öğrendiniz. Peki bu alellerden hangisinin bir karakter üzerinde etkisini göstereceği nasıl belirlenir?

Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Anne karakteri baskınsa çocuk anneye benzer, baba karakteri baskınsa çocuk babaya benzer.

Aleller, çekinik ve baskın olmak üzere iki çeşit gene sahiptirler.
Bu cevaplar doğru değildir, bu öğrencilerin hatalarının nerede olduğunu hep birlikte inceleyelim.
Bu soruya cevap vermeden önce aşağıdaki şekil 2' yi inceleyelim.



Anneden gelen kromozom Babadan gelen kromozom

Şekil 2- homolog kromozomlarda taşınan aleller

Şekilde de görüldüğü üzere biri anneden diğeri babadan gelen homolog kromozomların karşılıklı gelen bölgelerinde bir karakterin belirlenmesinde etkili olan bir gen çifti bulunur. T-t harfleri saç rengi ile ilgili alelleri, A-a harfleri ise göz rengi ile ilgili alelleri simgelemektedir. Buna göre bu anne ve babadan doğacak çocuğun saç rengi ve göz rengi için ne söyleyebilirsiniz?

Bir araya geldiğinde etkisini gösteren alele **baskın (dominant) alel**, etkisini gösteremeyen alele **çekinik (resesif) alel** denir. Baskın olan alellerin belirlediği özellikler baskın özellik ya da baskın karakter adını alır. Çekinik alellerin belirlediği özellik ise çekinik özellik ya da çekinik karakter olarak adlandırılır. Baskın alel büyük harfle, çekinik alel ise aynı harfin küçüğü ile gösterilir. Şekildeki harflerden T ve A baskın alelleri, t ve a çekinik alelleri göstermektedir. O halde bu anne ve babadan doğacak çocuğun siyah saçlı ve siyah gözlü olacağı söylenebilir.

Aşağıdaki tabloda insanlar için bazı baskın ve çekinik karakterler gösterilmiştir.

Baskın karakter	**Çekinik karakter**
Siyah ten	Açık ten
Siyah göz rengi	Mavi göz rengi
Kıvırcık saç	Düz saç
Ayrık kulak memesi	Yapışık kulak memesi
Dil yuvarlayabilme	Dil yuvarlayamama

Tablo 3

İnsanda kıvırcık saç (E) düz saça (e) baskındır. Hem annesinden hem de babasından düz saç alelini alan bireyin saç şekli nasıl olur, neden?

Kıvırcık saç

Düz saç

Bir canlı bir özellik için aynı aleli içeriyorsa yani hem annesinden hem de babasından aynı aleli aldıysa bu canlı **homozigot (arı döl)** olarak nitelendirilir.

Hem annesinden hem de babasından düz saç alelini alan birey (ee) düz saçlı olur. Bu birey düz saçlılık özelliği bakımından homozigottur.

Peki bu birey annesinden kıvırcık saç alelini (E) babasından düz saç alelini (e) alsaydı saç şekli nasıl olurdu, neden?

Bir canlı bir özellik için farklı alelleri içeriyorsa yani anne ve babasından farklı alelleri aldıysa bu canlı **heterozigot (melez=hibrit)** olarak nitelendirilir.

Annesinden kıvırcık saç alelini (E), babasından düz saç alelini (e) alan birey (Ee) kıvırcık saçlı olur. Bu birey saç şekli özelliği bakımından heterozigottur.

Resesif karakterler ancak homozigot durumda ortaya çıkar. Yukarıdaki bireyin düz saçlı olabilmesi için (ss) alellerine sahip olması gerekir, aksi halde kıvırcık saçlı olur.

Bir canlının sahip olduğu genlerin toplamına o canlının **genotipi** denir. Bir canlının belirli yaş ve çevredeki dış görünüşüne ise o canlının **fenotipi** denir.

genotip

fenotip

B: Siyah göz rengi

b: Mavi göz rengi

D: Kıvırcık saç

d: Düz saç

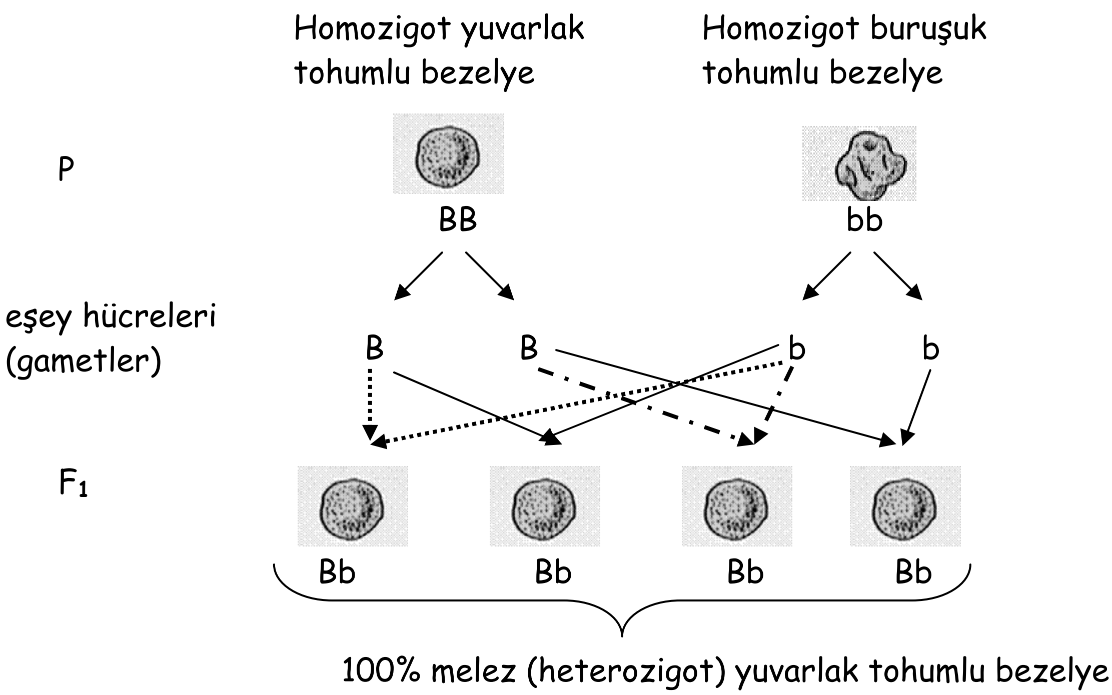
Yanda verilen bilgilere göre göz rengi bakımından heterozigot, saç biçimi bakımından homozigot resesif (çekinik) olan bir bireyin genotipini ve fenotipini yazınız.

Göz rengi: Bb Saç şekli: dd
Genotip: Bbdd
Fenotip: Siyah gözlü, düz saçlı.

MENDEL İLKELERİ

- Değişik özellikleri olan iki arı dölün çaprazlanması sonucu elde edilen F_1 dölleri %100 melezdir. Melez döl her iki dölün de genlerini taşır. (Karakterlerin Birleşmesi Kanunu)

Bu kanunu bir örnekle açıklayalım.
Tek özellik için (tohum şekli) homozigot (arı döl) baskın ve homozigot çekinik olan iki bireyin çaprazlanması aşağıdaki gibi olur;
B: yuvarlak tohumlu bezelye
b: buruşuk tohumlu bezelye



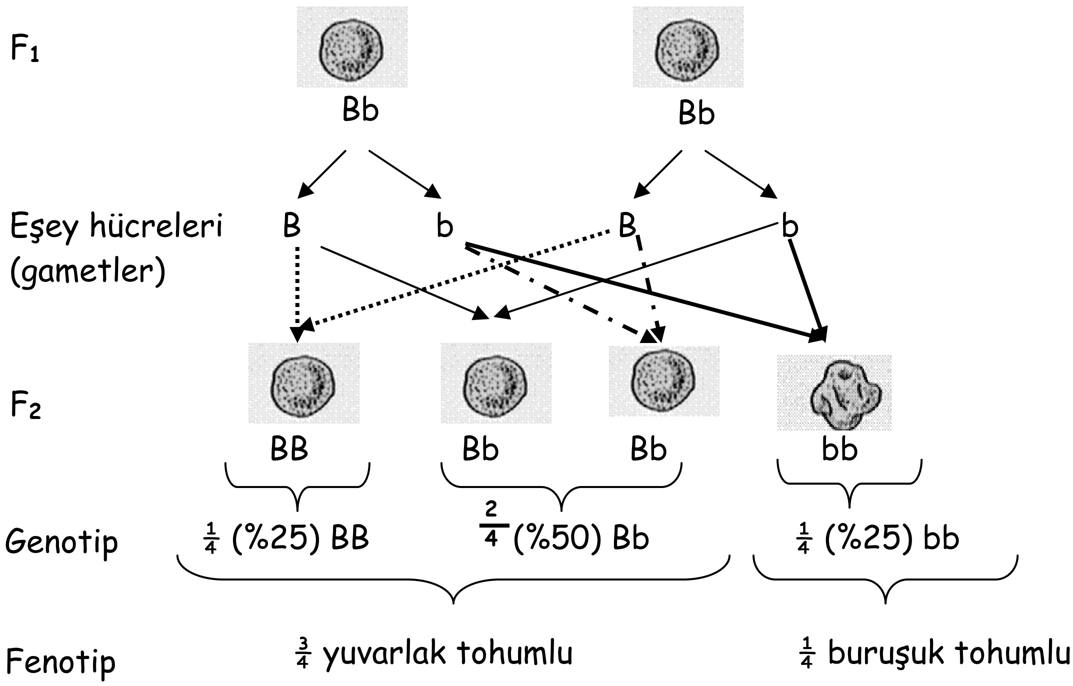
Şekil 3

- Melez döllerdeki alellerin biri baskın, diğeri ise çekiniktir. F_1 dölünün görünüşü baskın karaktere benzer. (Karakterlerin Gizli Kalması Kanunu)

Şekil 3' de de gösterildiği üzere F_1 dölü melezdir (Bb). Bu alellerden B (yuvarlak tohumlu bezelye), b (buruşuk tohumlu bezelye)' ye baskındır ve F_1 dölünün görünüşü baskın olan B aleline benzer ve yuvarlak tohumludur.

- İki melez döl arasında yapılan çaprazlama sonucu elde edilen F_2 dölünde 1/4 oranında birinci arı döl, 2/4 oranında melez, 1/4 oranında da ikinci arı döl karakterleri ortaya çıkar. (Karakterlerin Ayrılması Kanunu)

Şekil 3' te verilen F_1 döllerini çaprazlayalım.

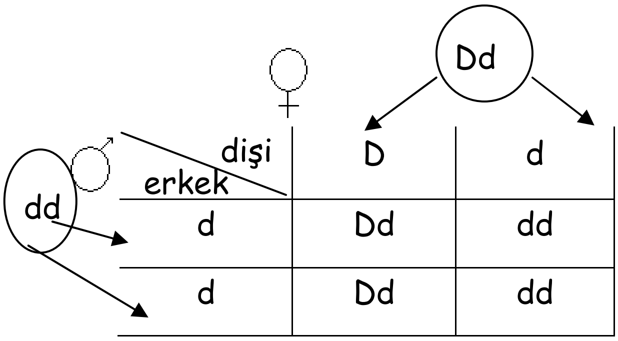


Şekil 4

Tarihsel Bilgi

Tek özellik için (tohum şekli gibi) çaprazlamayı **Punnett karesi** ile de gösterebiliriz. Punnett karesi İngiliz bir bilim adamı olan Reginald Punnett (1875 – 1967) tarafından geliştirilmiştir ve bir dölün belli bir genotipe sahip olma olasılığını belirlemek için kullanılır.

Örnek; Heterozigot yuvarlak tohumlu bezelye bitkisi ile buruşuk tohumlu bezelye bitkisi çaprazlanıyor. Oluşan döllerin genotipi ve fenotipiyle bunların oranları nedir?
D: yuvarlak tohum, d: buruşuk tohum



Şekil 5

Punnet karesine göre incelendiğinde oluşan döllerin genotipi ve fenotipi aşağıdaki gibi olur;

Genotip: $\frac{1}{2}$ heterozigot baskın döl
$\frac{1}{2}$ çekinik döl

Fenotip: $\frac{1}{2}$ uzun boylu
$\frac{1}{2}$ kısa boylu

Punnett karesinin dışında bulunan (D) ve (d) harfleri neyi temsil etmektedir ve neden karenin içindeki gibi yan yana değil de ayrı ayrı yazılmıştır?
Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Bu harfler kromozomları temsil etmektedirler.
Bu harfler zigotu temsil etmektedirler.
Bu harfler anne ve babanın vücut hücresini temsil etmektedirler.
Bu harfler oğul döllerin genotipidir.

Şimdi bu öğrencilerin nerede hata yaptıklarını bulalım.

Punnett karesinin dışında bulunan (D) ve (d) harfleri anne ve babanın oluşturduğu gametlerin taşıyabileceği olası alelleri temsil etmektedir. Şekil 5'te gösterilen Punnett karesinde annenin gametlerinden biri (D) alelini taşırken diğeri (d) alelini taşımaktadır. Babanın gametlerinin ikisi de (d) alelini taşımaktadır. Buradan da anlaşılacağı üzere her bir gamet sadece bir aleli taşıyabilir. Punnett karesinin içinde ise oluşacak yavru bireylerin sahip olduğu genotip verilmiştir ve çaprazlanmadan sonra oluştukları için iki alel de yan yana yazılır.

İnsanda ayrık kulak memesi şekli yapışık kulak memesi şekline baskındır. Buna göre heterozigot iki ayrık kulak memeli bireyin çaprazlanması sonucu oluşacak bireylerin genotiplerinin dağılım oranını Punnett karesini kullanarak belirleyiniz. Yapışık kulaklı bireyin olma olasılığını hesaplayınız.
(A: ayrık kulak memesi, a: yapışık kulak memesi)


Ayrık kulak memesi


Yapışık kulak memesi

Saç rengi karakteri için heterozigot olan bir anne ile heterozigot olan bir babanın dört çocukları vardır. Bu çocukların saç karakteri için ne söyleyebilirsiniz?
Bu soruya bazı öğrenciler aşağıdaki yanıtları vermişlerdir;

Birinci çocuk kesinlikle dominant karakter özelliğine sahip olur.

Dört çocuğun üçü kesinlikle dominant karakter özelliğine sahip olur.

Tüm çocuklar kesinlikle dominant özelliğe sahip olur.

Erkek çocukların saç karakteri babalarına, kız çocukların ki annelerine benzer.

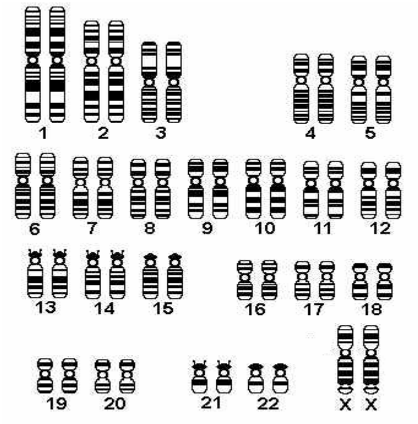
Bu cevapların hepsi bilimsellikten uzaktır. Şimdi bu öğrencilerin nerede yanlış yaptıklarını bulalım.

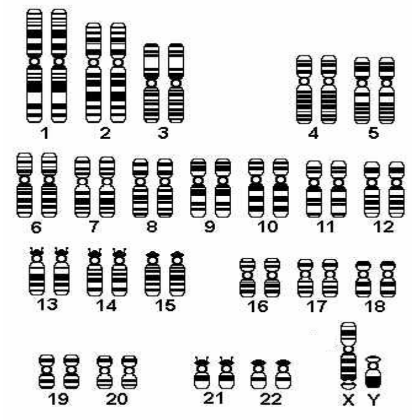
Doğru cevabı bulmak için saç rengi karakteri bakımından heterozigot olan bir anne ile heterozigot olan bir babanın çaprazlanması sonucu oluşacak bireylerin özelliklerine hep birlikte bakalım.
(H) dominant saç rengi alelini, (h) ise çekinik saç rengi alelini temsil etsin. Hem anne hem de baba saç rengi karakteri bakımından heterozigot oldukları için ikisinin de genotipleri (Hh) olur.

dişi / erkek	H	h
H	Hh	Hh
h	Hh	hh

Punnett karesinde de görüldüğü üzere döllerin dominant karakter özelliğine sahip olma olasılığı $\frac{3}{4}$ iken, çekinik karakter özelliğine sahip olma olasılığı $\frac{1}{4}$ ' tür. Fakat bu çaprazlamada oluşacak bireylerin sahip olacakları özellikler şansa bağlı olarak değişir, kesin bir şey söyleyemeyiz. Anne ve babanın oluşturacağı gametlere baskın karakterin mi yoksa çekinik karakterin mi gideceğini bilemeyiz. Dolayısıyla sorudaki dört çocukta dominant özelliğe sahip olacağı gibi tamamı çekinik özelliği de taşıyor olabilir.

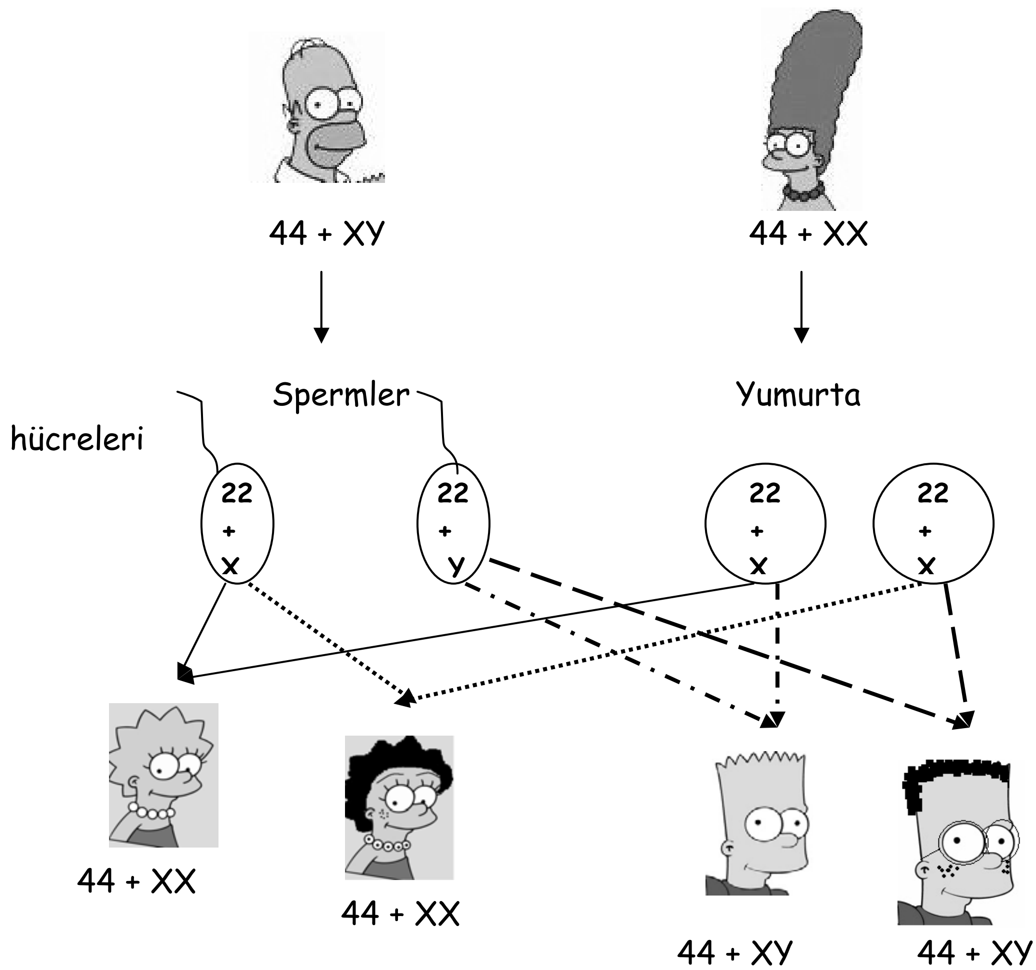
Şimdiye kadar insanlara ait bazı karakterlerin kalıtımla nasıl yeni döllere aktarıldığını gördünüz. Peki insanda cinsiyetin belirlenmesi nasıl olur?
İnsanda 23 çift (46 tane) kromozom bulunur. Bu kromozomlardan 22 çifti (44 tanesi) vücut özelliklerini belirler. Geri kalan bir çift (2 tane) kromozom ise insanın dişi ya da erkek oluşunu kontrol eden genleri taşır. Bu kromozom çiftine **cinsiyet kromozomu** denir. Cinsiyeti belirleyen X ve Y kromozomlarıdır. Cinsiyet kromozom çifti dişilerde XX ile gösterilir. Erkeklerde ise cinsiyet kromozomları XY ile gösterilir. Öyleyse, dişi ve erkeğin kromozom takımı aşağıdaki şekilde gösterilir;





Dişi ⟶ 44 + XX   Erkek ⟶ 44 + XY

Anne ve baba arasındaki çaprazlanmaya bakalım;



Şekil 6

Şekil 6' da da görüldüğü gibi dişinin yumurta hücresi, erkeğin (22 + X) kromozomlu spermiyle birleşirse (44 + XX) kromozomlu kız çocuk meydana gelir. Eğer yumurta hücresi, erkeğin (22 + Y) kromozomlu spermiyle birleşirse (44 + XY) kromozomlu erkek çocuk meydana gelir. Dolayısıyla, çocuğun kız ya da erkek olma olasılığı hep %50'dir. Çocuk kaçıncı çocuk olursa olsun kız ya da erkek olma olasılığı %50 yani $\frac{1}{2}$' dir.