THE EFFECT OF 5E LEARNING CYCLE INSTRUCTION ON 10TH GRADE STUDENTS' UNDERSTANDING OF CELL DIVISION AND REPRODUCTION CONCEPTS

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HARİKA ÖZGE ARSLAN

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THE EFFECT OF 5E LEARNING CYCLE INSTRUCTION ON 10TH GRADE STUDENTS' UNDERSTANDING OF CELL DIVISION AND REPRODUCTION CONCEPTS

submitted by **HARİKA ÖZGE ARSLAN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Secondary Science and Mathematics Education Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** _______________

Prof. Dr. Ömer Geban
Head of Department, **Secondary Sci. and Math. Education** _______________

Prof. Dr. Ömer Geban
Supervisor, **Secondary Sci. and Math. Edu. Dept., METU** _______________

Prof. Dr. Necdet Sağlam
Co-supervisor, **Nanotech. and Nanomed. Dept., Hacettepe University** _______________

Examining Committee Members:

Prof. Dr. Ayhan Yılmaz
Secondary Science and Mathematics Education Dept., HU _______________

Prof. Dr. Ömer Geban
Secondary Science and Mathematics Education Dept., METU _______________

Assoc. Prof. Dr. Esen Uzuntiryaki-Kondakçı
Secondary Science and Mathematics Education Dept., METU _______________

Assoc. Prof. Dr. Özgül Yılmaz-Tüzün
Elementery Education Dept., METU _______________

Assoc. Prof. Dr. Yezdan Boz
Secondary Science and Mathematics Education Dept., METU _______________

Date: 02.06.2014

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Harika Özge ARSLAN

Signature :

ABSTRACT

THE EFFECT OF 5E LEARNING CYCLE INSTRUCTION ON 10TH GRADE STUDENTS' UNDERSTANDING OF CELL DIVISION AND REPRODUCTION CONCEPTS

Arslan, Harika Özge
Ph.D., Department of Secondary Science and Mathematics Education
Supervisor : Prof. Dr. Ömer Geban
Co-supervisor: Prof. Dr. Necdet Sağlam

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The purpose of this study was to investigate the effect of 5E learning cycle instruction (LCI) and gender on 10^{th} grade students' understanding and achievement in cell division and reproduction concepts, and their alternative conceptions on these concepts compared to conventional classroom instruction (CCI). The sample consisted of 241 students from two public high schools at Ankara. The classes were randomly assigned to CCI and LCI groups. In the LCI groups, 5E learning cycle model was used, whereas in the CCI groups conventional classroom instruction was used to teach cell division and reproduction concepts throughout 10 weeks. Cell Division and Reproduction Achievement Test (CDRAT), and Cell Division and Reproduction Diagnostic Test (CDRDiT) were administered to both CCI and LCI groups as a pre-tests and post-tests. In addition, Science Process Skill Test (SPST) was administered to all participants to assess their science process skills before the treatment. After the treatment, 12 students were interviewed semi-structurally. Multivariate Analysis of Covariance (MANCOVA) was used for analysis of hypotheses and the qualitative data was transcribed, coded and categorized. The results indicated that 5E LC instruction showed significantly superior effect over CCI for improving students' conceptual understanding in the cell division and reproduction concepts and discarding alternative conceptions. Drawings and the interview results supported these findings. However, there was no difference found between CCI and LCI group students' post-achievement scores. In addition, there was no statistical evidence is found that the effect of the treatment on students' understanding the concepts differs across gender.

Keywords: 5E learning cycle model, alternative conceptions, biology education, cell division, reproduction, understanding, achievement, gender.

ÖZ

5E ÖĞRENME DÖNGÜSÜ İLE ÖĞRETİMİN 10. SINIF ÖĞRENCİLERİNİN HÜCRE BÖLÜNMESİ VE ÜREME KONULARINI ANLAMALARINA ETKİSİ

Arslan, Harika Özge
Doktora, Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü
Tez Yöneticisi : Prof. Dr. Ömer Geban
Ortak Tez Yöneticisi: Prof. Dr. Necdet Sağlam

Haziran 2014, 280 sayfa

Bu çalışmanın amacı 5E öğrenme döngüsü ile öğretimin ve cinsiyetin 10. sınıf lise öğrencilerinin hücre bölünmesi ve üreme konularını anlamaları, bu konulardaki başarıları ve kavram yanılgıları üzerine etkisini geleneksel sınıf öğretimine karşı araştırmaktır. Bu çalışmanın örneklemini Ankaradaki iki farklı devlet okulunda öğrenim gören 241 onuncu sınıf öğrencisi oluşturmuştur. Sınıflar 5E öğrenme döngüsü ve geleneksel öğretim grubu olarak rastgele seçilmiş ve her öğretmen iki deney iki kontrol grubunda öğretimi gerçekleştirmiştir. Hücre bölünmesi ve üreme kavramlarını anlatmak için, deney gruplarında 5E öğrenme döngüsü modeli, kontrol gruplarında ise geleneksel yöntem kullanılmıştır. Hücre Bölünmesi ve Üreme Başarı Testi ve Hücre Bölünmesi ve Üreme Tanı Testi her iki gruba ön-test ve son-test olarak uygulanmıstır. Bunların yanısıra, uygulamadan önce tüm gruplara öğrencilerin bilimsel işlem becerilerini kontrol etmek amacıyla Bilimsel İşlem Beceri Testi uygulanmıştır. Uygulama sonrasında 12 öğrenci ile yarı-yapılandırılmış mülakatlar yapılmıştır. Çok değişkenli kovaryans analizi (MANCOVA) nicel verilerin analizi için kullanılmıştır. Nitel veriler birebir olarak yazılmış, kodlanmış ve kategorize edimiştir. Sonuçlar 5E öğrenme döngüsü kullanılan dersin, öğrencilerin hücre bölünmesi ve üreme konuları ile ilgili kavramsal anlamalarını gelistirmelerinde ve kavram yanılgılarını gidermede daha etkin olduğunu göstermiştir. Öğrencilerin çizimleri ve mülakat sonuçları bu bulguları desteklemektedir. Fakat, uygulama sonrasında öğrenme döngüsü uygulanmış grup ile geleneksel sınıf öğretimi yöntemi uygulamış grubun başarıları arasında fark bulunmamıştır. Bunların yanısıra, uygulamanın etkinliğinin öğrencilerin cinsiyetlerine göre farklılık gösterdiğine dair bir kanıt bulunamamıştır.

Anahtar Kelimeler: 5E öğrenme döngüsü modeli, kavram yanılgısı, biyoloji eğitimi, hücre bölünmesi, üreme, anlama, başarı, cinsiyet.

Dedicated to My Beloved Husband

&

My Family

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LIST OF ABBREVIATIONS

5E	: Engage, Explore, Explain, Elaborate, and Evaluate
A	: Alternative conceptions
AAAS	: American Association for the Advancement of Science
ANCOVA	: Analysis of Covariance
BSCS	: Biological Sciences Curriculum Study
CCI	: Conventional Classroom Instruction
CDRAT	: Cell Division and Reproduction Achievement Test
CDRDiT	: Cell Division and Reproduction Diagnostic Test
Chem Study	: Chemical Education Materials Study
df	: Degrees of Freedom
DNA	: Deoxyribonucleic acid
DVs	: Dependent Variables
ESS	: Elementary Science Study
IVs	: Independent Variables
LCI	: Learning Cycle Instruction
M	: Mean
MANCOVA	: Multivariate Analysis of Covariance
MONE	: Ministry of National Education
N	: Sample Size
NRC	: National Research Council
NSF	: National Science Foundation
Pre-AC	: Alternative conception scores calculated with Pre-CDRDiT.
Pre-CDRAT	: Cell Division and Reproduction Achievement Pre-Test
Pre-CDRDiT	: Cell Division and Reproduction Diagnostic Pre-Test
Post-AC	: Alternative conception scores calculated with Post-CDRDiT.
Post-CDRAT	: Cell Division and Reproduction Achievement Post-Test

Post-CDRDiT : Cell Division and Reproduction Diagnostic Post-Test
SCIS : Science Curriculum Improvement Study
SD : Standard Deviation
SPSS : Statistical Package for the Social Sciences Program
SPST : Science Process Skill Test

CHAPTER 1

INTRODUCTION

'If I had to reduce all educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the pupil already knows. Ascertain this and teach him accordingly'

(Ausubel, 1968, p. 235)

"How is it possible to ensure concept formation of students?" is one of the prominent questions that the most science educators discuss and conduct studies to design effective teaching methods helping students construct new conceptual knowledge over six decades. Under the influence of cognitive learning theories, the varieties of the factors that have effect on students' understanding have induced a large body of literature. As pointed by Ausubel, the students' previous knowledge has focused special attention because of its undeniable effect on meaning construction. With the constructivist point of view, the assumption of the student's 'blank mind' can be filled with teacher science has been shifted toward the assumption of the students have some conceptual view of a new science concepts before being taught and they are very active in learning processes. These conceptual views which are different from the scientifically accepted ones are called by various terms in the science education literature, some of them are; alternative conceptions, alternative frameworks, anchoring conceptions, conceptual frameworks, intuitive belief, preconceptions, misconceptions, misunderstandings, and phenomenological primitives (Abraham, Grzybowski, Renner, & Marek, 1992; Andersson & Smith, 1983 as cited in Griffiths & Preston, 1992; Clement, Brown, & Zietsman, 1989; Driver & Easley, 1978 as cited in Cho, Kahle, Nordland, 1985; Driver, 1981; diSessa, 1993; McCloskey, 1983 as cited in Cho, Kahle, Nordland, 1985; Odom & Barrow, 1995; Wandersee, Mintzes, & Novak, 1994). The alternative conceptions formed in students' minds disrupt the meaningful learning process by acting as a barrier to the connection between the new and the old concepts.

Hundreds of studies searching for the characteristics of alternative conceptions, the effect of these conceptions on students' meaning construction and identifying alternative conceptions held by students on different subjects have conducted worldwide. In addition to these studies, several instructional approaches such as; concept maps, cooperative learning, conceptual change model, discovery learning originated from constructivism have developed in order to restructure students' ideas and dispel alternative conceptions. Inquiry based approach which was first advocated by John Dewey is one of these instructional approaches. According to Anderson "what is called inquiry learning in the literature is very similar to what others call constructivist learning" (2007, p. 809). Parallel with the constructivist origin, generation of hypothesis and alternative hypothesis and their testing through experimentation are the bases of this approach. Hofstein and Lunetta described inquiry as 'more authentic ways in which learners can investigate the natural world, propose ideas, and explain and justify assertions based up evidence and, in the process, sense the spirit of science' (2004, p. 30). According to this approach, alternative conceptions of the students are seen as alternate hypotheses that should be tested. 'Thus when tested and contradicted by evidence alternative conceptions-alternative analogies play an integral role in prompting disequilibrium, argumentation, inquiry and conceptual change' (Lawson, 2010, p. 278). Therefore the importance of alternative conceptions is emphasized in this approach and they should be revealed, discussed and tested during the instruction. From this perspective, identification of alternative conceptions in different science areas, the lack of awareness about what alternative conceptions that students are likely to hold and what kind of instructional process needs to be followed by teachers to overcome these alternative conceptions became potential research areas.

In the late 1950s, during the movement of the curriculum development in United States, lots of inquiry oriented projects, such as Biological Sciences Curriculum Study (BSCS), Science Curriculum Improvement Study (SCIS), the Chemical Education Materials Study (Chem Study), the Physical Science Study Committee (PSSC Physics), and the Elementary Science Study (ESS) founded by National Science Foundation (NSF). All of these curriculum projects aimed to ensure meaningful learning construction by active participation of the students in science, biology and earth sciences. Among these projects, SCIS took an important role by proposing a systematic approach to instruction, the learning cycle model, to the science education literature by J. Myron Atkin and Robert Karplus with the influence of the Piagetian theory. Although the terms exploration, invention, and discovery are used clearly, the name of the learning cycle did not appear in any of the early SCIS publications and it is included in about 1970 (Lawson, 2010). These three instructional phases are modified to the terms as exploration, concept/term introduction and concept application because of the teachers' difficulty in understanding what invention and discovery meant clearly. Lawson pointed out the need of this change by stating 'the learning cycle, as originally conceived, is too limited to serve as a general guide to teaching practice which has as primary aims both the teaching of domain specific biology concepts and the development of general scientific reasoning skills' (1988, p. 266). Therefore, several variations of learning cycle (three, four, five and seven phases) appeared by the time. Among these, the well-known project, BSCS, also used a learning cycle as a teaching method with addition of two phases and the modification of the above mentioned three phases. So, in BSCS, there are five phases which are called 5E; engage, explore explain, elaborate and evaluate. Bybee, et al. (2006) described each phase with a short phrase.

Engagement: students' prior knowledge accessed and interest engaged in the phenomenon

Exploration: students participate in an activity that facilitates conceptual change

Explanation: students generate an explanation of the phenomenon

Elaboration: students' understanding of the phenomenon challenged and deepened through new experiences

Evaluation : students assess their understanding of the phenomenon

Since the late 1980s, the 5E model has been used widely in elementary, middle, and high school biology and integrated science programs to develop new instructional materials by BSCS (Bybee, et al. 2006). Bybee and his colleagues emphasized that each phase of 5E learning cycle has a particular function to foster both teachers' instruction and the learners' understanding of scientific concepts (2006). In 1995, Wells, Hestenes and Swackhammer derived '*modeling cycles'* in which move students systematically through all phases of model development, evaluation, and application in concrete situations' from learning cycle (p. 606). The popularity of learning cycle instruction increased with the publishment of guidelines on how science should be taught by National Research Council (NRC, 2000). Similar to BSCS, NRC put forward five phases instruction. Lawson interpreted this report as a consensus on the usage of learning cycle while teaching science and as an end of the debate among experts about how science should be taught (Lawson, 2010). More recently, 7E model was proposed by expanding the engagement phase of 5E learning cycle into two parts; *elicit* and *engage*, and expanding the last two stages of elaborate and evaluate into three components *elaborate*, *evaluate* and *elicit* in the Active Physics project granted by NRC (Eisenkraft, 2003).

A large number of studies conducted to analyze the effectiveness of the different types of the learning cycle instruction on students' scientific reasoning abilities, students' understanding of domain specific concepts, their attitudes, motivation, and discarding alternative conceptions (Ates, 2005; Balci, Cakiroglu, & Tekkaya, 2006; Bektas, 2011; Campbell, 1977; Cavallo & Laubach, 2001; Cavallo, McNeely, & Marek, 2003; Ceylan, 2008; Dogru-Atay, 2006; Johnson, 1993; Lavoie, 1999; Lawson & Johnson, 2002; Lord, 1999; Marek, Cowan, & Cavallo, 1994; Musheno & Lawson, 1999; Oren & Tezcan, 2009; Saunders & Shepardson, 1987; Schneider & Renner, 1980; Wilder and Shuttleworth, 2005). Researchers reported that learning cycle instruction promotes conceptual change (Boylan, 1988; Bybee,et al., 2006;

Marek, Cowan, & Cavallo, 1994; Stepans, Dyche, & Beiswenger, 1988), enhances mastery of subject matter, improves students' general reasoning abilities, and cultivates interest and attitudes about science (Bybee, et al., 2006). Lawson explained 'use of the learning cycle provides the opportunity for students to reveal prior conceptions/misconceptions and the opportunity to argue and test them, and thus become "disequilibrated" and develop more adequate conceptions and reasoning patterns' (1988, p.273). Odom and Kelly (2001) claimed that learning cycle bring about opportunities for students to explore their beliefs, that might result in argumentation, prediction, and hypothesis testing, improving in their self-regulation and knowledge construction. In addition, learning cycle instruction provides retention and increase self-regulation especially during the exploration phase (Lawson, 1995). Moreover, Lawson, Abraham and Renner (1989) found that students in classrooms using the learning cycle had more positive attitudes toward science and science instruction than traditional instruction. Most of these researchers attribute this success to the nature of learning cycle that presents learning environment for interaction and dialogue between students, learning experiences and activities in a systematic instruction phases (Barman, 1989) and also its consistency with the inquiry oriented nature of the scientific discipline (Lawson, Abraham & Renner, 1989).

In the biology education field, learning cycle model is preferred to develop lesson plans on several biology concepts such as; cell (Kaynar, Tekkaya, & Cakiroglu, 2009; Wilder & Shuttleworth, 2005), diffusion and osmosis (Atilboz, 2007; Lawson, 2000; Marek, Cowan, & Cavallo, 1994; Odom & Kelly, 2001), ecology (Blank, 2000; Dwyer & Lopez, 2001; Lauer, 2003), food chain (Cate & Grzybowski, 1987), genetics (Dogru-Atay, 2006; Yilmaz, Tekkaya, & Sungur, 2011), human circulatory system (Sadi & Cakiroglu 2010), photosynthesis (Balcı, Cakiroglu, & Tekkaya, 2006; Cakiroglu, 2006; Lawson, Rissing, & Faeth, 1990; Ray & Beardsley, 2008), plants (Cavallo, 2005), plant nutrition (Lee, 2003), genetics and inheritance, homeostasis and ecology together (Lavoie, 1999). Most of these studies reported the superiority of learning cycle instruction on students' understanding of subject matter compared to more traditional instruction similar to the studies on different science subjects.

Cell division, which is crucial concept in biology curriculum, is directly related with inheritance and reproduction. “A strong understanding of biological inheritance necessarily requires a clear conception of cell division and of the differences and importance of mitosis and meiosis” (Williams et al., 2012, p. 82). Consequently, lack of understanding and disconnection among meiosis, sexual reproduction and inheritance result in poor conceptual basis of genetics (Knippels, 2002). Therefore, students need to have depth understanding of mitosis, meiosis, asexual and sexual reproduction in order to acquire success in genetics. However, the research-based findings on students’ understanding of genetic inheritance and cell division indicated that these subjects are very difficult science topics to learn (Bahar, 2002; Bahar, Johnstone, & Hansell, 1999; Brown, 1990; Kindfield, 1991; Law & Lee, 2004; Tsui & Treagust, 2003; Wiliams, et. al., 2012). Most of the students have a great deal of difficulties in keeping the name of the different phases, conceptualizing the structure, the function of chromosomes (Brown, 1990; Kindfield, 1991; Smith, 1991), and the processes during these phases (Dikmenli, 2010), differentiating the phases of mitosis and meiosis, combining their daily life experiences to the knowledge of asexual and sexual reproduction (Knippels, 2002; Tekkaya, Ozkan, & Sungur, 2001). Domain specific terminology (Lewis, Leach, & Wood-Robinson, 2000), abstract nature of genetic concepts (Knippels, 2002; Tekkaya, Ozkan, & Sungur, 2001), and alternative conceptions on cell division and reproduction (Atilboz, 2004; Brown, 1990; Kindfiled, 1991; Stewart, Hafner, & Dale, 1990) were stated among the sources of these difficulties. In addition to these, Smith specified that doubling, pairing, and separating are three basic phenomena that confuse students and he stated “ recognizing the similarities among the common meanings of these terms gives a clearer view of some reasons why students find cell division a difficult topic” (1991, p.31).

The findings of the studies conducted on students’ conceptions of cell division and reproduction concepts revealed that students hold a mixture of many scientific and alternative conceptions in specifically about the purpose and the products of mitosis and meiosis processes (Brown, 1990; Kindfield, 1994; Lewis, Leach, & Wood-Robinson, 2000; Stewart, Hafner, & Dale, 1990; Williams, et al., 2012). The more prevalent alternative conceptions are about the chromosome structure, chromosome number, homologous chromosomes, duplication, separation and crossing over in chromosomes, distinguishing the mitosis and meiosis processes. Dispelling alternative conceptions requires more specific instructional strategies other than traditional teaching methods because of the fact that alternative conceptions are stable and often resistant to change (Fisher, 1985). In their study, Banet and Ayuso (2000) emphasized that traditional teaching strategies have slight effect on students' construction of meaningful understanding of inheritance, and they suggested that 'significant changes should be made in both curriculum planning and the sequencing of teaching when genetics is taught at the secondary school level' (p.314). Under this focus, several strategies such as hands on activities, models, laboratory investigations, and paper-pencil strategies were suggested by many investigators to facilitate conceptual change and promote more meaningful learning while teaching both inheritance and cell division concepts (Chinnici, Neth, & Sherman, 2006; Chinnici, Yue, & Torres, 2004; Clark & Mathis, 2000; Farrar & Barnhart, 2011; Levy & Benner, 1995; McKean & Gibson, 1989; Mertens & Walker, 1992; Oakley, 1994; Smith & Kindfield, 1999; Stencel, 1995; Taylor, 1988; Williams, Linn, & Hollowell, 2008; Wyn & Stegink, 2000). In addition to these strategies, Danieley (1990) and Lawson (1991) prepared sample three phases learning cycles to show how learning cycle was used to introduce the concept of mitosis. However, the researches on the effectiveness of the learning cycle instruction on cell division and reproduction concepts are limited (Canli, 2009; Haras, 2009; Onder, 2011).

There has been a debate on the gender differences in students' achievement and understanding of science concepts among researchers for a long time. The gender studies in education literature does not point out unambiguous results on which gender outperform other in science achievement. Becker (1989) reported that the magnitudes of gender differences in science achievement differ across the subject matter as a result of meta-analysis study. For instance; there were significant advantages of males in biology, general science, and physics, but no significant differences in mixed science content, geology and earth sciences. Similar to these findings some of the studies indicated no significant gender difference (Hupper, Lomask, & Lazarowitz, 2002; Okeke & Ochuba, 1986; Ugwu & Soyibo, 2004), but some of them found significant gender differences (Cavallo, Potter, & Rozman, 2004; Stark & Gray, 1999; Young & Fraser, 1994). The result pattern of these studies is not clear that favored males in some studies and females in others. As an example, Young and Fraser (1994) reported significant gender differences in biology achievement in favour of the boys. However, the study of Stark and Gray (1999) showed that girls performed higher on tasks where the content/context was drawn from the biological sciences than males. Investigation of the reasons under these differences was in the focus of lots of studies. The interaction between gender and teaching method might be one the potential reason of the gender differences. Therefore, one of the aims of the present study was to find an aswer to the question of whether there is any interaction between gender and teaching methods related to students' achievement, understanding and alternative conceptions. When the related literature examined, the studies investigated the effectiveness of learning cycle across gender, they found no interaction between gender and LC (Ates, 2005; Bektas, 2011; Bulbul, 2010; Cakiroglu, 2006; Cetin-Dindar, 2012).

1.1 The Purpose of the Study

In the light of the reported literature, the advantages of learning cycle model on science and biology education triggered this study to investigate the effect of 5E learning cycle instruction (LCI) over conventionally designed classroom instruction (CCI) on tenth grade high school students' conceptual understanding and achievement in cell division and reproduction concepts.

1.2 Significance of the Study

Alternative conceptions are problematic issues for both teachers and students especially in science classes. When students enter the classroom with alternative conceptions about scientific phenomena; these conceptions would affect how the corresponding scientific explanations are learned (Hewson & Hewson, 1983). Students' alternative conceptions can influence their science achievement and these kind of conceptions should be overcome through instruction (Beeth, 1998). At this point teaching plays an undeniable important role however, in most of the time teaching science with traditional methods does not emphasized identification and remediation of alternative conceptions, instead of that the science teachers might pass on their alternative conceptions to, or might fail to correct, the students they teach (Dove, 1996; Groves & Pugh, 1999). 'Although inquiry is the experts' teaching methods of choice, many science teachers in the 'United States and in other countries still spend most of their time teaching in more traditional didactic ways' (Lawson, 2010, p.98). Most of the teachers are rarely addressing alternative conceptions, since they most probably are unaware of the importance of student's prior knowledge and do not know how to address or identify them or they think that explaining the correct ideas automatically make students think otherwise (McComas, 2005). Therefore, most of the science educators claim that a majority of students leave their science classes with little or no change in their thinking. In Turkey, even the national biology curriculum was developed based on constructvist approach and emphasized the crucial role of student-centered activities, most of the teachers prefer traditional intstruction techniques; such as representing the concepts by using chalk and board, asking questions to students, and geting them to take notes (Ekici, 2000).

As a solution to this important problem, increasing teachers' awareness about students' preconceptions especially the ones that are categorized under alternative conception in specific science concepts and improving teachers' knowledge on the methods of remediating alternative conceptions needs to be provided for meaningful and effective learning (Lawson, 2001; Pashley, 1994). Researchers also suggested constructivist teaching strategies to eliminate alternative conceptions for science concepts (Posner, Strike, Hewson, & Gertzog, 1982; Lawson, 2001; Yager, 1995). Learning cycle instruction is one of the recommended teaching models that found to be effective at helping students overcome alternative conceptions (Lawson, 1988; 2001; Ray & Beardsley, 2008). Lawson claimed in his study entitled with “A better way to teach biology” that the correct use of the learning cycle provides students the opportunity to reveal prior conceptions/misconceptions and the opportunity to argue and test them, and thus become "disequilibrated" and develop more adequate conceptions and reasoning patterns to debate and test them (1988, p. 273). In addition to this claim, the extended version of three phase learning cycle, 5E instructional model is especially designed to facilitate the progress of conceptual change (Bybee, et al. 2006).

Today, the learning cycle instruction continues to be an integral component of many teaching practices and research attempts to enhance students’ outcomes (Marek, Laubach, & Pedersen, 2003). In the literature, the results of the studies on the significant effect of learning cycle instruction reported, such as; the improvement of reasoning skills (Schnieder & Renner, 1980), conceptual achievement (Balci, 2009; Cakiroglu, 2006; Ercan, 2009; Sadi & Cakiroglu 2010; Saunders & Shepardson, 1987), scientific attitudes (Barman, 1989; Brown, 1996; Lawson et al., 1989; Oren & Tezcan, 2009), and bringing about conceptual change (Boylan, 1988; Bybee, et al. 2006; Marek, Cowan, & Cavallo, 1994; Stepans et al., 1988) compared to teacher centered instruction.

Whereas most of the issues on biology curriculum are interconnected to each other and daily life, the dominant way of thinking about the learning and teaching biology is subject and memorization specific. Most of the students tend to resort to a rote learning style which is a common practice in biology teaching (Yip, 1998b). Therefore, biology has seen among hard lessons to understand, most of the students tried to memorize and repeat the terms and concepts until the exam pass and then forget most of them. Specifically, genetics and the related concepts in biology curriculum have counted between the most difficult concepts in biology to learn by students (Bahar, 2002; Bahar, Johnstone & Hansell, 1999; Brown, 1990; Kindfield

1991; Law & Lee, 2004; Tsui & Treagust, 2003; Wiliams, et. al., 2012). However, learning these concepts might provide a key solution to health and disease in today's society since most of the disease originated from the modifications in human genetics. Therefore, the need of promoting the effective teaching and learning of the fundamental ideas that underlie human genomics and genetic modification, such as inheritance, cell division, and sexual reproduction concepts appeared because of the important role of genetics in the society (American Association for the Advancement of Science [AAAS], 2001; NRC, 1996; Wiliams et. al., 2012).

In science education literature, several teaching strategies are proposed to provide meaningful understanding of genetics concepts, especially on Mendelian genetics, mitosis and meiosis processes (Chinnici, Neth, & Sherman, 2006; Chinnici, Yue, & Torres, 2004; Clark & Mathis, 2000; Farrar & Barnhart, 2011; Levy & Benner, 1995; McKean & Gibson, 1989; Mertens & Walker, 1992; Oakley, 1994; Smith & Kindfield, 1999; Stencel, 1995; Taylor, 1988; Williams, Linn, & Hollowell, 2008; Wyn & Stegink, 2000). However, the researches on the effectiveness of these strategies especially the learning cycle instruction on cell division and reproduction concepts is limited. In Turkey, there are three dissertation studies and none of them investigate the effect of learning cycle instruction on meaning construction of students or their alternative conceptions (Canli, 2009; Haras, 2009; Onder, 2011). Although many studies have been performed that compare teaching procedures, few have examined the effectiveness of the learning cycle instruction on the alternative conceptions related with the biology concepts. None of these limited number of studies (Marek, Cowan, & Cavallo, 1994; Saygin, 2009; Stepans et al., 1988) performed hypothesis testing, they reported results via just percentages of alternative conceptions before and after implementation. In view of the deficiency of research in this aspect of biology learning, the present study is aimed to design a cell division and reproduction unit based on 5E learning cycle instruction and investigate the effectiveness of it in improving the students' achievement, understanding and eliminating alternative conceptions. Therefore, the results of this study will provide empirical evidence to the learning cycle literature especially related to the effectiveness in dispelling alternative conceptions.

1.3 Definition of Important Terms

The terms related with this particular study are defined in the following.

The 5E Learning Cycle Instruction: An inquiry-based teaching model which was first proposed in the curriculum project named as 'The Biological Science Curriculum Study' (BSCS). There are five instructional phases, these are; engagement, exploration, explanation, elaboration, and evaluation. The key point was the lessons were student-centered and they constructed their own knowledge spontaneously with help of activities by following each phases under the guidance of teacher.

Conventional Classroom Instruction: The conventional classroom instruction in this study is based on lectures given by teachers by using of textbooks. The key point was that the lessons were totally teacher-centered and teachers transferred biological knowledge to the students with direct, clear and detailed instructions. Based on traditional teaching method, it is contained reading about biology, watching demonstrations, listening to lectures, and memorizing scientific terms and principles (Bybee & Landes, 1990, p. 93).

Achievement on Cell Division and Reproduction: It was defined as superior performance on The Cell Division and Reproduction Achievement Test (CDRAT) developed by researcher. To succeed in answering questions on the test indicates mastery in cell division and reproduction concepts.

Alternative Conceptions: Duit and Treagust explained alternative conceptions as 'students already hold deeply rooted conceptions and ideas that are not in harmony with the science views or are even in stark contrast to them' (2003, p. 671). Results of the studies on alternative conceptions reveals that they play a role as an obstacle for meaningful learning, they remain intact as a result of traditional instruction and need to be overcome (Fisher, 1985; Posner, Strike, Hewson, & Gertzog, 1982; Simpson & Marek, 1988; Wandersee et al., 1994).

Three-tier Diagnostic Test: Instrument type designed to diagnose alternative conceptions includes three tiers; content, reason and confidence tiers. Three-tier test were proposed to compensate for the likely weakness of the diagnostic tests (Caleon & Subramaniam, 2010a; Pesman & Eryilmaz, 2010) and it is claimed that three-tiers diagnostics test not only diagnose misconceptions and but also differentiate them from a lack of knowledge (Arslan, Cigdemoglu, & Moseley, 2012; Pesman & Eryilmaz, 2010).

1.4 The problems

In this section, the main problems, sub-problems and hypotheses of the study were stated.

1.4.1 The Main Problems

The main problem of this study is;

1. What is the effect of 5E learning cycle instruction (LCI) and gender on 10th grade science major public Anatolian high school students' conceptual understanding and achievement in cell division and reproduction concepts, and their alternative conceptions on these concepts compared to conventional classroom instruction (CCI) in Etimesgut district of Ankara?

2. How do 10th grade science major public Anatolian high school students' conceptual understanding of cell division and reproduction concepts differ across groups exposed to 5E learning cycle instruction (LCI) and conventional classroom instruction (CCI) in Etimesgut district of Ankara?

1.4.2 The Sub-problems

Sub-Problem 1

What is the main effect of teaching methods (5E learning cycle and conventional method) on the population mean of collective dependent variables of 10th grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 2

What is the main effect of gender on the population mean of collective dependent variables of 10th grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 3

What is the effect of interaction between teaching methods (5E learning cycle and conventional method) and gender on the population mean of collective dependent variables of 10th grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 4

Is there a statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of the groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 5

Is there a statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 6

What is the interaction effect between teaching methods (5E learning cycle and conventional method) and gender on students' posttest scores of achievement in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 7

Is there a statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 8

Is there statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 9

What is the effect of interaction between teaching methods (5E learning cycle and conventional method) and gender on students' posttest understanding scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

Sub-Problem10

Is there a statistically significant mean difference between posttest alternative conceptions scores about 'cell division and reproduction concepts' of groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 11

Is there statistically significant mean difference between posttest alternative conceptions scores about 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills?

Sub-Problem 12

What is the effect of interaction between teaching methods (5E learning cycle and conventional method) and gender on students' posttest alternative conceptions scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills?

1.5 Hypotheses

$H_0$1: There is no statistically significant main effect of teaching methods (5E learning cycle and conventional method) on the population mean of collective dependent variables of 10^{th} grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

$H_0$2: There is no statistically significant main effect of gender on the population mean of collective dependent variables of 10^{th} grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

$H_0$3: There is no statistically significant effect of interaction between teaching methods (5E learning cycle and conventional method) and gender on the population mean of collective dependent variables of 10^{th} grade science major public Anatolian high school students' posttest scores of achievement, conceptual understanding and alternative conceptions about 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

$H_0$4: There is no statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of the groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills.

$H_0$5: There is no statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills.

$H_0$6: There is no statistically significant effect of interaction between teaching methods (5E learning cycle and conventional method) and gender on students' posttest scores of achievement in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

$H_0$7: There is no statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills.

$H_0$8: There is no statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills.

$H_0$9: There is no statistically significant effect of interaction between teaching methods and gender on students' posttest understanding scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

$H_0$10: There is no statistically significant mean difference between posttest alternative conceptions scores in 'cell division and reproduction concepts' of groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills.

$H_0$11: There is no statistically significant mean difference between posttest alternative conceptions scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills.

$H_0$12: There is no statistically significant effect of interaction between teaching methods and gender on students' posttest alternative conceptions scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills.

CHAPTER 2

LITERATURE REVIEW

In this chapter, related literature of the current study is presented under titles as; how learners construct knowledge, constructivism and gender. Studies on the learners' knowledge construction in terms of the cell division and reproduction concepts were reviewed. Detailed information on constructivist teaching strategies, inquiry based science and the place of 5E learning cycle model in this literature was given. The studies with learning cycle instruction in biology education were summarized in table. At the end, the summary of the literature review were placed to provide short feature of the important parts.

2.1 How Learners Construct Knowledge

During the last 40 years, many science researchers have conducted studies in order to understand how students construct knowledge and their understandings of scientific concepts. Gilbert, Osborne, and Fensham conclude that children are not passive learners and while constructing meanings with their experiences, these experiences led to intuitive knowledge which is named as 'children's science' at three decades ago (1982, p. 623). Research based evidences reveals that 'students already hold deeply rooted conceptions and ideas that are not in harmony with the science views or are even in stark contrast to them' (Duit & Treagust, 2003, p. 671). In the literature, these pre-instructional ideas were called with various terms. Some of them are; alternative conceptions, alternative frameworks, anchoring conceptions, conceptual frameworks, intuitive belief, preconceptions, misconceptions, misunderstandings, and phenomenological primitives (Abraham, Grzybowski, Renner, & Marek, 1992; Andersson & Smith, 1983 as cited in Griffiths & Preston, 1992; Clement, Brown, & Zietsman, 1989; diSessa, 1993; Driver, 1981; Driver & Easley, 1978 as cited in Cho, Kahle, Nordland, 1985; McCloskey, 1983 as cited in Cho, Kahle, Nordland, 1985; Odom & Barrow, 1995; Wandersee et al., 1994). Although science educators used different terms, they are in consensus that many of these pre-instructional ideas are different from scientific ones that are accepted by most of the scientists. Similar with Wandersee et al., (1994), a term 'alternative conceptions' is used in this study to denote students' understandings of concepts which are conflicted with the scientific point of view.

2.1.1 Alternative Conceptions

Hundreds of studies searching for the characteristics of alternative conceptions, the effect of these conceptions on students' meaning construction and identifying alternative conceptions held by students on different subjects were conducted worldwide. Results of these studies reveals that alternative conceptions have role as an obstacle for meaningful learning, they remain intact as a result of traditional instruction and need to be overcome (Fisher, 1985; Simpson & Marek, 1988; Posner, Strike, Hewson, & Gertzog, 1982, Wandersee et al., 1994). Wandersee et al. reviewed studies on alternative conceptions in science and stated eight claims as follows;

> "- Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events.
> - The alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries.
> - Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies.
> - Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.

- Alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture, and language, as well as in teachers' explanations and instructional materials.
- Teachers often subscribe to the same alternative conceptions as their students.
- Learners' prior knowledge interacts with the knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.
- Instructional approaches that facilitate conceptual change can be effective classroom tools" (1994, p.181-191).

Different sources of alternative conceptions were given by Duit (1991) as everyday experiences; everyday language, innate structures of the brain, learning in students' social environments, and instruction. Textbooks (Cho, Kahle, & Nordland, 1985; Kindfield, 1991; Sanger & Greenbowe, 1999; Storey, 1990), teachers (Dove, 1996; Groves & Pugh, 1999; Sanders, 1993; Yip, 1998a, Yip, 1998b), traditional instruction (Kindfiled, 1991; Stewart, Hafner, & Dale, 1990), personal experiences (Lawson, 1988) and mass media (Carin & Bass, 2001; Donovan & Venville, 2012; Duit & Treagust, 1995) were also reported between the origins of alternative conceptions. Being aware of alternative conceptions on intended science concepts and planning instruction according to these alternative conceptions becomes very important to ensure meaningful learning and improve science teaching. In order to this aim, there were lots of pioneer studies exploring students' conceptions were conducted in science education field such as; in chemistry (Novick & Nussbaum 1978; 1981 as cited in Nakhleh, 1992), in physics (Osborne & Gilbert, 1979 as cited in Osborne & Gilbert, 1980) and in biology (Brown, 1990; Brumby, 1979 as cited in Wandersee, Fisher & Moody, 2000; Deadman & Kelly, 1978 as cited in Chattopadhyay, 2005, Fisher, 1985; Simpson & Marek, 1988). A trend of focusing on students' and/or teachers' alternative conceptions on specific science content still continues today (Caleon & Subramaniam, 2010a; Chattopadhyay, 2012; Chu, Treagust, & Chandrasegaran, 2009; Dikmenli, 2010; Pesman & Eryilmaz, 2010; Sesli & Kara, 2012; Williams et al., 2012).

2.1.2 Identifying Alternative Conceptions

"People who first read or hear about misconceptions imagine that they must come tumbling out of students' mouths in every classroom. If this were the case, students' naive conceptions would have been discovered long ago" (Wandersee et al., 2000, p.59). They stated four factors obstructed teachers to know what students' real thoughts are. First, students do not aware of their thinking or their assumptions, second, they are not encouraged to talk about on their thinking in traditional classrooms. Third, as a result of multiple-choice and short answer type testing students do not have opportunities to express their thoughts in nonverbal ways and fourth, the distracters in multiple-choice test items were generated according to teachers' judgment, not included what students really think. Therefore, identifying alternative conceptions needs different methodologies than those are used in traditional classrooms (Wandersee et al., 2000).

Various types of methodologies included concept maps (Hazel & Prosser, 1994; Kinchin, 2000), clinical interviews (Kindfield, 1991; Osborne & Gilbert, 1980; Stewart et al., 1990), both drawings and interviews (Dikmenli, 2010; Smith, 1991), open-ended questionnaires (Atilboz, 2004), questionnaires with open-response items (Dove, 1996; Khalid, 2001, 2003), two tier diagnostic tests (Mann & Treagust, 1998; Odom & Barrow, 1995; Sesli & Kara, 2012; Treagust, 1988), three-tier diagnostic tests (Arslan et al., 2012; Caleon & Subramaniam, 2010a; Kaltakci, & Eryilmaz, 2010; Pesman & Eryilmaz, 2010), as well as four-tier diagnostic tests (Caleon & Subramaniam, 2010b) were used in order to identify alternative conceptions of students on science concepts. When the concept maps considered, mastering in concept maps even application and analysis process requires extra time and effort for both teachers and students (Wandersee et al., 2000). Similar negative characteristics of conducting interviews with concept maps make them hard to use for science teachers. Alternate to concept maps and interviews, multiple-choice tests might be preferred since their easy administration and evaluation characteristics for large group of students as well as teachers familiarity with them. However, multiple-choice test items fail to diagnose underlying reasons for the answers of the participants (Palmer, 1998). Therefore, several studies from different content areas preferred to use diagnostic tests instead of multiple choice test items to collect more information on students' knowledge construction than classical testing techniques (Chu, Treagust, & Chandrasegaran, 2009; Griffard & Wandersee, 2001; Odom & Barrow, 1995; Tsui & Treagust, 2010; Wang, 2004). Treagust (1988) introduced two-tier diagnostic instruments with additional reason tier included alternative conceptions to classic multiple choice tests to the field of science education research. Two-tier diagnostic tests became popular instruments and a great amount of studies used them in different science subject matter (Chu, Treagust, & Chandrasegaran, 2009; Griffard & Wandersee, 2001; Odom & Barrow, 1995; Tsui & Treagust, 2010; Wang, 2004). Despite the usefulness of two-tier tests to provide more information on students' understanding than most of other commonly used diagnostic techniques, there were some limitations that have been identified. Students may guess the correct answer by chance either on the first or the second tier of two-tier tests therefore, the results of these test might overestimate not only students' levels of knowledge but also their misconceptions (Caleon & Subramaniam, 2010a; 2010b; Pesman & Eryilmaz, 2010). An additional tier that asks for the certainty of response has been proposed to increase the incredibility of these tests by providing discrimination of lack of knowledge from misconceptions (Hasan, Bagayoko, & Kelley, 1999; Pesman & Eryilmaz, 2010).

2.1.3 Alternative Conceptions in Cell Division and Reproduction Concepts

The findings of the studies conducted on students' conceptions of cell division and reproduction concepts revealed that students hold many alternative conceptions in these concepts since there are lots of new terms and procedures introduced to the students. Most of the students have a great deal of difficulties in keeping the name of the different phases, conceptualizing the structure, the function of chromosomes (Brown, 1990; Kindfield, 1991; Smith, 1991), and the processes during these phases (Dikmenli, 2010), differentiating the phases of mitosis and meiosis, combining their daily life experiences to the knowledge of asexual and sexual reproduction (Knippels, 2002; Tekkaya, Ozkan, Sungur, 2001). Domain specific terminology

(Lewis, Leach, & Wood-Robinson, 2000), abstract nature of genetic concepts (Knippels, 2002; Tekkaya, Ozkan, Sungur, 2001), and alternative conceptions on cell division and reproduction (Atilboz, 2004; Brown, 1990; Kindfiled, 1991; Stewart et al., 1990) were stated among the sources of these difficulties. Cell division, which is crucial concept in biology curriculum, is directly related with inheritance and reproduction. "A strong understanding of biological inheritance necessarily requires a clear conception of cell division and of the differences and importance of mitosis and meiosis" (Williams et al., 2012, p. 82). Consequently, lack of understanding and disconnection between meiosis, sexual reproduction and inheritance result in poor conceptual basis of genetics (Knippels, 2002). Therefore, students need to have depth understanding of mitosis, meiosis, asexual and sexual reproduction in order to acquire success in genetics.

A number of studies have been reported various alternative conceptions on the structure, function of chromosomes as well as on the cell division and reproduction concepts of students' in different grade levels; some of these studies are reviewed below:

In the end of 80's and the beginning of 90's a set of studies were conducted on student conceptions in genetics and findings of these studies indicated that students hold a variety of alternative conceptions on the process of meiotic division (Brown, 1990; Kindfield, 1991; Stewart et al., 1990; Smith, 1991). Brown (1990) examined alternative conceptions in meiosis and provided four red and four green pipe cleaners, two plastic ties, four small self-adhesive labels and a few centimeters of adhesive tape to 614 students and had them to construct a model that represents the structure of a pair of homologous chromosomes at the metaphase I (in meiosis). 52.9% of the students were successful to show the chromosome duplication by using identical pipe cleaners. However, 18.2% of the failing group demonstrated sister chromatids with different colour pipe cleaners and 9.6% represented a two-chromosome model but each chromosome was constructed with four pipe-cleaners. Therefore, these results indicated that the students do not know the fact that the chromosome duplication results in two identical chromatids and they have lack of understanding in homologous chromosomes. In addition, when they were asked to show the chromosome carried heterozygous allele A, 22.8% of the subjects do not attempt to complete this task. Only 16% of the subjects completed this task successfully and unsuccessful attempts showed several alternative conceptions of the students. Results revealed that students have lack of understanding of the concept 'locus' since they labelled alleles at different positions on homologous chromosomes.

Stewart et al., (1990) explored 50 freshman and sophomore high school students' alternative views of meiosis. Each subject of the study, who had received one month instruction in meiosis before, participated in a 50 minute problem solving /interview session. They were asked for thinking aloud while solving problems. Forty-one of the 50 students obtained correct answers to the dihybrid problems. However, 35 of those 41 were able to construct and discuss chromosome/gene models. The researchers categorized students' drawings according to chromosome number that the participants used. Although correct model had been presented during the instruction, nine of the students drawn one-chromosome model and these students had a very little knowledge of the mechanism of meiosis. Nineteen students constructed a two-chromosome model which indicated little higher level of knowledge on the mechanism than one-chromosome model however most of these are produced by an "all possible combinations" approach which means these models were not derived with a complete understanding of meiosis. In addition, some students have a tendency to confuse the concepts of "chromatid" and "chromosome". Fourteen students drawn four-chromosome model but three of those 14 was able to produce correct gamete types and these three correct models. It can be concluded that students might gave correct answers to the problems without a complete understanding of the meiosis even they hold alternative conceptions. Therefore the researcher suggested that being aware of these alternative conceptions and rewarding little understanding instead of correct answers should be essential points in genetic learning.

Smith (1991) interviewed six junior and senior undergraduate students enrolled in a genetics course in order to gain an understanding of their difficulties with cell division. After the subjects had been presented in class, approximately 90 minutes interviews conducted were videotaped. Students were asked to talk about their personal definitions of number of genetic terms, and diagram mitosis and meiosis on the chalkboard while thinking aloud to describe in detail the events. After the researcher identified the basic pattern of the difficulties in these interviews, he obtained more information from 50 undergraduate students enrolled an introductory biology course. During this course students diagramed cell division as a part of two ungraded surprise quizzes, homework, a midterm and a final exam. Collected data were analyzed for the evidence of alternative conceptions on cell division concepts. Reported prominent difficulties are summarized in the followings;

- Students often diagramed that two-chromatid chromosomes are formed by preexisting monads.
- Students do not understand the distinction between chromosome and chromatid so they often confused about the chromosome number.
- Students thought that two new cells produced and the original parent cell continues to exist after mitosis.
- Students could not realize what event is relatively unimportant in the cell division process. For instance, they diagramed cytoplasmic events in detail but not important chromosomal events.
- Presenting crossing over contributes students' misunderstandings if they do not conceptualize cell division concepts in detail.

As a conclusion, Smith specified that doubling, pairing, and separating are three basic phenomena that confuse students and he stated " recognizing the similarities among the common meanings of these terms gives a clearer view of some reasons why students find cell division a difficult topic" (1991, p.31).

Studies of Brown 1990, Stewart et al., 1990 and Smith (1991) findings on students' difficulties in understanding chromosome structure, especially participant students' drawings of both two alleles of a gen on one chromatid triggered Kindfield (1991) designed a study to examine students' alternative conceptions on the chromosome number and structure in the context of meiosis. She conducted 1.5-2 hour individual interviews with five biology undergraduate students enrolled in their first university genetics course. She named them as 'inexperienced novices' since their prior knowledge on meiosis was gained from only high school biology and university introductory biology courses. During the interviews students tried to solve a non-traditional genetics problem, answered follow-up questions, identified and discussed some standard representations of DNA, genes, and chromosomes. Three of those five inexperienced novices explicitly hold the ploidy/structure alternative conception that chromosome structure is viewed as a function of chromosome number. According to one of these students, 'the chromosome structure and chromosome number were completely connected and haploid chromosomes joined to form diploid chromosomes via fertilization' (p.196). In addition to these three students, the fourth inexperienced novice had difficulty in deciding or remembering the time of replication and this situation was also connected with her association between chromosome structure and ploidy.

Kindfield (1993-1994) characterized components of 15 participants' conceptual understanding of subcellular processes like mitosis and meiosis. Different from the previously reviewed study, the participants have different degree of formal training in genetics; 6 geneticists (2 professors, 2 visiting lecturers, and 2 advanced graduate students), 5 genetics majors (senior undergraduate genetics honor students) from the genetics department, 5 biology majors (undergraduate students enrolled in an introductory genetics course). 1.5 to 2 hours clinical interviews were conducted with the participants while they had been working on genetic problems. After they complete problem solving, they were shown 10 standard diagrams of chromosome and DNA, and asked to identify each one. The results of the study indicated that 2 geneticists and 3 genetic majors displayed completely correct chromosome/process models, 3 geneticists and 1 genetic major showed correct chromosome models and slightly flawed process models, and 1 genetic major and all 5 biology majors showed flawed chromosome/process models. All of 15 participants drawn diagrams of chromosomes, however the less advanced participants often drew chromosomes that have no bearing on the mechanics of meiosis. The results supported the idea that the representation/ diagrams of chromosomes play and important role on conceptual understanding on cell processes.

Yilmaz (1998) identified 10th grade high school students alternative conceptions related to cell division unit and investigate the effects of conceptual change texts accompanied with concept mapping on remediation of these alternative conceptions. 10 students were interviewed to determine common alternative conceptions to construct a diagnostic test. The researcher reported the following alternative conceptions that the students held:

- '…chromosomes and DNA are present separately inside the nucleus and also their functions are different
- …cells (somatic and germ cells) have different DNA structure because they can manage different events
- …meiotic cells have more DNA and chromosome than the mitotic cells
- the mother cell would dissapper after the cell division
- one of the new daughter cell is the mother cell and the other cell is the newly formed cell.
- …meiotic cells are formed after mating of mother and father cell and during this mating, chromosomes were combined with each other
- combination of homologous chromosomes was the replication of the chromosome and also duplication of replicated chromosomes produced the homologous chromosomes
- ... homologous chromosomes were present in meiotic cells, not in mitotic cell
- chromatids of the replicated chromosome were known as homologous chromosomes.
- Students replicated the chormosomes conservatively
- …mitosis occur at multicellular organisms
- …crossing over is the exchange of the genes between the chromatids of the replicated chromosomes

- Mutation in any cell of an individual can create the variation between the people (p.53-70)

The studies of Lewis and Wood-Robinson (2000) and Lewis, Leach, and Wood-Robinson (2000) pointed out that most of the students have several alternative conceptions and reported their findings on students' understandings on processes, purposes and products of cell division and fertilization. Written responses of 482 students, aged 14-16, were collected into two sets of questions focused on mitosis, meiosis and fertilization and also an open-ended question asked the reason for their answers. Particularly, results indicated that the widespread lack of understanding of the physical link between chromosomes and genetic material and the relationship between the behavior of chromosomes at cell division and the continuity of genetic information (p.189). Many students have difficulty in the terminology, two thirds of the sample does not distinguish between mitosis and meiosis and some of them confused the process of meiosis and the process fertilization. In many cases, although they gave correct answer to the question, their reasons were not compatible with the scientific view. Specifically, over one third of the ones who gave correct response to the question what the chromosome number of skin cells will be after division said that the chromosome number would remain the same because the cells were of the same type (skin cells). The others reported reasoning in responses of students are;

- The daughter cells are new and young and so have more chromosomes.
- The chromosomes will eventually start to die so the chromosome number will start to reduce.
- Chromosomes and/ or genetic information are shared but not copied during cell division.
- The daughter cells would carry same genetic information but would have less/more chromosomes.
- Cells in plants are rigid so they cannot divide.
- Egg cells have only two chromosomes (XX).
- Egg cells only got X's, but the sperm cells has got X and Y.
- When a cell divides (meiosis) its chromosomes double.

- Daughter cells in meiosis will contain the same number as in the original cell because this is how your baby looks like you.
- Different types of cells have different genetic information that they need for their specific function.
- Plants grow from roots; they don't mate together because they can't move.
- Mitosis/Meiosis is the only type of cell division that occurs in plants.
- Sperm cells have more chromosomes/genetic information than egg cells.
- The number of chromosomes in fertilized egg would remain same with egg cell.
- Seeds are the product of asexual reproduction.
- Bright colored plants reproduce sexually because bees bring pollen whereas dark colored plants make their own pollen and eggs to fertilize together.

In addition to these above mentioned results, Lewis and Wood-Robinson (2000) represented students' alternative understanding under subtitles as, uncertainty about the relationship between genes and chromosomes, difficulties with the concept of 'cell', confusion about the terminology of cell division and its meaning, difficulty in distinguishing between processes.

Chattopadhyay (2005, 2012) carried out a study to examine Indian students' understandings of cell division concepts by using a questionnaire developed by Lewis et.al., (2000). There are six set (titled as; size sequence, living things, biological terms, cell division, reproduction, and cells) of questions which combines both fixed- and free-answer types. Results of the data that were collected from 289 12th grade high school students were reported in two papers (Chattopadhyay, 2005; 2012). The findings of the cells and the reproduction sections indicated that noticeable proportion of students confused similarities and/or differences between genetic information of the cells from different tissues in an individual, especially in sex cells. In addition, none of the participants could differentiate between somatic and germ cells (Chattopadhyay, 2005). The results of the cell division section showed that 44.5% of the students thought that chromosome number would be double after mitosis, however 76.0% selected the genetic information would remain same (Chattopadhyay, 2012). Therefore, students' ideas on the relationship between chromosome and genetic information are not consistent. Additionally, the students could not distinguish between mitosis and meiosis in terms of the cells or tissues that these processes occur.

Similar findings with Chattopadhyay (2012) and Lewis and Wood-Robinson (2000) were reported in the research of Williams, Debarger, Montgomery, Zhou, Tate (2012). In this particular study, 209 seventh graders were treated with WISE genetic inheritance materials for 5 weeks and pre/post tests were administered. They found that understanding of the differences between mitotic and meiotic divisions are challenging for middle school students. Regardless of achievement level, most of them hold both normative and non-normative ideas on cell division, especially on the purpose and the products of two different divisions. In addition, low-achievers, some of the middle and high-achievers have very limited understanding of the importance of the cell division processes and could not distinguish between mitosis and meiosis.

In the study of Quinn, Pegg and Panizzon (2009) noted similar problems in students' conceptions with those mentioned above after they studied with 334 first year biology students' understandings of the process of meiosis. Following a teaching procedure covered DNA, chromosomes; basic cell structure and introduction to meiosis, students' understandings of meiosis were investigated by two open questions. In addition to that semi-structured interviews were conducted with 16 students approximately 30 minutes to 1 hour in duration in order to data triangulation. Higher frequency of written responses were categorized under concrete symbolic mode which means that the written responses include elements relating to how meiosis works but in an incomplete and incoherent form or as discrete unrelated points. Interview findings of the study revealed students' confusion and alternative conceptions about meiosis. Several students have difficulty in understanding the nature of homologous pairs and held alternative conceptions about how homologous are formed, how they differ from replicated chromosomes and how their separation provides full genome structure in meiosis. For instance, one of the participant thought that two chromatid form a homologous chromosome; one of them confused about whether homologues or sister chromatids are the same, and one of them expressed chromatids as single-stranded DNA molecules. Although the results of the study are in harmony with the previous studies (such as Brown, 1990; Smith, 1991), the last alternative conception example is same with the findings of Kindfield's (1991) study that showed students hold the ploidy/structure alternative conception.

Banet and Ayuso (2000) identified 267 secondary students (aged 15-16) ideas on some basic aspects related to the location of inheritance by using various question types (open-ended, multiple choice and two tier items) and interviews altogether. They found that many students have significant alternative conceptions regarding inheritance information and reported them as the followings;

- Plants do not have chromosomes.
- Some invertebrates, plants, or mushrooms do not have genes.
- Plants do not reproduce sexually.
- Sex chromosomes only exist in gametes
- Somatic cells except brain do not carry the inheritance information.
- Only gametes carry inheritance information.
- Cells possess only specific genes in accordance with their function (for instance; the cells of the heart do not carry inheritance information about eye color, but they do carry information on a person's blood group) (Similar finding with Lewis et al., 2000).
- While a baby formed, inheritance information in zygote is divided up among different cells (consistent with Lewis et al., 2000).

In addition to these alternative conceptions, Banet and Ayuso concluded that students were unaware about the facts that cells are formed from the zygote by mitotic cell cycles and inheritance information transmitted to daughter cells is identical.

Riemeier and Gropengießer (2008) investigated students' difficulties in learning cell division, the roots of these difficulties and also the impact of learning activities on students' conceptions. Teaching experiments which lasted about 75-90 minutes with three 9th grade students were videotaped and students' dialogues were analyzed. Before activities students thought that growth provided by cell multiplication and imagine this multiplication through division but they did not realize that becoming smaller is a natural result of division. The findings of the study revealed four major difficulties in learning cell division and their roots. First, students' thought that growth as becoming mature. This difficulty is originated from that these students have no direct experiences for growth on the microscopic level. Second, students believed that cell division is just multiplication of cells. This belief might be root from the usage of the scientific term "cell division" which emphasize on the division process and disregards the necessary enlargement of the cells between two cell divisions. Third, the number of chromosomes decreases in daughter cells since chromosomes are viewed as a collection of pieces that are distributed between these cells. Fourth, students' thought that enlargement of the nucleus is occurred during division. According to the researchers this difficulty is rooted from the conception acquired during teaching experiment which is the need of enlargement of cells before division and students transferred their new conceptions to nucleus of cell. In addition, the researchers categorized students conceptions of cell division into three different levels; cell, nucleus and chromosomes.

Studies on understanding of cell division concepts in Turkey indicated that there is widespread confusion and alternative conceptions among Turkish students. Atilboz (2004) determined 9th grade 139 Turkish students' understanding levels of mitosis and meiosis concepts and identified alternative conceptions on these concepts by administering both close-ended and open-ended questions. Results of the study indicated that students do not understand the concepts of DNA, chromosome, chromatid, homologous chromosome, haploid and diploid, therefore they could not conceptualize mitosis and meiosis correctly. She reported 16 alternative conceptions on mitosis and meiosis concepts, these are;

- Diploid cells are formed as a result of meiosis.
- Haploid cells are formed as a result of mitosis.
- Somatic cells have only one homologous chromosome from each pair.

- Gamete cells have two sets of homologous chromosomes.
- The amount of DNA doubled after meiosis.
- The number of chromosomes and chromatids is equal to each other.
- The structure of a chromosome includes chromatin fibers.
- Crossing over occurs between homologous chromosomes.
- Homologous chromosomes are the sister chromatids.
- Sister chromatids are the one of the homologous chromosomes that placed side by side.
- The chromosome number is constant in the anaphase II of meiosis.
- The chromosome structure of a cell in prophase of mitosis is same with the daughter cell.
- Chromosomes move to opposite ends of the cell during the metaphase.
- Homologous chromosome pairs are placed in the equator of the cell during the metaphase of the mitosis.
- Chromosomes are placed in the equator of the cell during the the anaphase.
- Homologous chromosomes move to opposite ends of the cell during the telophase.

Adiguzel (2006) conducted study with 1180 8th grade students in order to identify their alternative conceptions on mitosis and meiosis concepts and with 65 science teachers to define their opinions on reasons and solutions of these alternative conceptions n Turkey. 20 items instrument, first tiers were classic multiple choice test item and second tiers included 3- level certainty index, was used to determine students alternative conceptions. Although the identified alt were not reported one by one, students have alternative conceptions on 12 of the 14 reported subtopics such as the phases of mitosis, the number of daughter cells after mitosis and meiosis, and common characteristics of mitosis and meiosis. When teachers' opinions on the reasons of these alternative conceptions were analyzed, sixty six percent of the teachers thought that course book do not contain enough knowledge and 63% of the thought that students do not have possibilities to conduct experiments in their school.

Sesli and Kara (2012) developed a two tier diagnostic test to determine students' understanding of cell division and reproduction concepts and administered it to 403 Turkish high school students (aged 16-19). After the analysis, the most frequent alternative conceptions among the reported twenty-three are listed below;

- Prokaryotes reproduce through mitosis (34.9%).
- The cells formed through the same type of cell division would have the same genetic information (33.9%).
- There is no genetic difference among one celled organisms (27.5%).
- Simple species only reproduces asexually (26.1%).
- Meiosis can occur both in somatic and reproductive cells of the body (25.1%).
- Since plant and animal cells are different, plant cells cannot have cell division (23.8%).

Researchers of this study concluded that there is consistency between alternative conceptions and lack of understanding (especially on the relationship between types of cell division or genetic information and on sexual/asexual reproduction in prokaryotes). In addition, "alternative conceptions were related to many other alternative conceptions about reproductive systems, growth and development, inheritance, genetics and evolution" (p. 220).

The participants of most of the studies on alternative conceptions on cell division concepts were primary and secondary school students or undergraduate biology majors. However, teachers are one of the primary sources of students' alternative conceptions and sometimes they have the same alternative conceptions with their students (Hashweh, 1987). According to Arslan et al., (2012), teachers' lesson plans as well as their teaching affected by these alternative conceptions and result in reinforcing students' alternative conceptions instead of remediating them with scientific facts. A few studies were conducted with in-service or pre-service teachers. For instance, Dikmenli (2010) identified 124 Turkish pre-service biology teachers' alternative conceptions on cell division by using their drawings and interviews. Participants gained knowledge on cell division from the courses cytology, genetics and molecular biology before the study. First drawings of 124 pre-service biology teachers were collected and analyzed. Then, based on the results of these drawings, 15 students who held alternative conceptions were interviewed. Results of the drawings indicated that 46% of the participants did drawings included alternative conceptions on mitosis and 54% of these included alternative conceptions on meiosis. A total of 32 alternative conceptions were listed as findings of the drawings and interviews. Most of these alternative conceptions were on the process of the stages of mitosis and meiosis, the exact time of the DNA replication during cell cycle, the number and the structure of the chromosomes. Some of these alternative conceptions were similar with the findings of the previous studies. The most prevalent of them are listed below;

- Interphase is the resting phase of mitosis.
- DNA replication occurs in prophase during the process of cell division.
- The chromosome number is doubled in the prophase of mitosis and halved in the anaphase of mitosis.
- Chromosomes and chromatids are essentially the same thing.
- The chromosome number remains the same during meiosis-I and is halved during meiosis-II.
- In mitosis, homologous chromosomes separate in the anaphase. (Dikmenli, 2010, p.241).

The findings of this study have important implications on both science and biology teacher preparation programs since the participants of the study had already instructed on cell division concepts in various courses of their programs.

Tekkaya, Capa, and Yılmaz (2000) also conducted study with 186 pre-service biology teachers to determine their alternative conceptions on general biology concepts. The researchers asked in which stage the DNA replicated and 54.8% of the participants answered correctly however, 24.2% of the rest selected "prophase", 9.7 of them selected "metaphase" and 7% of them selected "anaphase" from the distracters of the related item. Responses of student teachers to another item indicated that 53.2% of them thought that the amount of DNA is different during the prophase, metaphase and anaphase stages of the mitosis. In addition to these findings researchers stated that the participants have misunderstandings on some important concepts such as; gene, allele, homologous chromosome, replicated chromosomes, chromosome numbers, DNA strands.

Emre and Bahsi (2006) identified alternative conceptions on cell division concepts of the Turkish pre-service science teachers' and reported similar findings with the previously reviewed studies. Data collected from 76 sophomore science teacher candidates revealed that they held alternative conceptions on mitosis for instance; 60.5% of them thought that plants do not undergo mitosis, 34.2% of them thought that cell could reproduce, repair and grow with mitosis, and 31.6% thought that mitosis consist of interphase, karyokinesis and cytokinesis. When meiotic division considered four frequent alternative conceptions that the students held were listed; crossing over occurs between sister chromatids (75%), homologous chromosomes separate right after crossing over (61.8%), mitosis results in genetic recombination (40.8%), crossing over is the only reason of genetic diversity (30.3%).

The literature on the conceptions of reproduction concepts is not extensive, few related studies are reviewed in the report of Leeds National Curriculum Science Project (Leeds, 1992) on children' ideas about reproduction and inheritance. Some of the notions stated in this report are;

- Eggs and seeds are not alive (Tamir, 1981).
- Plants are not capable of sexual reproduction (Okeke & Wood-Robinson, 1980).
- Asexual reproduction is restricted to micro-organisms (Okeke & Wood-Robinson, 1980).
- A human ovum contains yolk on the same scale as a birds' egg (Okeke & Wood-Robinson, 1980).
- Sexual reproduction must involve mating (Hampshire, 1986).
- Male animals are always bigger and stronger than females (Hampshire, 1986).

- Animals consciously plan their reproductive strategies (Hampshire, 1986).
- Asexual reproduction results in weakness and sexual reproduction always produces stronger individuals (Hampshire, 1986).
- Hermaphroditism is the same as asexual reproduction (Hampshire, 1986).
- Mother provides the main contribution in the transmission of characteristics or same sex inheritance (from mothers to daughters and from fathers to sons) occurs (Hampshire, 1986; Engel-Clough & Wood-Robinson, 1985; Kargbo, Hobbs, & Erickson, 1980).
- The source of variation is just environmental factors (sexual reproduction is not recalled by students)

Berthelsen examined students' naive conceptions in life science and listed them for different content areas. The ones that are related with reproduction are presented below;

- Daughters inherit most of their characteristics from their mothers. Boys inherit most of their characteristics from their fathers.
- Sexual reproduction occurs in animals but not in plants.
- Students do not distinguish between sexual and asexual reproduction.
- Asexual reproduction produces weak offspring, sexual reproduction produces superior offspring.
- Students do not understand the relationship between DNA, genes, and chromosomes (as cited in Perrone, 2007, p. 13).

2.2 Constructivism

Constructivism is a theory of knowing and learning which often contrast with the behaviourist tradition in learning and not included teaching in the beginning of the theory introduced. Giambattista Vico is given credence as a first psychologist defined a way of knowing and learning as constructivism in his published treatise on the construction of knowledge in 1710. In his study, he proposed the idea that "knowledge is something that is constructed by the knower" (Gruender, 1996). After a while, the constructivism was integrated with teaching by the studies of the primary contributors to this theory such as; Jean Piaget, Jerome Bruner, Lev Vygotsky, John Dewey, Von Glasersfeld, and Nelson Goodman. The points of views of these pioneers slightly differ, and these differences results in a broad categorization of constructivism as; cognitive, radical and social. Driscoll emphasized that "There is no single constructivist theory of instruction. Rather, there are researchers in fields from science education to educational psychology and instructional technology who are articulating various aspects of a constructivist theory" (1994, p.360). However, there is a common assumption that the constructivist theory rests on; knowledge is constructed by learners who are not an empty vessels waiting to be filled but rather active organisms seeking meaning.

According to Doolittle, in general, eight factors underlined by constructivists even they have different aspects, these are:

- "Learning should take place in authentic and real-world environments.
- Learning should involve social negotiation and mediation.
- Content and skills should be made relevant to the learner.
- Content and skills should be understood within the framework of the learner's prior knowledge.
- Students should be assessed formatively, serving to inform future learning experiences.
- Students should be encouraged to become self-regulatory, self-mediated, and self-aware.
- Teachers serve primarily as guides and facilitators of learning, not instructors.
- Teachers should provide for and encourage multiple perspectives and representations of content" (1999, p.4-7).

Therefore, in contrast to the objectivist view that concentrates on identifying entities, relations and attributes that the learner must know, the constructivists proposed learning goals should emphasize the process of learning in the context of meaningful activity and they recommend various instructional methods to meet this goal (Driscoll, 1994). The implication of these instructional methods such as, cooperative learning (e.g. Johnson, Johnson, & Smith, 1991; Lord, 2001; Tanner, Chatman, &

Allen, 2003), concept mapping (e.g. Novak, 1990; Uzuntiryaki & Geban, 2005; Wallace & Mintzes, 1990), conceptual change approach (e.g. Nussbaum & Novick, 1982; Pearsall, Skipper, & Mintzes, 1997; Posner, Strike, Hewson, & Gertzog, 1982; Songer & Mintzes, 1994; Venville & Treagust, 1998), learning cycle model (e.g. Campbell, 1977; Cavallo & Laubach, 2001; Cavallo, McNeely, & Marek, 2003; Johnson, 1993; Lavoie, 1999; Lawson & Johnson, 2002; Lord, 1999; Musheno & Lawson, 1999), cognitive apprenticeship (e.g. Collins, Brown, & Newman, 1989; Hennessy, 1993), role plays (e.g. McSharry & Jones, 2000; Ross, Tronson, & Ritchie, 2008), argumentation (e.g. Niaz, Aguilera, Maza, & Liendo, 2002; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002) have been conducted in several years. Among these methods, conceptual change model have become very popular in science education community and lots of studies were conducted based on this strategy. In the current study, conceptual change approach that connects the alternative conception studies with constructivist approach will be explained in detail.

2.2.1 Conceptual Change Model

Alternative conception studies triggered researchers to study on teaching science effectively and these studies were embedded in conceptual change model which was first proposed by Posner, Strike, Hewson, and Gertzog three decades ago. They contended that a theory based on Kuhn's and Lakatos's approaches and also Piaget's ideas of assimilation and accommodation might change learners' knowledge structure on a specific subject matter. The theory, conceptual change becomes a kind of scientific paradigm shift by being the most significant learning model and posits that learning consists of repeated interactions that take place between students' existing conceptions and their new experiences. Although the most predominant conceptual change model is the first proposed one, it was expanded by Hewson (1981, 1982) and revised by Strike and Posner (1985, 1992).

There are two kind of conceptual change approach described in the first model; assimilation and accommodation. If students use their existing concepts to deal with new phenomena; it is named as assimilation. Assimilation is seen as relatively easy form of conceptual change, since elementary school students do not find it difficult to add facts to an existing conceptual structure when these facts are consistent with the knowledge that is there already (Vosniadou, 1994). However, if students' current concepts are inadequate to accomplish new conceptions; in that case students should replace or reorganize their existing ideas (accommodation). According to Vosniadou "when the beliefs of a specific theory are constrained by a framework theory, conceptual change can be very difficult to achieve (1994, p.49).Posner et al. suggested four conditions for conceptual change;

"1. There must be dissatisfaction with existing conceptions.
2. A new conception must be intelligible.
3. A new conception must appear initially plausible.
4. A new concept should suggest the possibility of a fruitful research program" (Posner et al., 1982, p. 214).

The first condition requires that teachers must be aware of learners' preexisting ideas, point out the contradictions between these ideas and the scientifically accepted ones and provide persuasive reasons for questioning their ideas. Diagnosing students' alternative conceptions and guiding them according to these conceptions plays a crucial role in conceptual change approach. The second condition, intelligibility, can be ensured by using analogies, metaphors and physical models (Posner et al., 1982; Vosniadou & Brewer, 1987). There are five ways by which a conception can become initially plausible were listed in their study. These are;

1. "One finds it consistent with one's current metaphysical beliefs and epistemological commitments.
2. One finds the conception to be consistent with other theories or knowledge.
3. One finds the conception to be consistent with past experience.
4. One finds or can create images for conception, which match one's sense of what the world is or could be like.
5. One finds the new conception capable of solving problems of which one is aware" (p. 218).

The last condition need that the learner has already conflicted with the preexisting knowledge found the new idea intelligible and plausible and started to interpret experiences with it, in that sense the new conception should lead new insights and discoveries so become fruitful. These four conditions need to be meet in order for a learner to experience conceptual change. Hewson emphasized that "the extent to which the conception meets these three conditions is termed the status of a person's conception. The more conditions that a conception meets, the higher is its status" (1992, p.8). He also mentioned the second important component of conceptual change model- the person's conceptual ecology-

> "… the person's conceptual ecology that provides the context in which the conceptual change occurs, that influences the change, and gives it meaning. The conceptual ecology consists of many different kinds of knowledge, the most important of which may be epistemological commitments (e.g. to consistency or generalizability), metaphysical beliefs about the world (e.g. the nature of time), and analogies and metaphors" that might serve to structure new information.
>
> Learners use their existing knowledge (i.e. their conceptual ecology), to determine whether different conditions are met, that is whether a new conception is intelligible (knowing what it means), plausible (believing it to be true), and fruitful (finding it useful). If the new conception is all three, learning proceeds without difficulty" (1992, p.8).

The importance of learners in learning costruction rather that teacher is emphasized by both Posner et al. and Hewson since the learner makes the decisions about conceptual status and conceptual changes and manage his her own learning.

How these conditions and learners' conceptual ecology applied to instruction was also explained by Hewson (1992). According to him there are three stages in conceptual change teaching. These are;

1. *Diagnosis / Elicitation:* Does the teacher use any diagnostic techniques to elicit students' existing conceptions and reasons why they are held?

2. *Status Change:* Does the teacher use strategies designed to help students lower the status of existing, problematic knowledge, and raise the status of other, competing ideas? Are there other application sites where the new conception can be used?

3. *Evidence of outcome:* Is there evidence that students' learning outcomes are based, in part, on an explicit consideration of their prior knowledge? (p.11)

A number of different studies that investigated the effect of the model compared to more traditional methods emerged from the implication of conceptual change model for science education. Among the pioneer studies, Hewson and Hewson (1983) used the conceptual change model to examine the effects of the students' prior knowledge and conceptual change strategies on science learning. In this work, pre- and post-tests relating the concepts of mass, volume and density were used to assess the conceptual change of students. They reported that the experimental group students showed significant improvement in the acquisition of scientific conceptions.

Hynd, Alvermann and Qian (1997) investigated changes in pre-service elementary school teachers' conceptions about projectile motion. A study with a group of teachers (n=73) randomly assigned to groups of using combination of texts and demonstrations and only texts technique was carried out where the concepts were the lessons. Demo-text technique was found to be effective in short-term assessment while only text group found to be more successful in producing long-term change.

There are number of teaching strategies to promote conceptual change in students. For instance; Eryılmaz (2002) investigated the effects of conceptual assignments and conceptual change discussions on students' misconceptions and achievement regarding force and motion and indicated that the conceptual change discussion was an effective tool for reducing the number of misconceptions students held about force and motion. Conceptual change texts and concept maps were used. Sungur, Tekkaya, and Geban (2001) was conducted to investigate the contribution of conceptual change texts accompanied by concept mapping instruction to 10th- grade students' understanding of the human circulatory system. It was found that conceptual change texts accompanied by concept mapping resulted in better understanding. Demonstrations are also used in conceptual change approach as a teaching strategy. Gedik, Geban and Ertepınar (2002), stated that the demonstration method based on conceptual change approach caused a significantly better acquisition of scientific conceptions related to electrochemistry and elimination of misconceptions than the traditional method. Similary, Yavuz (2005) conducted a study by using demonstration based on conceptual change approach. The results strongly support that demonstrations are popular teaching tools. In this study, most of the students agreed that demonstrations helped them understand theories and formed an encouraging link between demonstrations and educational value. In addition, refutational texts, storytelling, analogy, portfolio and cooperative learning strategies can be listed among the strategies that are proposed to promote conceptual change in students. In their meta-analysis study, Guzzetti, Snyder, Glass, and Gamas, (1993) identified 86 different instructional strategies used by science researchers to replace alternative conceptions with scientifically accepted conceptions and illuminated that instructional interventions designed to offend the intuitive conception were effective in promoting conceptual change based on statistical evidence of the studies.

Although the theory ‘have proven superior to more traditionally-oriented approaches in a number of studies’ (Duit & Treagust, 2003, p.674), it has drawn some criticisms from science researchers. Sinatra (2005) pointed out that researches did not explain why change often occurs for some students and not for others who have similar background knowledge. The difference in the effectiveness of conceptual change among learners might be sourced from the individual differences. According to Pintrich, Marx and Boyle (1993), cognitive processes can be influenced by students’ motivational beliefs and they called conceptual change as a ‘cold case’ in their study. In fact, this is not a new assumption since Piaget have already noted that cognition and affect were inseparable and proposed that affect was related to energizing of all action, including cognitive activity (as cited in Pintrich et al, 1993). In addition to that Strike and Posner have already stated that "noted motives and goals and the institutional and social sources of them need to be considered in conceptual change models" (1992, p.162).

2.2.2 Inquiry-Based Science

The criticism of traditional teaching methods that are teacher centred and emphasize memorization direct science educators to design different instructional methods rather than the ones used in classes such as; problem solving, discussions and cook book laboratories. John Dewey proposed an instruction that was emphasized science as a method of inquiry. He argued that the nature of scientific inquiry provides the basis of this new approach in the beginning of nineties. However, the implication of inquiry approach into a large scale science curriculum movement takes more than 40 years. The accepted superiority of Soviet Union successfully launched Sputnik I affected science education like political, military, technological, and scientific developments. After 1950s, NSF sponsored lots of curriculum development projects that are originated from inquiry based science in USA. Lots of inquiry oriented projects, such as Biological Sciences Curriculum Study (BSCS), Science Curriculum Improvement Study (SCIS), the Chemical Education Materials Study (Chem Study), the Physical Science Study Committee (PSSC Physics), and the Elementary Science Study (ESS) were developed. All of these curriculum projects aimed to ensure meaningful learning construction by active participation of the students in science, biology and earth sciences. Among these projects, SCIS took an important role by proposing a systematic approach to instruction, the learning cycle model, to the science education literature by J. Myron Atkin and Robert Karplus with the influence of the Piagetian theory.

2.2.3 Learning Cycle

Robert Karplus, director of the SCIS and professor of physics at the University of California, Berkeley, claimed that the science teaching requires more than content and proposed a teaching procedure originated from both the nature of scientific discipline and the manner in which students learn (Marek & Cavallo, 1997). He named this teaching procedure as "learning cycle" and asserted that it will satisfy the requirements of science teaching (Lawson, Abraham, & Renner, 1989). The first proposed model had three phases; "preliminary exploration", "invention", and discovery (Karplus & Their, 1967 as cited in Lawson, Abraham, & Renner, 1989, p. 9). Lawson and Renner claimed that these three phases of the learning cycle "represent a process that will lead the learner to move from physical action to abstract mental conceptualizations" (1975, p. 340). Although all of these terms are clearly spelled out in the early SCIS publications, the label learning cycle does not appear in any of them (Lawson, 2010). These three phases have been renamed as exploration, term/concept introduction and concept application because of the fact that many teachers were having a difficult time to understand what invention and discovery meant in classroom context (Marek & Cavallo, 1997, p.14). The nature of learning cycle is contrary to the traditional teaching procedure summarized as inform-verify-practice (IVP) (Marek & Cavallo, 1997). In the majority of science classrooms, IVP are preferred and in its the first phase, the teacher informs the students what is to be learned, in the second phase students usually are shown proof that they have been told is true. In the last phase of IVP, students need to solve problems or do additional readings. Marek & Cavallo emphasized that "the IVP teaching procedure tells students that science is a finished procedure- here are its products- that they are expected to know" (1997, p. 4). In addition, IVP leads students to memorizing and repeating. However, during exploration phase of learning cycle, students often explore a new phenomenon with minimal guidance, so it helps students to absorb the concepts before they identified it and in the last phase the students have a chance to expand the new ideas to other ideas. The key point is that the teachers should introduce terms during the second phase without introducing the concepts since they must be invented by students. Figure 2.1 summarize the first proposed learning cycle model by Karplus.

According to Marek, et al., "The learning cycle is not a method or model of teaching…. The learning cycle, a comprehensive approach, is a specific organization of phases dominated by the integrity of the whole and the relationships of the phases to each other for experiencing science by inquiry and for organizing science curricula" (2003, p.148). They emphasized that the learning cycle instruction can be designed by all tools and methods of teaching such as; questioning, group work, demonstrations, technology, laboratory investigations, and field trips as well as all models of instruction like jigsaw, cooperative learning, direct instruction.

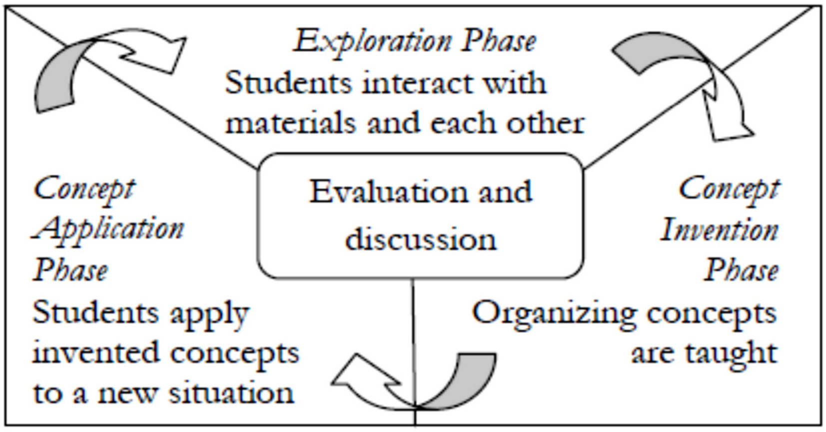


Figure 2.1 The learning cycle model by Karplus (Carin & Bass, 2001, p.117)

Specifically, in the exploration phase of this model, teachers get students to explore the concepts in order to construct new knowledge and to develop understanding by inquiry, perform hands-on activities, and discover concepts. Therefore, students have chance to attribute real meaning to concepts by following the scientific discipline procedures and explore the concepts by being active participant of the learning process. In this phase, students' prior knowledge especially their prior experiences about concepts in real life contexts has a crucial role on development of understanding concepts since new concepts needs to assimilate into them.

The second phase, conceptual invention, enables teacher to introduce the terms and discuss the scientific explanations of the concepts with students in order to make the concepts understandable. In this phase students have already think about the new concepts by considering their prior knowledge in the exploration phase, therefore the scientific explanation become less confused and students accommodate the new concepts into their mental structure easily. The exploration and concept invention stages provides for assimilation and construction of new mental structures (accommodation).

The last phase, concept application, is designed to let students to relate their newly learned concept to other concepts or to apply these new concepts in other situations (Lawson, 2010). According to Lawson (1995) without the application phase, many students may fail either to abstract the concepts from its concrete examples or to generalize it to other situations. Teachers might facilitate the third phase of learning cycle through computer programs, videos, readings, laboratory investigations, demonstrations, field trips or discussion (Gerber, Cavallo, & Marek, 2001). Each learning cycle phase corresponds to the process of organization in Piaget's model of mental functioning. Figure 2.2 illustrates this relation.

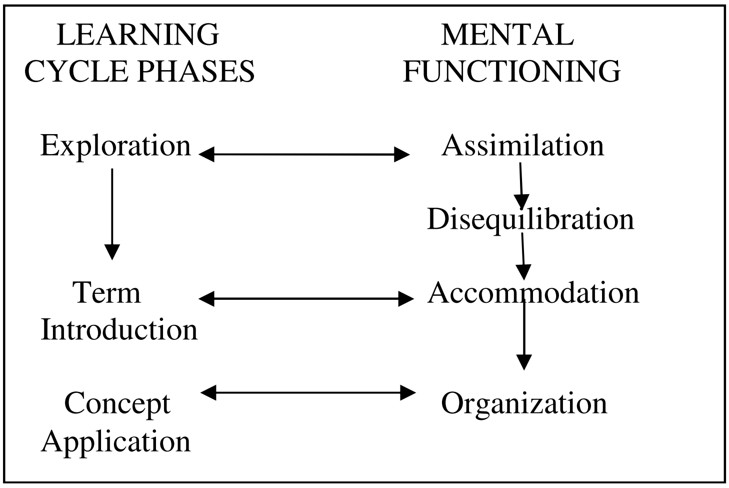


Figure 2.2 The learning cycle model and Piaget's model of mental functioning (Marek & Cavallo, 1997, p.70)

Although learning cycle model originated from Piaget's mental functioning model it is also based on Vygotsky's (1986) social constructivist theory as well as Ausubel's (1963) meaningful learning theory. Learning cycle model emphasizes both on scaffolding and student's zone of proximal development for development and student activity in learning process through meaningful learning strategies (Marek, Gerber & Cavallo, 1999).

Lawson, (1988) and Lawson, Abraham and Renner (1989) classified learning cycles into three types; descriptive, empirical-abductive and hypothetical-deductive. In the descriptive learning cycles, the students and teacher try to describe what they observe without attempting to explain their observations. This type of learning cycles answer the question of “What?", instead of the causal question "Why?". Descriptive learning cycles are designed to get students observe a small part of the world, discover a pattern, name it and look for the pattern elsewhere. Therefore, most of the time there is little or no disequilibrium occur.

In the empirical-abductive learning cycles, students discover and describe an empirical pattern in a specific context (exploration) like in the descriptive learning cycle; however they need to go further by generating possible causes of that pattern. The students should do more than just describe a phenomenon, they need to find explanations under these phenomenon. These explanations opens the door to students' alternative conceptions. Therefore, the empirical-abductive learning cycles can be used to promote disequilibrium and the acquisition of conceptual knowledge and the development of procedural knowledge.

Different from descriptive and empirical-abductive learning cycles, the hypothetical-deductive learning cycles generally start with a statement of the causal question (a specific hypotheses) continues with testing it in exploration phase, thus the third type of learning cycle represent the classic view of experimental science. The main differences among learning cycle types is “the degree to which students either gather data in a purely descriptive fashion (not guided by explicit hypotheses they wish to test) or initially set out to test alternative hypotheses in a controlled fashion” (Lawson, Abraham, & Renner, 1989, p. 47). Lawson (2010) summarized these three types of learning cyles with the following Figure 2.3. Although Lawson, Abraham and Renner proposed a classification system, they stated that “some learning cycles will be difficult to classify as they will have characteristics of more than one type of learning cycle” (1989, p. 55).

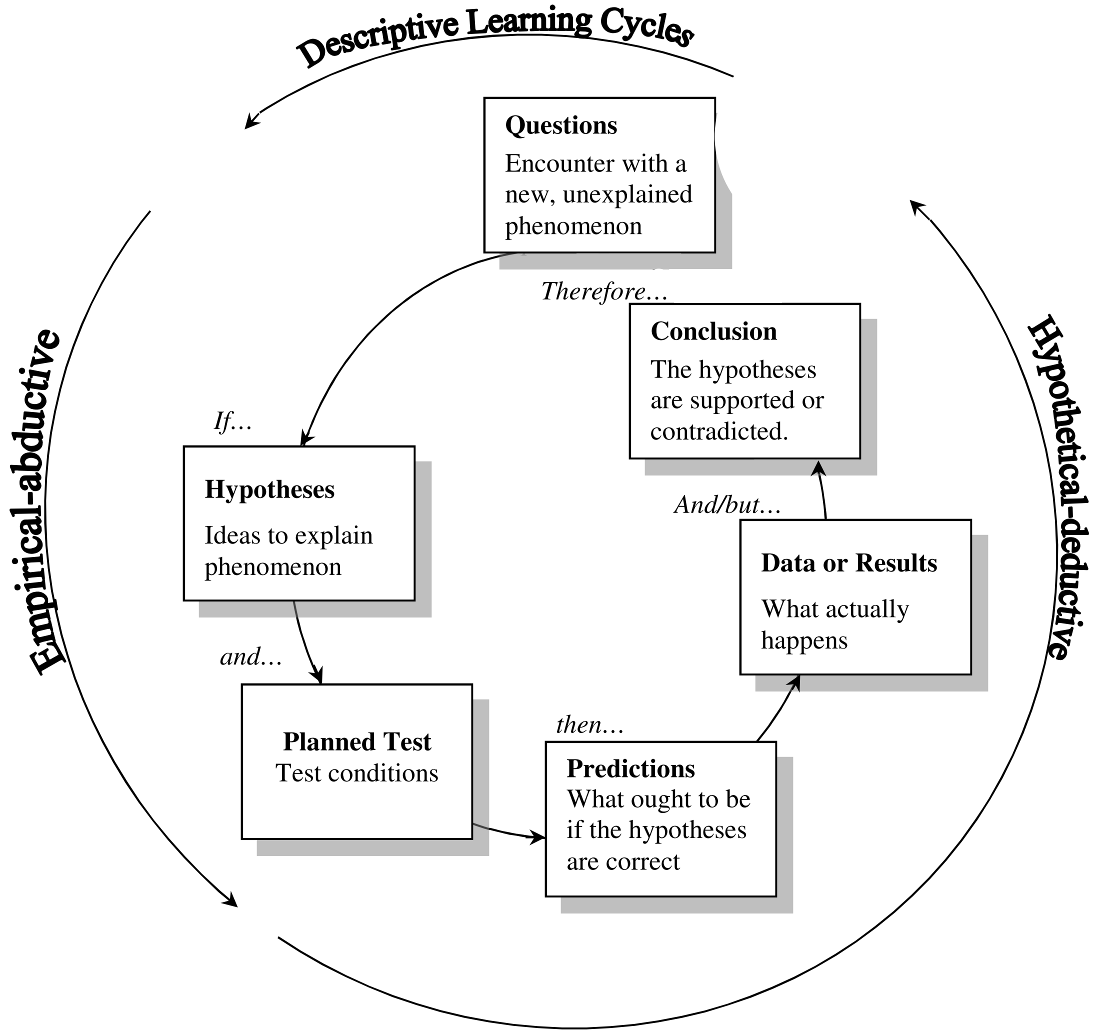


Figure 2.3 Classification of Learning Cycles (Lawson, 2010, p.108)

After SCIS being implemented, both the effectiveness of program and the learning cycle instruction were evaluated by several studies. Lawson, Abraham, and Renner reviewed these studies and reported that the results of the most of these studies indicated that learning cycle is superior in developing more positive attitudes towards science and scientific literacy, producing higher levels of self-concept and greater curiosity towards science, improving both content and process skills development than other approaches usually identified as traditional or non SCIS (1989). Guzzetti et al. conducted a meta-analysis of 47 learning cycle studies and stated that "research testing the success of the Learning Cycle and its modifications in eradicating misconceptions provides support for the approach. When the Learning Cycle included lecture, teacher-led discussion, nonrefutational text, and audiovisuals, the average effect was about 1/4 standard deviation unit" (1993, p. 146).

Renner (1986) examined the effectiveness of the learning cycle over expository instruction in fostering gains in achievement and intellectual development of 9th and 10th grade high school students. Results of the study revealed that students at the concrete level exposed to the learning cycle method gained significantly greater achievement on concrete concepts and changed more often their developmental level to another than the students in the expository group. Saunders and Shepardson (1987) compared the effects of learning cycle (concrete) and traditional (formal) instructions on sixth-grade students' reasoning and science achievement. They found that students in the learning cycle group showed significantly higher levels of performance in science achievement and cognitive development. Similar findings were reported by Marek, Cowan, and Cavallo (1994), the learning cycle instruction is more effective in promoting high school students understanding of diffusion than expository instruction. Likewise Barman, Barman, and Miller, (1996) explored the effectiveness of the learning cycle instruction over a textbook/demonstration method of instruction in facilitating 5th grade students' conceptual change concerning sound. Thirty-four fifth graders were randomly selected as a participant and they were assigned to the two treatment groups. The findings revealed that students in the learning cycle group had a significantly better understanding than the students in the textbook/demostration group. More recently Slone (2007) investigated the 26 sixth grade students'conceptions of magnets and magnetic phenomena before and after learning cycle instruction. Results indicated that before the learning cycle instruction students were likely to hold non-scientific conceptions and after the implementation period, fewer students held non-scientific conceptions and most of them held at least some scientific understandings. Therefore, the researcher concluded that the learning cycle instruction was somewhat effective in promoting conceptual change.

In addition to providing better conceptual understanding, learning cycle instruction enhances the improvement of scientific reasoning abilities (Gerber, et al., 2001;

Lawson, 2001; Saunders & Shepardson, 1987). In their study, Gerber et al., (2001) investigated possible differences in students' scientific reasoning abilities in different classroom teaching experiences (non-inquiry, inquiry). They used learning cycle instruction as an inquiry method. Five hundred and five high school students were the participants of the study. They reported that students in inquiry-based science classrooms showed higher scientific reasoning abilities compared to those in non-inquiry science classrooms.

Although SCIS was a program in both physical and biological science for grades K-6 and learning cycle appeared during this program, Marek, Maier, and McCann stated that "The learning cycle can be used to implement inquiry science at the elementary, middle, and high school and college levels" (2008, p.376).

Some studies proposed revised learning cycles with additional phases to the first developed three phase learning cycle, therefore four (Barman, 1997), five (Bybee & Landes, 1990) and even seven phases (Eisenkraft, 2003) appeared by the time. Among these, the well-known project, BSCS, also used a learning cycle as a teaching method with addition of two phases and the modification of the above mentioned three phases.

2.2.3.1 Learning Cycle 5E Model

The 5E model was developed by the Biological Sciences Curriculum Study (1989) group and it is used extensively in the development of new curriculum materials and professional development experiences. Rodger W. Bybee, who is associate director of Biological Sciences Curriculum Study (BSCS) stated that "We have modified and extended this learning cycle using research from the cognitive sciences, specifically research dealing with students' misconceptions or naive theories" (Bybee & Landes, 1990, p.96) and summarized the characteristics of each phase in the Table 2.1.

Table 2.1 5E Learning Cycle Model (Bybee & Landes, 1990, p.96)

ENGAGEMENT
This phase of the instructional model initiates the learning task. The activity should (1) make connections between past and present learning experiences and (2) anticipate activities and focus students' thinking on the learning outcomes of current activities. The student should become mentally engaged in the concept, process, or skill to be explored.
EXPLORATION
This phase of the teaching model provides students with a common base of experiences within which they identify and develop current concepts, processes and skills. During this phase, students actively explore their environment or manipulate materials.
EXPLANATION
This phase of the instructional model focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities for them to verbalize their conceptual understanding, or demonstrate their skills or behaviours. This phase also provides opportunities for teachers to introduce a formal label or definition for a concept, process, skill, or behaviour.
ELABORATION
This phase of the teaching model challenges and extends students' conceptual understanding and allows further opportunity for students to practice desired skills and behaviours. Through new experiences, the students develop deeper and broader understanding, more information and adequate skills.
EVALUATION
This phase of the teaching model encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

A new initial phase (engagement) to engage the learner’s prior knowledge and a final phase (evaluation) to evaluate the student’s understanding were added to the first proposed three phase learning cycle (Bybee et al., 2006). In addition, other phases were modified from SCIS by given names as exploration, explanation, and elaboration. The 5E learning cycle instructional model is based on a constructivist view of learning. According to Bybee and Landes “using this approach, students redefine, reorganize, elaborate and change their initial concepts through self-reflection and interaction with their peers and their environment” (1990, p. 96).

Engagement: The first component of 5E learning cycle instruction is intended to attend curiosity and provide focus for the following activities. This phase provides an opportunity for teachers to identify the prior conceptions that students have about the topic of the lesson. Bybee advised that a discrepant event, questioning, or some other act secures the learners’ attention and interest in the topic. The teachers’s role in this phase is important the teacher expected to “raise questions and problems, create interest, generate curiosity, and elicit responses that uncover students’ current knowledge” (Bybee, 1997, p. 178).

Exploration: During the second phase of 5E learning cycle, students “have common, concrete experiences upon which they continue building concepts, processes, and skills” (Bybee, 1997, p. 177). Students use a variety of observational and experimental investigations, gathering data use their simple process skills such as how to observe, measure, record their discoveries infer and predict. The teacher should act as a facilitator by encouraging cooperative group discussions by asking guiding questions and serving as a resource for students.

Explanation: the definition of the explanation phase stated by Bybee is “to present concepts, processes, or skills briefly, simply, clearly, and directly” (Bybee, 1997, p. 180). One can easily interpret from that explanation as the teacher should explain the scientific knowledge under the exploration phase by direct instruction. Beyond that, the teacher asks students to describe what they have noticed during the explore phase, reflect on their observations, and give their own theories and explanations that make sense of the observational data. Teacher should get students to build accurate scientific explanations that help to answer the initiating question rather than just acquiring terminology and facts.

Elaboration: Concept application takes place in this phase. The main goal of the elaboration phase of 5E learning cycle "generalization of concepts, processes, and skills is the primary goal of the elaboration phase" was stated by Bybee (1997, p. 181). During this phase, students are encouraged to extend their understanding of a scientific concept what they have experienced through the previous three stages. Therefore, teacher should encourage students to use formal science terms and identify alternative ways to explain phenomena.

Evaluation: Assessing new learning and conceptual change is the last and one of the most important components of the 5E learning cycle instruction. The collected data provide a basis for decisions related to how to improve teaching and learning. In the 5E learning cycle model, assessment can be gathered through formative and summative assessment procedures. Self- assessment provided opportunity to students in order to monitor their own understanding might be preferred to improve students' learning, self-regulation and motivation.

As expected, the effectiveness of 5E learning cycle instruction over traditional instruction in promoting conceptual understanding in biology as well as other science disciplines has been the focus of lots of studies since 1990's. Today, this trend has still continued even in different grade levels and educational settings. Most of these studies reported that 5E learning cycle instruction is an effective way to teach science and it produce better conceptual understanding (Akar, 2005; Bektas, 2011; Campbell, 2000; Cavallo, McNeely, & Marek, 2003; Ceylan & Geban, 2009; Hiccan, 2008). Some example studies were reviewed below.

Akar (2005) conducted a study to find out the effectiveness of 5E learning cycle instruction over traditional instruction on 56 tenth grade students' understanding of acid-base concepts and attitudes towards chemistry. The groups were randomly assigned and the same teacher taught these groups. The results revealed that 5E learning cycle instruction caused a significantly better acquisition of acid-base concepts and produced significantly higher positive attitudes toward chemistry than the traditional instruction.

Campbell (2000) explored the effects of the 5E learning cycle model on the fifth grade students' understanding of force and motion concepts. After 14 weeks implementation period, analysis of post-test scores and additional reviews of lab activity sheets, other classroom-based assessments, and interviews indicated that student knowledge of force and motion concepts did increase.

Ceylan and Geban (2009) investigated a study to compare the effectiveness of 5E learning cycle instruction and traditional chemistry instruction on 10th grade students' understanding of state of matter and solubility concepts. 119 tenth grade high school students were the participants and they were instructed by same teacher. The results showed that 5E learning cycle instruction provides significantly better understanding of the state of matter and solubility concepts than traditional instruction.

Learning cycle instruction is not only used in science education, it is also applied in mathematics education and other disciplines. For example, Hiccan (2008) investigated the effectiveness of 5E learning cycle model on academic achievement in mathematics of 7th grade primary school students on linear equations in one variable. The subjects of this study composed of 24 students. Both quantitative and qualitative data were collected after 12 class hours implementation period. Learning cycle instruction was found to be meaningfully effective on teaching linear equations in one variable.

The first National Research Council (NRC) of USA report, *How People Learn* supported the design and sequence of 5E learning cycle instruction by stating the name of each phases (as cited in Bybee, et al., 2006). In addition to that support research based evidences should be found to show the effectiveness of the model. Bybee, et al., (2006) and Bybee (2009) reviewed studies that conducted on the effectiveness of BSCS and also 5E learning cycle instruction on different variables. For instance, Maidon and Wheatley (2001) compared the end of semester test grades of fifth grade students who used *Science for Life and Living* (the first developed BSCS module) and students who used an activity-centered (more traditional) science program for a full academic year. There was statistically significant difference found between gropus on their process skills, conceptual knowledge, nature of science, manipulative skills, lower-order thinking skills, higher-order thinking skills in favor of 5E learning cycle instruction group. Likewise, during the development and field-testing of *BSCS Curriculum: Middle School Science & Technology*, valuable data about student learning and attitudes was collected. The results showed statistically significant differences ($p < 0.01$) between groups. The students using BSCS module had higher raw scores, answered more questions, and they used more scientific vocabulary words correctly and had higher-quality responses on open-ended questions (BSCS, 1994). Bybee et al. reported that there has been some research based evidence of increased in learners' mastery of subject matter however they are not enough and more studies needs to be conducted to provide strong evidence on the effectiveness of 5E learning cycle instruction.

2.2.3.2 Studies with Learning Cycle in Biology Education

Teaching biology concepts by using learning cycle model is recommended by several studies (Cate & Grzybowski, 1987; Danieley, 1990; Lawson, 1988; 1991; 1996; 2000; 2001; Lawson & Renner, 1975; Levitt, 2002; Ray & Beardsley, 2008; Wilder & Shuttleworth, 2005). Lawson claimed in his study entitled with "A Better Way to Teach Biology" that the correct use of the learning cycle provides students the opportunity to reveal prior conceptions / misconceptions and the opportunity to argue and test them, and thus become "disequilibrated" and develop more adequate conceptions and reasoning patterns to debate and test them (1988, p. 273). In addition, Wilke and Granger (1987) found that the learning cycle increased students' retention rate of biological concepts (as cited in Allard & Barman, 1994).

In the current study, thirty-two studies with learning cycle instruction model in several biology concepts are reviewed in table 2.2. The effectiveness of various learning cycle instructions were explored such as; 3, 4, 5 and 7 phase learning cycles, and combinations of an instructional method (i.e. concept mapping, conceptual change texts, etc.) with learning cycle instruction over traditional instruction. Twelve of these studies compared just 5E learning cycle instruction with traditional instruction. As seen from table 2.2, participants of the reviewed studies are ranged from grade level 4 to college biology students even pre-service biology teachers. The most tested variables are students' conceptual understandings in several biology concepts and their achievement. Diffusion and osmosis and genetics are the most preferred concepts among the other biology concepts. Most of the results of the studies on the effectiveness of the learning cycle instruction indicated that learning cycle instruction is more effective to improve conceptual understanding (Balci, Cakiroglu, & Tekkaya, 2006; Bulbul, 2010; Haras, 2009; Kaynar, 2007; Lord, 1999; Marek, Cowan, & Cavallo, 1994; Musheno & Lawson, 1999; Saka & Akdeniz, 2006; Saygın, Atılboz, & Salman, 2006; Yılmaz, 2011), to produce greater achievement (Appamaraka, et al., 2009; Balci, 2009; Cakiroglu, 2006; Canli, 2009; Dogru-Atay & Tekkaya, 2008; Ebrahim, 2004; Sadi & Cakiroglu, 2010; Somers, 2005) and retention in biology concepts (Blank, 2000; Cumo, 1991) than traditional instruction. In addition, the learning cycle instruction has positive effect on students' science process skills (Appamaraka, et al., 2009; Cumo, 1991; Lavoie, 1999; Sornsakda, et al., 2006) and motivation (Saygın, 2009). Although some of these studies reported positive effect of learning cycle instruction on students' attitudes towards science or biology as a school subject (Bulbul, 2010; Cumo, 1991; Ebrahim, 2004), some of them found no effect on students' attitudes (Atilboz, 2007; Canli, 2009; Garcia, 2005; Haras, 2009; Kaynar, 2007).

Table 2.2 Learning Cycle Studies on Biology Education

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Appamaraka, Suksringarm, & Singseewo, 2009	5E LC with metacognitive strategies & Teacher’s handbook instruction	6 weeks (3 hours per week)	- Achievement - Science process skills - Critical thinking	Environment	82 Students Grade 9	LC is more effective to produce achievement, integrated science process skills and critical thinking than teacher’s handbook approach.
Atılboz, 2007	3 Phase LC & TI	4 weeks	- Understanding - Biology teaching self-efficacy beliefs - Attitudes towards biology teaching	Diffusion and Osmosis	33 Pre-service biology teachers	LC is more effective to improve the subjects’ understanding than TI, whereas it has no significant effect on teaching self-efficacy beliefs and attitudes towards biology teaching.
Balcı, 2009	5E LC & TI	8 weeks	- Achievement	Systematics of Vertebrates	29 Pre-service biology teachers	LC is superior to TI in improving achievement in biology concepts.
Balcı, Cakiroglu, & Tekkaya, 2006	5E LC & Conceptual Change Texts & TI	3 weeks (six 40 minute per week)	- Students’ understanding	Photosynthesis and Respiration in Plants	101 Students Grade 8	Both the 5E LC and the conceptual change text instruction caused a significantly better acquisition of conceptions than TI. Neither 5E LC and nor CCT are not superior to each other.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Blank, 2000	3 Phase LC & Metacognitive Learning Cycle	3 Months	- Students' understanding - Students' retention	Ecology	46 Junior high school students Grade 7	Metacognitive Learning Cycle did not produce a greater content knowledge, but is more effective in permanent restructuring of knowledge than LC.
Bulbul, 2010	7E LC with computer animations & TI	Over 4 weeks (three 40-minute per week)	- Students' understanding - Attitudes toward biology - Gender	Diffusion and Osmosis	66 Grade 9	7E LC with computer animations is better to improve understanding and attitudes of the subjects' than TI. No significant effect of gender difference on dependent variables.
Cakıroglu, 2006	5E LC & TI	Six 40 minute periods	- Students' achievement -Gender	Photosynthesis and respiration in plants	67 Students Grade 8	A statistically significant difference is found between groups in the favour of experimental group. No significant gender difference.
Canli, 2009	5E LC & TI	9 weeks (Twenty seven 40 min periods)	- Students' achievement - Attitudes toward science	Reproduction and Development in Living Organisms	50 Students Grade 8	5E LC instruction is superior to traditional instruction to increase achievement however has no effect on students' attitude towards science.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Cumo, 1991	3 Phase LC & TI	4 weeks	- Achievement - Attitudes - Science Process skills - Gender - Retention - Reasoning pattern	Diffusion and osmosis	153 Grade 7	LC has positive effect on students' reasoning patterns, retention, science process skills, and their attitudes. There was significant gender effect on achievement and retention in favour of male students.
Doğru-Atay & Tekkaya, 2008	3 Phase LC & TI	4 weeks (three 40 minute per week)	- Achievement - Gender - Prior knowledge - Meaningful learning orientation - Reasoning ability - Self-efficacy - Locus of control - Attitudes toward science	Genetics	213 Students Grade 8	Learning cycle instruction improved students' achievement in genetics compared to traditional instruction. Students' logical thinking ability and meaningful learning orientation accounted for a significant portion of variation in genetics achievement. No gender difference in achievement was found.
Ebrahim, 2004	4E LC & TI	1 month	- Achievement - Attitude toward science	Plants	111 Grade 4	4E LC produces significantly greater achievement and attitudes toward science than traditional instruction.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Ercan, 2009	5E LC & TI	4 weeks	- Achievement	Material Cycle in Ecosystem	50 Grade 10	5E LC is more effective than traditional instruction.
Garcia, 2005	5E LC & TI	4 weeks	- Students' understanding - Attitudes towards the subject of science	Evolution	160 Students Grade 7	No difference in understanding or in attitudes towards the subject of science.
Hagerman, 2012	5E LC	8 months	- Students' understanding - Scientific literacy skills	Cellular structure, Genetics, Evolution	42 Students Grades10-12	5E learning cycle is an effective method for developing scientific literacy in students.
Hanley, 1997	3 Phase LC& TI	4 weeks	- Student knowledge	Ecology	222 Students 87% Grade10 13% Grade11 and 12	No difference
Haras, 2009	5E LC & TI	8 weeks	- Students' conceptual understandings - Attitudes towards biology	Reproduction	36 Students Grade 10	LC is more effective than TI in students' conceptual understandings however no difference found between students' attitudes towards biology.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Kaynar, 2007	5E LC & TI	3 weeks	- Students' understanding - Attitude toward science - Scientific epistemological beliefs	Cell and Organelles	160 Students Grade 6	LC is superior than TI in students' understanding of cell concepts and epistemological beliefs. No significant difference on attitude toward science
Lavoie, 1999	Prediction /discussion-based learning cycle (HPD-LC) & 3 Phase LC	3 months	- Science process skills - Logical thinking - Conceptual understanding	Genetics and inheritance, Homeostasis, Natural Selection and Ecology	250 Students Grade 10	HPD-LC treatment compared to the LC treatment achieved significantly greater gain scores for science process skills, logical thinking, and conceptual understanding.
Lord, 1999	5 E LC & TI	One semester	- Students' understanding	Environmental Science	181 College students Freshman	The students in the LC group had a much better understanding than did students in the TI group.
Marek, Cowan, & Cavallo, 1994	3 Phase LC & Expository Teaching		- Students' understanding - Retention	Diffusion	35 Students Grades 9 through 12	LC is more effective to eliminate students' misconceptions than expository teaching practices.
Mecit, 2006	7E LC & TI	4 weeks	- Critical Thinking Skills - Gender	Water Cycle	46 Students Grade 5	LC is more effective to improve students' critical thinking skills than TI. No gender effect is found.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	# and type of participants	Major Findings
Musheno & Lawson, 1999	LC Text & Traditional Text	A class hour	- Students' understanding - Retention	Symbiosis, Mutualism, Commensalism and Parasitism.	123 Students 65 Grade 9 58 Grade 10	Students who read the learning cycle passage earned higher scores on concept comprehension questions than those who read the traditional passage, at all reasoning levels. No significant difference between groups on retention.
Odom & Kelly, 2001	Concept Mapping & 3 Phase LC & Expository Teaching& Concept mapping and 3 Phase LC Combination	6 days	- Students' understanding - Retention	Diffusion and osmosis	108 Students Grades 10-11	Concept mapping and learning cycle combination and just concept mapping treatment groups significantly outperformed the expository treatment group in conceptual understanding.
Sadi & Cakiroglu 2010	5E LC & TI		- Achievement	Human Circulatory System	60 Students Grade 11	LC is more effective to improve students' achievement compared to traditional instruction.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	**Intervention**	**Duration**	**Dependent Variables**	**Topic**	**Number and type of participants**	**Major Findings**
Saka & Akdeniz, 2006	5E LC with computer animations		- Conceptual Understanding	Genetics	25 pre-service science teacher	5E LC with computer animations increase pre-service teachers’ understating of genetics concepts
Saygın, 2009	3 Phase LC & TI	4 weeks	- Students’ Understanding - Motivation	Nucleic acids and protein synthesis	103 Students Grade 11	LC is better to improve understanding, intrinsic goal orientation, control beliefs, self-efficacy, meta-cognitive self-regulation, help seeking and eliminate misconceptions than TI.
Saygın, Atilboz, Salman, 2006	5E LC & TI	8 weeks	- Students’ Understanding	Cell	47 Students Grade 9	Students in LC group learn better than TI group students.
Sornsakda, Suksringar m& Singseewo, 2009	7E LC with metacognitive techniques & Teacher’s handbook instruction	5 weeks (2 hours per week)	- Achievement -Science process skills - Critical Thinking	Environment	93 Students Grade 11	LC is more effective to produce achievement, integrated science process skills and critical thinking than teacher’s handbook approach.

Note. LC: Learning Cycle, TI: Traditional Instruction.

(Table 2.2 continued)

Author and Year	Intervention	Duration	Dependent Variables	Topic	Number and type of participants	Major Findings
Somers, 2005	7E LC & TI	2 to 3 weeks	- Environmental Literacy	Ecology	155 Students Grade 7 and 8	LC is superior in improving students' content knowledge to TI.
Sriwattanarothai, Jittam, Ruenwongsa, & Panijpan, 2009	3 Phase LC	Two periods (six hours each).	- Students' Understanding - Perceptions	Enzymes and DNA	152 College Students Sophomore	LC enables students to conceptualize concepts. Additionally, these learning units promote students' positive perception of science learning
Tweedy, 2004	3 Phase LC & Traditional Laboratory	1 week	- Students' understanding - Retention	Diffusion and osmosis	229 Students enrolled in Biology 101 in University	No significant difference was found between students' understanding
Yilmaz, 2011	Prediction/discussion-based learning cycle (HPD-LC) & Conceptual Change text (CCT), & TI	Over a five-week period	- Students' understanding - Motivation - Retention	Genetics	81Students Grade 8	Both HPD-LC and CCT are superior to TI in students' understanding and retention. HPD-LC students used elaboration strategies significantly more than CCT students.

Note. LC: Learning Cycle, TI: Traditional Instruction.

A depth look into the literature on 5E learning cycle instruction might be proper by presenting the results of some studies. Balcı (2009) conducted study with 29 pre-service biology teachers to compare the effectiveness of 5E learning cycle instruction over traditionally designed instruction on achievement in sytematics of vertebrates. Quasi-experimental reserach design was used, in addition to pre-tests and post-tests, experimental group students were interviewed semi-structurely to investigate the ideas on learning cycle after the implementation period. The classes were randomly assigned as control (15 students) and experimental groups (14 students) and implementation took 8 weeks. The results indicated that there was statistically significant diffecerence in the achievement scores of the experimental group and the control group in favor of 5E learning cycle instruction. Data gathered from the interviews showed that the students had more fun in 5E lerning cycle instruction and have a positive attitude towards this approach.

Balci, Cakiroglu, & Tekkaya, (2006) compared the effectiveness of the 5E learning cycle instruction, conceptual change texts and traditional instructions on elementary school students' understanding of photosynthesis and respiration in plants. 101 eight grade students consisted of the subjects of the study. Teaching methods were randomly assigned to three groups and treatment period took 3 weeks (six 40 minute per wek). The researcher observed all groups during the whole implementation period. All groups were instructed on photosynthesis and respiration in plant concepts and were administered a diagnosing test on these concepts before and after teaching. After the analysis the data, it aws found that both 5E and conceptual change texts were effective on students' understanding of photosynthesis and respiration in plant concepts than traditional instruction however, none of them is superior to the other.

Similary, Cakiroglu (2006) explored the effectiveness of 5E learning cycle instruction on 8^{th} grade students' achievement in photosynthesis and respiration in plants concepts over traditional instruction. Participants were 67 eight grade students from two intact classes. The Photosynthesis and Respiration in Plants Concept Test (PRCT) developed by Haslam and Treagust (1987) was administered before and after the three week treatment on the target concepts. In addition, The Test of Logical Thinking (TOLT), was used to determine the formal reasoning ability of the students. Pre-PRCT and TOLT scores were used as covariates and ANCOVA was performed. The results showed that there was statistically significant difference between groups' post-PRCT scores and also gain scores in favour of 5E learning cycle instruction. Additionally, no gender differences and no significant interaction effects between treatment on understanding of the target concepts, $F\ (1,\ 60) = 0.07$, $p > 0.05$ were reported.

Canli (2009) investigated the effects of 5E learning cycle instructional approach on 8th grade students' achievement in the concepts of reproduction and development in living organisms and attitudes towards science as an MS thesis study. Two groups of 50 students were instructed with the concepts for 9 weeks. Science and Technology Achievement Tests and Science and Technology Attitude Scale were administered to all students as a both pre-test and post-test. Findings of the study revealed that teaching with 5E instructional models is more effective on achievements of 8th grade students than traditional instruction. However, no attitutional difference was found between groups after the implementation. Similar study was conducted by Haras (2009) with 10th grade students to find the effects of 5E learning cycle instruction on conceptual understanding of reproduction and their attitudes towards biology. After 8 weeks implementation period of 36 students, the researcher reported similar findings with Canli (2009). The results indicated that learning cycle instruction is more effective than traditional instruction to promote students' conceptual understanding however no difference was found between their attitudes towards biology. Likewise, the findings of the study conducted by Kaynar (2007) showed that learning cycle instruction is superior than traditional instruction in promoting 6th grade students' understanding of cell concepts but is as effective as traditional instruction to increase their attitudes towards science.

Recenty, Hagerman (2012) sought answers to two research questions; if the use of the 5E instructional model in a sophomore (10th grade) and junior level (12th grade) biology course would increase student understanding of science concepts and processes, fostering application to real-life situations and student's scientific literacy skills. Three units, celular structure, genetics and evolution, were taught in four biology classes composed of 42 students by using 5E learning cycle instruction for the period of eight months. Multiple data collection through surveys, interviews, inquiry process analysis, lab assessments, team performance assessments, journals, scientific papers was performed during the whole implementation period. At the end, researcher reported that the development of student comprehension of content seemed to be less developed and the continued development throughout the study of students' ability to read, write and communicate about science represents gains in scientific literacy as an outcome of the 5E learning cycle.

2.3 Gender Issues in Science Education

During the last 25 years, gender difference in science education is among the most studied issues. The research studies on gender issues have sought to answer to the questions like; what role gender has on the learning, involvement in, and success in science and science related fields, especially in females (Kahle & Meece, 2004), most of them reported that there is a gender gap of women in science. Therefore, some special programs have developed to encourage women in order to help them participate in the sciences; however, the results have showed that there is limited involvement by females (Fuselier & Jackson, 2010). Osborne, Simon and Collins (2003) claimed that the difference in behaviors of male and female in science education starting in early education years. Similary, Adamuti-Trache and Andres (2008) asserted that some influences (especially by parents) in the early years of schools affect students' views toward school subjects, the following years being a critical time in students' life to evaluate career opportunities. If the differences in career selections of students considered, females tend to prefer more biological sciences whereas males tend to work in physical sciences. The results of a study included samples from all European Union countries reported that "women account for 61% entrants in Life science (including biology and biochemistry as well as environmental sciences) but 49% in mathematics and statistics and 44% in physical sciences" (European Commission, 2009).

Methods of instruction may also have a role in the development of gender differences in science education. Seymour (1999) have reported that males like to receive more attention and praise for feedback than females; in addition females learning is more passive, in less experiential way, therefore the researchers concluded that the difference in male and female students learning style might have effect on the number of females engaging in science. According to Kahle (1990), males tend to dominate whole class activities however; females prefer cooperative learning to competitive activities. Therefore, studies search for the interaction between gender and teaching methods have become important for science teaching literature since gender differences in achievement might be minimized by using appropriate instructional methods. When the literature reviewed for whether the effects of learning cycle differ across gender, some of the studies reported no interaction (Bektaş, 2011; Bulbul, 2010; Cakiroglu, 2006), some of them reported significant gender effect on achievement in favour of male students (Cumo, 1991; Saunders & Shepardson, 1987). However, the limited number of the studies has not presented enough evidence to conclude whether an interaction exists or not. Thus, based on the literature of gender issues in science education, a deeper understanding is needed to determine if there is a difference between males and females gains after learning cycle instruction in biology courses.

In the light of the above literature review, there is widespread confusion over the concepts related with cell division and reproduction (such as; Knippels, 2002; Lewis et al., 2001; Tekkaya, Ozkan, Sungur, 2001; Wood-Robinson et al., 2000) and learners' have difficulties to construct conceptual understanding on these concepts (Bahar et al., 1999) and so, the related concepts such as genetics and inheritance (Kibuka-Sebitosi, 2007). Even several instructural activities were proposed to encourage meaningful learning on these concepts and to eliminate alternative conceptions; most of these activities were not tested. Learning cycle instruction is one of these recommended teaching models that claimed to be effective at helping students overcome alternative conceptions (Bybee et al., 2006; Lawson, 1988; 2001; Ray & Beardsley, 2008). Although, three dissertation studies were conducted to investigate the effect of learning cycle instruction (Canli, 2009; Haras, 2009; Onder, 2011), none of them search for the effect on meaning construction of students or their alternative conceptions. Regardless from the cell division and reproduction concepts, few studies have examined the effectiveness of the learning cycle instruction on the alternative conceptions related with the biology concepts (Marek, Cowan, & Cavallo, 1994; Saygin, 2009; Stepans et al., 1988). However, none of these limited number of studies (Marek, Cowan, & Cavallo, 1994; Saygin, 2009; Stepans et al., 1988) performed hypothesis testing, they reported results via just percentages of alternative conceptions before and after implementation. When the studies on the effect of gender and the interaction between gender and learning cycle reviewed, no clear pattern was recognized. Therefore, in view of the deficiency of research in this aspect of biology learning, the present study is aimed to design a cell division and reproduction unit based on 5E learning cycle instruction and investigate the effectiveness of it and gender in improving the students' achievement, understanding and eliminating alternative conceptions. The results of this study will provide empirical evidence to the learning cycle literature especially related to the effectiveness in dispelling alternative conceptions.

CHAPTER 3

METHOD

After related literature on research questions of this study were presented in the previous chapters, the details about the methodology of the study were explained under the subtitles of design, population and sample, variables, instruments, procedure, treatments, the treatment fidelity and verification, ethical issues, statistical analysis, power analysis, unit of analysis, assumptions and limitations in this chapter.

3.1 Design of the Study

For this study, mixed methods research design is utilized in order to find answers to the research questions by collecting and analyzing both quantitative and qualitative data in a single study (Creswell, 2013, p. 240). In this study, explanatory design started with quantitative methods and then followed up with qualitative methods is used to explain the initial quantitative results (Creswell, Plano Clark, & Garrett, 2008). The main aim is to explore students' understandings in detail with a few cases. "On the issue of sample size, the size of quantitative and qualitative samples may be unequal given the nature of quantitative research to generalize to a population whereas the qualitative sample provides in depth understanding of a small group of individuals" (Creswell, Plano Clark, & Garrett, 2008, p.76). Therefore; the two samples were necessary for this study. The participants of the quantitative part of the study could not be selected randomly from the population and the assignment of the participants to the groups could not be provided since the groups were formed by the administration of the schools before the study. However, intact classes were randomly assigned to treatments (5E learning cycle instruction and conventional classroom instruction) in each school. Therefore; two classes were instructed through conventional classroom instruction and two classes were instructed through learning cycle in each school. Table 3.1 summarizes the design of the study.

Table 3.1 Research design of the study

Groups	Pre-test	Treatment	Post-test
Learning Cycle Instruction Groups (LCI)	CDRAT CDRDiT SPST	LCI	CDRAT CDRDiT Interview*
Conventional Classroom Instruction Groups (CCI)	CDRAT CDRDiT SPST	CCI	CDRAT CDRDiT Interview*

Note. The abbreviations in the table are; CDRAT= Cell Division and Reproduction Achievement Test, CDRDiT= Cell Division and Reproduction Diagnostic Test, SPST= Science Process Skill Test, LCI= 5E Learning Cycle Instruction, CCI = Conventional Classroom Instruction,*12 students were interviewed.

As seen from the Table 3.1, students in learning cycle group (LCI) were treated with 5E learning cycle instruction on cell division and reproduction concepts while the students in conventional classroom instruction group (CCI) treated with traditionally on the same concepts. Cell Division and Reproduction Achievement Test (CDRAT) and Cell Division and Reproduction Diagnostic Test (CDRDiT) were administered to both LCI and CCI groups before and after the treatments. Science Process Skill Test (SPST) was distributed to both groups just before the treatments in order to control the possible differences in science process skills between groups before the treatments. After ten weeks implementation period, the post tests; Cell Division and Reproduction Achievement Test (CDRAT) and Cell Division and Reproduction Diagnostic Test (CDRDiT) were administered again. In addition to these tests, semi-constructed interviews were conducted with 12 students (six of them from LCI groups and six of them from CCI groups).

3.2 Population and Sample

All 10th grade students enrolled in biology course at public high schools in Ankara, Turkey constituted the target population of this study. The accessible population was all 10th grade students at public schools in Etimesgut district of Ankara. Convenience sampling method used while selecting sample from eight public high schools at Etimesgut district since voluntarily implementation of the treatments by the teachers is necessary and the teachers of the control and treatment groups should be same in each school to prevent implementation threat.

Eight classes taught by two teachers of two Anatolian high schools were selected conveniently for the quantitative part of this study. The students had to take a national high school placement exam to enroll Anatolian high schools and both of the schools were in the 5th percentile based the placement exam results administered in 2010. In addition, the level of students from two schools in this exam was very close to each other. Classes of each teacher were randomly assigned to the experimental and the control groups. Details about the sample of quantitative part of this study were summarized in Table 3.2. The sample included 241 (118 males and 123 females) students. Age range of the students was 16 to17 years.

Table 3.2 Distributions of the number of students in the sample across schools, groups and gender (Quantitative part)

	School 1				**School 2**				**Total**
	CCI-1	CCI-2	LCI-1	LCI-2	CCI-1	CCI-2	LCI-1	LCI-2	
Male	15	12	12	16	15	14	17	17	118
Female	14	18	18	12	15	16	15	15	123
Total	29	30	30	28	30	30	32	32	241

Note. LCI-1 and LCI-2 were treated with 5E learning cycle instruction; CCI-1 and CCI-2 were treated with conventional classroom instruction in each school.

In addition, 12 students among these students took part in the interview sessions. Purposive sampling was used to select interviewees because mid-level achievement, equal number of each gender and tendency to participate the interview was considered. Therefore, teachers helped selecting the students who have these characteristics. Semi-structured interviews were conducted with six students from each treatment groups after the treatment in order to data triangulation. Distribution of the participants of the qualitative part of this study to groups and gender is given in Table 3.3.

Table 3.3 Distributions of the number of students in the sample across schools, groups and gender (Qualitative part)

	School 1				**School 2**				**Total**
	CCI-1	CCI-2	LCI-1	LCI-2	CCI-1	CCI-2	LCI-1	LCI-2	
Male	1	-	1	1	1	1	-	1	6
Female	1	1	-	1	1	-	1	1	6
Total	2	1	1	2	2	1	1	2	12

Note. LCI-1 and LCI-2 were treated with 5E learning cycle instruction; CCI-1 and CCI-2 were treated with conventional classroom instruction in each school.

3.3 Variables

There were three independent variables (IVs) and three dependent variables (DVs) in this study. The list of variables and their characteristics were presented in the Table 3.4.

Table 3.4 List of variables

Variable	**Type**	**Type of value**	**Scale**
Teaching Method	IV	Categorical	Nominal
Gender	IV	Categorical	Nominal
SPST	IV	Continuous	Interval
Achievement (Post-CDRAT)	DV	Continuous	Interval
Understanding (Post-CDRDiT)	DV	Continuous	Interval
Alternative Conceptions (Post-AC)	DV	Continuous	Interval

3.3.1 Independent Variables

Teaching method, gender, and scores of the students on science process skill test (SPST) were independent variables of the study. SPST scores were used as potential covariate to control their possible effects on the results of this study. The IVs were continuous and measured in interval scale except teaching method and gender. Teaching method has two levels which were conventional classroom instruction (CCI) and 5E learning cycle instruction (LCI) and was measured in nominal scale. Similarly, gender has two levels, male and female.

3.3.2 Dependent Variables

Post-test scores of the students on cell division and reproduction achievement test (Post-CDRAT) as an indicator of students' achievement, post-test scores on cell division and reproduction diagnostic test (Post-CDRDiT) as an indicator students' understanding and the calculated post-alternative conceptions scores (Post-AC) from the students' incorrect responses on the post-CDRDiT as an indicator of students alternative conceptions were dependent variables of the study and both of them are continuous and in interval scale.

3.4 Instruments

Cell division and reproduction achievement test (CDRAT) and cell division and reproduction diagnostic test (CDRDiT), science process skill test (SPST) and semi-structured interviews were used to obtain necessary data to test the hypotheses of this study. Below, the characteristics of these instruments were explained in detail.

3.4.1 Cell Division and Reproduction Achievement Test (CDRAT)

CDRAT was developed and administered to both CCI and LCI groups by researcher to assess students' achievement on cell division and reproduction unit before and after the treatment. During the development procedure, first, the objectives of cell division and reproduction unit from the national 10^{th} grade biology curriculum (Ministry of National Education [MONE], 2011) were reviewed (Objective list is in the Appendix A). Second, questions in the biology textbooks, exercise books, dissertations on understanding of cell division and reproduction, and university entrance exam were used to construct the test items. Third, three multiple choice test items for each objectives were formed. Expert opinions were taken to provide evidence for validity of the test. A professor majoring in biology education and three biology teachers (one of them has PhD. degree and one of them has master's degree in biology education) reviewed the test items to check the consistency between objectives and items, and filled the blank tables of specification (Appendix B). In addition, these experts were asked to check the items for any ambiguity in item stems and any mistakes in the answer key. After the revisions, 35 multiple choice items with five distracters constituted the CDRAT.

The final form of CDRAT was piloted with 112 11^{th} grade Anatolian high school students who had studied cell division and reproduction unit before. In order to calculate scores of the students, correct responses were coded as 1 and incorrect responses were codded as 0, therefore the maximum score was 35 and the minimum was 0. Reliability of the test, the item difficulty, and discrimination index for each question were calculated by SPSS program. Table 3.5 shows descriptives and scale statistics of CDRAT in pilot administration.

The croncbach alpha reliability coefficient of CDRAT based on pilot study was .81 which means that the test has relatively high internal consistency since a reliability coefficient above .70 is considered as acceptable (Pallant, 2007). The item difficulty (p) is the percentage of students who answered the item correctly. A higher number shows an easy item which means that high number of students selects a correct answer. Similarly, a small number indicates difficult item so, alternative responses to the item were chosen by more students. The mean difficulty level of the CDRAT was .75 which shows that it was medium low difficult for 11^{th} grade level students. As desired for test development, p values of items were distributed in different ranges. Two questions (item 10 and item 33) has low difficulty indices (p= .34 and p= .39 respectively) and they were classified as difficult item.

Table 3.5 Descriptive and item statistics of CDRAT

Number of items	35
Number of participants	112
Mean / Standard deviation (SD)	26.41 / 5.01
Minimum	7
Maximum	34
Cronbach alpha	0.81
Difficulty indices (p)	
Mean	0.70
n of items (0.8 < p)	14
n of items (0.6 < p < 0.8)	13
n of items (0.4 < p < 0.6)	6
n of items (0.2 < p < 0.4)	2
Discrimination indices (D)	
Mean	0.41
n of items (0.5 < D < 0.6)	8
n of items (0.4 < D < 0.5)	12
n of items (0.3 < D < 0.4)	9
n of items (0.2 < D < 0.3)	4
n of items (D < 0.2)	2

When discrimination indices of items were checked according to Ebel and Frisbie (1986), items with D values range 0.20 - 0.29 needs to check and the items with D values below 0.20 should be discard or review in depth. Two items (item 1 and item 15) has lower discrimination value than 0.20. Item 1 dropped from the test and new question was generated instead of that and item 15 was reviewed. The final version of CDRAT (Appendix C) was administered to both CCI and LCI groups as a pre-test and post-test. The pre-test scores were used to compare whether students in CCI and LCI groups were different from each other when their knowledge on cell division and reproduction considered before the implementation. The administration of CDRAT needs approximately one class hour (40-45 minutes).

3.4.2 Cell Division and Reproduction Diagnostic Test (CDRDiT)

Since the researcher wanted to know if alternative conceptions about cell division and reproduction concepts persisted after instruction, she first needed to determine what students knew about these concepts before their lessons and what happened alternative conceptions after the treatment period. Therefore, CDRDiT was administered to both groups as a pre-test and post-test to diagnose participants' alternative conceptions on cell division and reproduction unit.

CDRDiT was adapted by researcher from two-tier cell division diagnostic test (Ozdemir, 2008). The original test was consisted of 16 two-tier multiple choice questions on cell division. The first tier of each item was a multiple-choice content question having usually two to three choices. Most of the first tier items ask for whether the proposed sentence is true or not. The second tier contained a set of possible reasons for the answers given in the first tier and one blank choice to express any reason that was not included in the choices. The distracters of the second tiers of the items consisted of alternative conceptions. The concepts in two questions were not with in the concepts included in the cell division and reproduction unit of 10^{th} grade level biology curriculum developed by MONE (2011). Therefore, 14 questions were selected from the above mentioned two tier diagnostic test. Due to the curriculum includes concepts related with reproduction and these concepts were not within the concepts of the present test. Studies on alternative conceptions about the reproduction were reviewed and listed to form new questions. 6 new questions on asexual and sexual reproduction concepts were generated by the researcher. The list of alternative conceptions which were detected by CDRDiT and alternative sets were presented in Table 3.6.

Table 3.6 Alternative conceptions list and alternative sets

Topic	Alternative conceptions	Alternative sets
Mitosis	1. In mitosis, the amount of chromosomal DNA is different in different stages.	1.1 b, 1.2 b, 1.3a
	2. DNA replication occurs during prophase.	1.1 b, 1.2 c, 1.3 a; 1.1 a, 1.2 c, 1.3 a; 7.1 a, 7.2 b, 7.3 a
	3. In mitosis, the amount of chromosomal DNA is halved in anaphase.	1.1 b, 1.2 d, 1.3 a
	4. In mitotic cycle, the amount of chromosomal DNA does not change.	1.1 a, 1.2 e, 1.3 a
	5. The number of chromosome is fixed and remains unchanged during the stages.	3.1 b, 3.2 a, 3.3 a
	6. The number of chromosome is halved in the anaphase of mitosis.	3.1 b, 3.2 b, 3.3 a; 3.1 b, 3.2 e, 3.3 a; 6.1 a, 6.2 c, 6.3 a
	7. The chromosome number is doubled in interphase and stays same during the stages.	3.1 b, 3.2 d, 3.3 a; 7.1 a, 7.2 a, 7.3 a
	8. Prophase is the resting and preparation phase of the mitosis.	7.1 b, 7.2 c, 7.3 a
	9. The number of chromosomes is same during the stages of the mitosis.	7.1 b, 7.2 e, 7.3 a
	10. Homologous chromosomes separate from each other during mitosis.	8.1 b, 8.2 a, 3.3 a
	11. Sister chromatids separate from each other only during mitosis.	8.1 b, 8.2 d, 8.3 a
	12. All of the organelles dissolve and disappear during mitosis.	9.1 b, 9.2 a, 9.3 a
	13. Golgi apparatus can be monitored during the mitosis.	9.1 b, 9.2 b, 9.3 a; 9.1 b, 9.2 d, 9.3 a
	14. Both Golgi apparatus and mitochondria can be monitored completely during the mitosis.	9.1 a, 9.2 e, 9.3 a
	15. There is no need for the organelles during the mitosis since preparation is done in the interphase.	9.1 b, 9.2 f, 9.3 a
	16. Spindle fibers are only formed by centrosomes.	10.1 a, 10.2 a, 10.3 a; 10.1 b, 10.2 b, 10.3 a
	17. There are centrosomes in plant cells.	10.1 a, 10.2 d, 10.3 a; 10.1 c, 10.2 d, 10.3 a
	18. Spindle fibers are formed by centromeres.	10.1 b, 10.2 e, 10.3 a

(Table 3.6 continued)

Topic	Alternative conceptions	Alternative sets
Asexual Reproduction	19. Only single-celled organisms can reproduce by mitosis.	4.1 b, 4.2 a, 4.3 a
	20. All single-celled organisms and multicellular organisms that have regeneration ability can reproduce by mitosis.	4.1 a, 4.2 b, 4.3 a
Meiosis	21. The number of chromosome remains unchanged after meiosis.	2.1 b, 2.2 a, 2.3 a
	22. Both homologous chromosomes and sister chromatids separate and the number of chromosomes halves in two times.	2.1 b, 2.2 b, 2.3 a; 11.1 b, 11.2 b, 11.3 a
	23. Homologous chromosomes separated in meiosis I and they are sent to daughter cells without a change.	2.1 a, 2.2 d, 2.3 a
	24. The number of chromosome remains unchanged in meiosis-I and halves in meiosis II.	2.1 a, 2.2 e, 2.3 a; 11.1 b, 11.2 a, 11.3 a
	25. Daughter cells have diploid chromosome number.	2.1 b, 2.2 f, 2.3 a
	26. Sister chromatids separate from each other only during meiosis.	6.1 b, 6.2 d, 6.3 a; 8.1 a, 8.2 c, 8.3 a
	27. Homologous chromosomes separate from each other during anaphase of meiosis II.	6.1 b, 6.2 e, 6.3 a
	28. DNA needs to be replicated after meiosis I.	11.1 b, 11.2 b, 11.3 a; 11.1 b, 11.2 d, 11.3 a
	29. All diploid cells can undergo cell division by mitosis and meiosis.	12.1 c, 12.2 a, 12.3 a; 12.1 b, 12.2 d, 12.3 a
	30. Only haploid cells can undergo mitosis.	12.1 a, 12.2 c, 12.3 a
Sexual Reproduction	31. Crossing over is the only way to provide genetic diversity.	13.1 b, 13.2 a, 13.3 a
	32. Fertilization is the only way to provide genetic diversity.	13.1 b, 13.2 b, 13.3 a
	33. Changes in the number of chromosomes provide genetic diversity.	13.1 b, 13.2 d, 13.3 a; 13.1 b, 13.2 e, 13.3 a
	34. Plants reproduce by only asexual reproduction.	14.1 b, 14.2 a, 14.3 a; 14.1 b, 14.2 b, 14.3 a
	35. Plants reproduce by pollination which is a kind of asexual reproduction.	14.1 b, 14.2 c, 14.3 a

(Table 3.6 continued)

Topic	Alternative conceptions	Alternative sets
Sexual Reproduction	36. Non-flowering plants reproduce by asexual but flowering plants reproduce by sexual reproduction.	14.1 a, 14.2 e, 14.3 a
	37. Fertilization occurs during parthenogenesis.	15.1 a, 15.2 a, 15.3 a; 15.1 b, 15.2 c, 15.3 a; 15.1 a, 15.2 e, 15.3 a
	38. Reproduction is not possible without fertilization.	15.1 a, 15.2 b, 15.3 a; 15.1 a, 15.2 e, 15.3 a
	39. Diploid zygote can develop without fertilization.	15.1 b, 15.2 c, 15.3 a
	40. Sexual reproduction must involve mating.	18.1 a, 18.2 a, 18.3 a; 18.1 a, 18.2 c, 18.3 a
Chromosomes and Organelles	41. Centrioles are located in nucleus of cell.	5.1 a, 5.2 b, 5.3 a
	42. Centrioles are located in the nucleus of the cell but move to cytoplasm after the nucleus wall dissolves.	5.1 a, 5.2 c, 5.3 a; 5.1 a, 5.2 d, 5.3 a
	43. Gamete mother cells are haploid.	16.1 b, 16.2 a, 16.3 a
	44. Gametes are diploid.	16.1 a, 16.2 b, 16.3 a
	45. Homologous chromosomes placed only in the daughter cells after meiosis.	16.1 b, 16.2 d, 16.3 a
	46. Somatic cells do not carry homologous chromosomes.	16.1 b, 16.2 e, 16.3 a
	47. Homologous chromosomes are produced by DNA replication.	17.1 b, 17.2 a, 17.3 a; 17.1 a, 17.2 b, 17.3 a; 17.1 a, 17.2 e, 17.3 a; 20.1 a, 20.2 a, 20.3 a
	48. Homologous chromosomes are formed only in meiosis.	17.1 b, 17.2 c, 17.3 a
	49. Homologous chromosomes and sister chromatids are essentially the same thing.	20.1 a, 20.2 c, 20.3 a
	50. Homologous chromosomes are tied each other from their centromeres.	20.1 a, 20.2 d, 20.3 a
Regeneration	51. Highly organized animals have more regeneration ability compared to primitive ones.	19.1 b, 19.2 a, 19.3 a
	52. Animals with large bodies have much regeneration ability.	19.1 b, 19.2 c, 19.3 a
	53. Genetic diversity can be provided by regeneration.	19.1 a, 19.2 d, 19.3 a

Two-tier diagnostic tests are undeniably superior than multiple choice tests to detect alternative conceptions, however, the likelihood of guessing in these tests might overestimate students' knowledge and misconception levels therefore these tests could not differentiate alternative conceptions from lack of knowledge (Arslan et al., 2012; Caleon & Subramaniam, 2010a; Pesman & Eryilmaz, 2010). In order to overcome this weakness of two tier diagnostic tests a third-tier (confidence tier) which asks that the subjects were confident or not about their responses were added to each items of CDRDiT. At the end of this process, the CDRDiT included 20 three-tier multiple choice questions was developed. A professor majoring in biology education and three biology teachers reviewed the items, after the revisions the CDRDiT was piloted with 85 11^{th} grade students.

Scoring procedure of the CDRDiT was quite complex than regular multiple choice tests since there are eight different answer combinations. Table 3.7 lists these combinations and the labels of these combinations that are determined according to the related literature (Arslan et al., 2012; Pesman & Eryilmaz, 2010).

Table 3.7 Answer combinations of the CDRDiT items and their labels

First tier	**Second tier**	**Third tier**	**Label**
Correct	Correct	Certain	Scientific knowledge
Correct	Incorrect	Certain	Alternative conception (false positives)
Incorrect	Correct	Certain	Alternative conception (false negatives)
Incorrect	Incorrect	Certain	Alternative conception
Correct	Correct	Uncertain	Lack of confidence/Lucky guess
Correct	Incorrect	Uncertain	Lack of knowledge
Incorrect	Correct	Uncertain	Lack of knowledge
Incorrect	Incorrect	Uncertain	Lack of knowledge

Note. Table is adapted from Arslan et al., 2012.

Correct answers to the first two tiers along with being certain were classified as scientific knowledge. In correct responses to one of the first two tiers or both of them with certainty gives alternative conceptions. Two combinations of the alternative conceptions were also referred to the terms used for the errors of assessment in scientific research; false positives and false negatives. A false positive is the term that is used for finding an effect that is not actually present and false negative means that failing to reveal an effect that is actually present. Therefore, selecting correct answer to the first tier but wrong reason to the second tier along with certainty were treated as false positives and wrong answer to the first tier with correct explanation to the second tier along with certainty were treated as false negatives in the present study. Hestenes and Halloun (1995) used false positives and false negatives as an evidence for content validity of the force concept inventory (FCI) the well-known instrument in physics education field. They suggested that the minimization of the probability of these errors ensures validity in multiple-choice and the probability of false negatives needs to be less than 10%. The percentages of false positives and false negatives were found to be 8.20% and 4.45% respectively in the pilot administration of CDRDiT.

Researchers developing diagnostic tests with certainty indices tend to treat all of the uncertain responses as lack of knowledge (Hasan et al., 1999; Odom & Barrow, 2007; Pesman & Eryilmaz, 2010). This approach might not be correct for the students' who gave correct answers to both tiers but was not certain about their responses since this situation might be just a lucky guess or lack of confidence. Low self confidence in science is not a rare situation between students. Therefore, the answer combination of 'correct, correct and uncertain' was treated as lack of confidence in this study similar to Arslan, et al. (2012). Each student has four scores on CDRDiT, these are; total score (Pre/Post-CDRDiT), alternative conception score (Pre/Post-AC), lack of knowledge score and certainty score. Figure 3.1 summarizes how these scores were calculated.

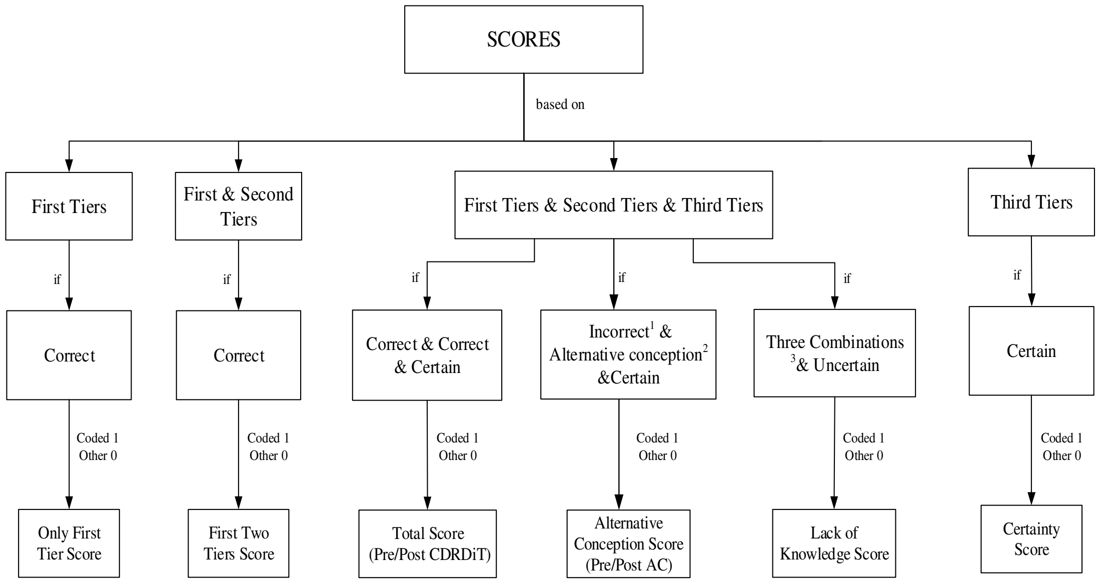


Figure 3.1 A diagram of coding and scoring procedure.

Note. [1]Correct answers to the first tier along with related misconception were also coded as 1. [2] alternative conception in the second tier have to be consistent with alternative sets given at the Table 3.6. [3]Three combinations are 'incorrect and correct', 'correct and incorrect', and 'incorrect and incorrect'.

The maximum score on CDRDiT was 20 and the minimum was 0. Cronbach alpha coefficient, item difficulty, and item discrimination indexes for each question were calculated by SPSS program. Table 3.8 shows descriptives and scale statistics of CDRDiT in pilot administration.

The croncbach alpha reliability coefficient of CDRDiT based on pilot study was .78 which means that the test has relatively high internal consistency since a reliability coefficient above .70 is considered as acceptable (Pallant, 2007). When alpha coefficient calculated with data obtained post administration of CDRDiT, it was .52 if only the answers to the one-tiers of the test were considered, it was .69 if the answers of first two tiers (both of tem should be corret) were considered and it was .79 if the aswers to the all three tiers of the test were considered. Therefore it can be concluded that the three-tier tests are more reliable than either regular multiple choice tests or two-tier diagnostic tests (Arslan et al., 2012; Cetin-Dindar, 2012; Pesman & Eryilmaz, 2010)

Table 3.8 Descriptive statistics of CDRDiT

Number of items	20
Number of participants	85
Mean / Standard deviation (SD)	9.42 / 4.04
Minimum	2
Maximum	17
Cronbach alpha	0.78
Difficulty indices (p)	
Mean	0.47
n of items (0.8 < p)	1
n of items (0.6 < p < 0.8)	5
n of items (0.4 < p < 0.6)	5
n of items (0.2 < p < 0.4)	8
n of items (p < 0.2)	1
Discrimination indices (D)	
Mean	0.44
n of items (0.6 < D < 0.7)	1
n of items (0.5 < D < 0.6)	5
n of items (0.4 < D < 0.5)	4
n of items (0.3 < D < 0.4)	10
n of items (0.2 < D < 0.3)	-

The item difficulty (p) is the percentage of students who answered the item correctly. A higher number shows an easy item which means that high number of students selects a correct answer. Similarly, a small number indicates difficult item so, alternative responses to the item were chosen by more students. The mean difficulty level of the CDRDiT was .47 which shows that it was difficult test for 11th grade level students. Item 17 was very difficult item and it should be reviewed.

When discrimination indices of items were checked according to Ebel and Frisbie (1986), items with D values range 0.20 - 0.29 needs to check and the items with D values below 0.20 should be discard or review in depth. Discrimination values of the

CDRDiT items was higher than .30 therefore, all of the items were retained. After item 17 were reviewed, the final version of CDRDiT (Appendix D) was administered to both CCI and LCI groups as a pre-test and post-test. The pre-test scores were used to compare whether students in CCI and LCI groups were different from each other when their understanding on cell division and reproduction considered before the implementation. Questions of CDRDiT can be answered approximately 30 minutes.

3.4.3 Science Process Skill Test (SPST)

SPST, which was originally developed by Burns, Okey, and Wise (1985), was translated and adapted to Turkish by Geban, Askar, and Ozkan (1992). The test was administered to assess participants' science process skills before the treatment to investigate whether there is a difference between groups in terms of their science process skills. The test was consisted of 36 four-alternative multiple choice items and five subscales related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations, and drawing graph and interpreting data (Appendix E). CCI and LCI groups took SPST before the treatment, correct answers of the students were coded as 1, and incorrect answers were coded as 0 so, maximum score was 36 and the minimum score was 0. The cronbach alpha for internal consistency was calculated .82 in the present study.

3.4.4 Interview Schedule

Collecting data from multiple sources increases the credibility and validity of the results of this study. Therefore, semi-structured interviews were conducted with six students from experimental and six students from control groups after the treatment in order to data triangulation. The students were selected purposively to ensure academic achievement variablility and gender equality; 6 students from each schools (3 from CCI and 3 from LCI group). There were 26 interview questions; 20 question related cell division and reproduction, six questions related with the teaching methods (Appendix F). These six questions were directed only LCI group students. During the interviews, students were asked to create their own representations of the stages of mitosis and meiosis. Interviews lasted about 25-30 minutes and were audiotaped and transcribed. A PhD. candidate on biology education analyzed the transcripts by using rubric and the drawings besides the researcher and the results were consistent with each other.

3.5 Procedure

The procedure for conducting this particular study included several steps. These steps were listed below;

- According to the researcher's interest on improvement of students' conceptual understandings, the effectiveness of learning cycle instruction was determined as a core of this study.
- Several key terms such as; "learning cycle", "5E learning cycle model", "conceptual change", "alternative conceptions", and "activities on cell division and reproduction" were used to make literature review. Literature review was a long process and carried out in every steps of the study.
- The research problem was stated after initial literature review performed with predetermined key terms through data bases (Educational Resources Information Center [ERIC], EBSCOhost, ProQuest Dissertations & Theses, and Education Research Complete), Science Direct, Google Scholar, METU Library Theses and Dissertations, and Turkish Higher Education Council National Dissertation Center.
- After reading process, theoretical framework of the present study was constructed with the help of related studies.
- Lesson plans and instructional materials were developed according to reviews of a professor majoring biology education and two biology teachers.
- In order to measure the effectiveness of the implementation, CDRAT and CDRDiT were developed by researcher. Revisions were done according to expert opinions. Pilot administrations of the tests were conducted 2011- 2012 fall semester. Item analyses were performed to calculate item difficulty and item discrimination of each question. Necessary improvements were done

and the final versions of CDRAT and CDRDiT were formed. In addition, permission to use SPST was obtained.

- Permissions from Applied Ethic Research Center at METU and the Ministry of Education were obtained to conduct this study with high school students enrolled in Anatolian schools in Etimesgut district of Ankara.
- Schools were visited and informed about the study. Volunteer 10^{th} grade biology teachers who have two intact classes were selected and trained in learning cycle, its implementation in class, and how lesson plans were applied in LCI groups.
- Pre-tests were administered to both LCI and CCI groups at the end of the 2011-2012 fall semester since cell division and reproduction unit was the first unit of the spring semester. Therefore, there were two weeks between pre-test and the beginning of the implementation.
- Implementation period lasted for ten weeks (2 class hours in a week) in the 2011-2012 spring semester. Classes were randomly assigned to treatments. Researcher observed lessons as a non-participant observer and rated classroom observation checklists (Appendix G). Before the lessons, technological equipment of class and laboratory materials to perform experiments were checked, necessary materials, handouts were provided by the researcher.
- Post-tests were administered to both groups and semi-structured interviews were conducted with 6 students from CCI groups and 6 students from LCI groups.
- Data obtained from pre and post-test were entered to SPSS to perform necessary analysis. In addition to that the data obtained from pre and post-CDRDiT was entered into MS Excel to calculate percentages of students' scores. The qualitative data from interviews of 12 students were transcribed.
- Descriptive and inferential analyses were done to test the hypotheses of this study and interpret the raw data. The transcribed interviews were coded and the drawings categorized under levels.
- Dissertation was written.

3.6 Treatments

This study included 10 weeks treatment period (two 45 minute sessions per-week) of 10^{th} grade students on cell division and reproduction unit. Lesson plans (Appendix H) based on 5E learning cycle model and conventional method were developed by researcher according to the objectives of national biology curriculum (Ministry of Education [MONE], 2011). Revisions were carried out based on feedbacks of a professor majoring biology education and two biology teachers. Before the implementation, two teachers, who has over 10 years' experience in biology teaching, were trained for application of learning cycle, how they should follow lesson plans and use teaching materials. In addition to that, before the each class session, researcher reminded teachers the important points of lesson plans approximately one hour in every week and provided handouts and materials (such as extra microscopes, acetocarmine, onion etc.) which were not included in schools' laboratories. In the control groups conventional teacher-centered biology instruction was used. The lesson plans were implemented by two biology teachers in a general high school setting during 10 weeks (20 class sessions) treatment period during the spring 2011-2012 school term. Instruments were administered during a week right before and after implementation period.

3.6.1 5E Learning Cycle Instruction

The 5E learning cycle model (Bybee et al., 2006) was used while designing the lesson plans on cell division and reproduction unit. The first step in this model elicit students' prior knowledge therefore, provides teacher a starting point to engage students in construction of new knowledge. Then students explore the scientific facts and try to explain the phenomena in their own words. Next, the teacher explains the scientific concepts by using specific terminology. As a fourth step, students elaborate which means they apply knowledge to a new domain or extend that to a new context. In the last step, students' understanding is evaluated. 5E learning cycle examples presented in the books by Bass, Contant, and Carin, (2009), Hammerman (2006) and Moyer, Hackett, and Everett, (2007) teaching recommendations on cell division stated in Smith (1991), Smith and Kindfield (1999), and Lewis, Leach, and Wood-

Robinson, (2000) were utilized for developing lesson plans based on the objective list (Appendix A). Four lesson plans were prepared on four subtitles of the cell division and reproduction unit according to the 5E learning cycle steps. The activities that were embedded into the lesson plans were given at Table 3.9.

Table 3.9 The details of the lesson plans used in LCI groups

Subtitles	**Activity**	**Duration**	**Objectives**
Mitosis (Lesson Plan I)	- Watching Video on Cancer (E1) - Let's Observe Cell Cycle (E2) - Modeling Mitosis with Play dough (E3) - Tumor Formation (E3) - Discussion (Mitosis in Plant cells)(E4) - Conceptual Questions (E5)	7 Class Sessions	1.1, 1.2, 1.3, 1.4
Asexual Reproduction (Lesson Plan II)	- Reading:"Batuhan's Summer Holiday" (E1) - Exploring Cell Division in Yeast (E2) - Asexual Reproduction Under a Microscope (E2) - Watching Video on Grafting (E3) - Daily Life Examples (E4) - Conceptual Questions (E5)	3 Class Sessions	2.1, 2.2
Meiosis (Lesson Plan III)	- Reading:"A story of Aydan & Caner" (E1) - Let's Observe Meiosis (E2) - Surprise with Sockosomes (E2- E3) - Watching Video on Mitosis and Meiosis (E4) - Bajema Strategy (E5)	6 Class Sessions	3.2, 3.4
Sexual Reproduction (Lesson Plan IV)	- Frayer Model (E1) - Explore an Egg (E2) - Watching Video on Fertilization (E2) - How do Living Creatures Reproduce? (E2) - Stem Cells (E3) - Reading: "Life cycle of Bees" (E4) - Comparison of Reproduction Types (E5)	4 Class Sessions	3.1, 3.3, 3.5, 3.6

Note. The abbreviations in the table are; E1= Engage, E2= Explore, E3= Explain, E4=Elaborate, and E5=Evaluate.

Knowing the concepts of cell, cell structure, their functions, and chromosome structure are prerequisite objectives in order to understand cell division and reproduction concepts. According to national curriculum, students have already instructed on these concepts in 8th and 9th grades. In the beginning, teacher reminded the concepts of chromosome, chromatid, homolog chromosome, sister chromosome, haploid and diploid briefly. In accordance with 5E learning cycle steps (engage, explore, explain, elaborate, and evaluate), teacher followed the lesson plan.

In engagement phase, she showed a video of a famous singer who died of lung cancer, and an actress who received treatment for breast cancer in order to engage students in the beginning of the first lesson plan. After watching the videos, teacher asked questions on student's knowledge of cancer, they discussed how cancer might develop and what causes cancer. Teacher serves as a moderator, showed the results of report on the reasons of died in Turkey, and asked further questions during this class discussion. Students guessed that the development of cancer is based on a fault in cell procedures.

In exploration phase, students performed three activities in order to understand the cell cycle concept in depth. In the first activity teacher distributed the activity sheet, made groups of 4-5 students, and asked them to read the reading that is named as "One to Many: Cell Cycle". After reading, their opinions on how body grows were discussed. Then, teacher performed six of nine steps of the first experiment (Lets' Observe Cell Cycle) as a demonstration in front of the class since these steps needs to use fire and lancet. She made students to follow the directions in activity sheet. She prepared two microscope slides for each group in order to show mitosis in onion root tip cells. Students tried to find the cell display under the microscope. Teacher and the researcher directed students to view cells since most of the students do not have any experience with microscope. In addition, images of onion root tip cells from Cordero and Szweczak (1994) were showed in order to help students imagine how an onion cell looks like, because most of them have never seen a cell under microscope. When they found any view, they asked teacher or researcher for confirmation. Teacher asked them to draw three cells with different appearance and to determine how many daughter cells are produced after division. At the end of the first activity teacher showed prepared microscope slides of the phases of mitosis in order to ensure that students see the desired display of the stages. Then, teacher distributed second activity sheet and make students to read individually a short biography of Theodor Boveri claimed that the chromosomes carry genetic material in late 1800. Teacher provided necessary materials for modeling mitosis to groups of 4-5 students, wanted them to perform second activity according to directions in the activity sheet. Teacher acted as an observer, did not interfere students models, just guide them to finish the model either correct or incorrect. Groups took notes of their questions and difficulties during the activity.

In the explanation phase, teacher asked one speaker from each group to explain their models right after the second activity; teacher encouraged students to speak and directed leading questions to make them realize their mistakes. Speakers also asked their noted questions and class discussed the answers. Teacher served as a moderator, helped them to conceptualize the logic of the each phase. Most of the groups have difficulties on the appearance of chromosomes before DNA replication, they asked questions about that. Some of the groups used figures on their textbook while constructing their mitosis model and they confused much. Because cell figures illustrated the phases of mitosis in students' textbook which is offered by MONE were depicted as having replicated chromosomes in each phase. When all of the questions discussed, teacher divided board into three parts with board marker, wrote cell cycle in top, and interphase, mitosis and cytokinesis in each cell respectively. Then she divided mitosis section into four parts and wanted students to tell what happens in cell cycle, wrote their responses into the related part and finally she wrote the name of the each phase. Teacher emphasized that cell cycle is constantly ongoing process and it is divided into parts to make it understandable. She also explained that regardless of the cell type (either prokaryotes or eukaryotes), all cells undergo cell cycle however they might stay in different stages or complete cell division. During this explanation phase teacher paid attention to alternative conceptions (researcher provided list of common alternative conceptions) that included in students answers. When she detected any alternative conception, she asked this as a question to class whether it is correct or wrong according to their exploration. She helped them to find correct explanations with reasons instead of providing knowledge. For instance, some of the groups let it drop that the interphase is the resting phase of cell cycle or chromosome number is same in all phases of mitosis. First teacher directed to the class, in some classes one group or one student gave the correct explanation however in some classes they could not find therefore teacher referred the activities that students done and want them to think and discuss, guide them to find the scientific explanations by their selves. Teacher did never explain directly the scientifically correct explanation in order to dispel alternative conceptions and provide retention. The third activity, Tumor Formation, was performed by groups of 4-5 students. The focus of the activity was on how tumors form in order to get students to conceptualize the importance of the control mechanism of cell cycle and what happens if the cell cycle could not controlled. First, groups discussed questions at the end of the activity sheet and then whole class discussed it. Then teacher explained the checkpoints of the cell cycle.

In the elaboration phase, teachers asked questions such as; "what changes occur in our body by the cell division?", "how cell cycle works in plants that do not have centrosome?" "Is it possible to have tumor for plants" or "Is there any cell that could not divide?". The class discussed these kinds of questions with the guidance of teacher. Therefore teacher tried to provide chance students to use their knowledge in different situations.

Then for evaluation step of 5E learning cycle, teacher showed real cell pictures which are in different phases of cell cycle, wanted students to determine the appropriate phase, tell their reasons and tried to explain the process of these phases. In addition, teacher made students summarize what they have learned by questions.

3.6.2 Conventional Classroom Instruction

In CCI groups traditional teacher-centered instruction was implemented by two teachers in regular classrooms. The teachers mainly used lecturing and questioning during the lessons. They followed textbook advised by MONE and asked students to read the related parts before classes. CCI group students did not make any activities performed in the LCI groups. However, CCI and LCI group students were in interaction during break times and they might hear about the activities in LCI group and receiving no treatment might affect their performance either in negative or positive manner. This confounding variable is named as John Henry effect (Hake, 1998). CCI group students read the same readings and watched the same videos on grafting and fertilization with the LCI groups to avoid this effect. The readings and videos that were embedded into the lesson plans were given at Table 3.10.

Table 3.10 The details of the lesson plans used in CCI groups

Subtitles	Activity	Duration	Objectives
Mitosis (Lesson Plan I)	- Remind prior knowledge - Present definitions directly - Explain each phase of mitosis - Show prepared posters - Explain mitosis in plant cells - Watching Video on Cancer - Ask conceptual questions	7 Class Sessions	1.1, 1.2, 1.3, 1.4
Asexual Reproduction (Lesson Plan II)	- Reading:“Batuhan’s Summer Holiday” - Present definitions directly - Give examples of organism - Watching Video on Grafting - Teacher explains the video	3 Class Sessions	2.1, 2.2
Meiosis (Lesson Plan III)	- Reading:”A story of Aydan & Caner” - Present definitions directly - Explain each phase of meiosis - Show prepared posters - Watching Video on Mitosis and Meiosis - Ask conceptual questions	6 Class Sessions	3.2, 3.4
Sexual Reproduction (Lesson Plan IV)	- Present definitions directly - Give examples of organism - Reading:”A Life cycle of Bees” - Watching Video on Fertilization- - Teacher explains the video	4 Class Sessions	3.1, 3.3, 3.5, 3.6

Similar with the LC group students, CCI group students have already instructed on the concepts of cell, cell structure, their functions, and chromosome structure in 8th and 9th grades. In the beginning, teachers reminded the concepts of chromosome, chromatid, homolog chromosome, sister chromosome, haploid and diploid briefly. They presented directly the definitions, processes and products of mitosis, asexual reproduction, meiosis, and sexual reproduction by using chalk and board. They showed similar prepared posters that were provided by MONE while explaining the procedures of mitotic and meiotic division. They directed questions to the students related to both previous and new concepts during the instruction. Most of the time students were passive and asked for time to take notes on their notebooks and teachers paused and waited for them. In addition, teachers get students to take note the important parts of the subjects. Also, further explanations of the concepts were provided by the teachers when students asked questions.

3.7 Treatment Fidelity and Verification

Treatment fidelity refers to the verification of the experimental groups were instructed with 5E learning cycle and control groups were instructed with conventional classroom instruction. In order to ensure treatment fidelity, learning cycle and conventional classroom instruction needs to be defined clearly. Literature review on 5E leaning cycle provide framework how learning cycle instruction should or should not be implemented. Especially, Bass et al. (2009) and Marek and Cavallo (1997) were used during the development of lesson plans. Supervisor and co-supervisor of this study guided and reviewed instructional materials.

Treatment verification of the study was ensured by rating classroom observation checklists throughout 10 weeks (20 class hours) implementation period. The checklists (Appendix G) developed by Pesman (2012) were rated for this purpose. For the treatment groups, the checklist indicated the degree to which the teachers implemented the 5E learning cycle instruction that is framed with lesson plans. The items of the classroom observation checklist included both the expected and unexpected behaviours based on 5E learning cycle method. For the control groups, the checklist verifies the absence of the 5E learning cycle instruction and the presence of conventional classroom instruction. The observation checklists were rated by the researcher for 8 weeks and by a research assistant majoring science education for 2 weeks of the lessons to obtain accurate data. During the class observations, researcher took some notes about the events occurred, students and teachers behaviours. Checklists rated by researcher and observer were compared and it was concluded that the notes and classroom observation checklists results showed that the teachers implemented teaching methods as proposed by the researcher, they follow the steps of 5E learning cycle in experimental groups and students engaged in activities. Teachers did not use direct instruction techniques. In conventional classroom instruction groups, teachers used direct instruction by using chalk and board, got students read same readings in experimental groups and showed posters of cell division processes.

3.8 Ethical Issues

This study did not intent to cause any possible harm to the participants (neither teachers nor students). The approval of the ethical issues on this study were investigated by a committee with five professors majoring educational sciences at METU. At the beginning of the study, the participants were informed on the rationale for the study and were guaranteed that any data collected from or about the participants held in confidence and the names of participants never be used in any publications. Their rights to withdraw from the study were emphasized. Although one of the participants took pre-tests, s/he withdrew from the study. During the data collection, the researcher reminded the aim of the study, the importance of results, and the absence of possible effects on participants' biology grades in school again.
In addition to them, the teachers were informed of the rationale for observing their lessons since observation may affect teachers' behaviors. Therefore, teachers should know that the aim of this study is not to investigate the teachers or their pedagogical content knowledge and the observations provided evidence that the implementation was carried out as the researcher planned.

3.9 Data Analysis

This study includes both qualitative and quantitative data. The quantitative data were collected with Cell division and reproduction achievement test (CDRAT) and Cell division and reproduction diagnostic test (CDRDiT) as pre-test and post-test and Science process skill test (SPST) as a pre-test. Data on students' background information; their date of birth, gender, mother and father education level, and pre-year biology grades were also collected. The data obtained from students' background questionnaire, pre and post-tests were entered into computer. The statistical analyses were conducted with IBM Statistical Package for the Social Sciences (SPSS) program. In addition students' responses to pre and post-CDRDiT were entered to MS Excel program in order to code data according to the pre-determined answer combinations and calculate percentages of students' scores.

In the beginning of the data analysis, the raw data were dichotomized according to the answer key of CDRAT, CDRDiT, and SPST. Students' who did not take any one of post-test were excluded from the data set since missing data in the dependent variables could not be compensated. 10 students did not take post-CDRDiT and 5 students were not in their classes during the administration of post CDRAT, and two of them were same persons who did not take post-CDRDiT. Therefore, 13 students were excluded from the data. Missing items in CDRAT and CDRDiT were replaced with 0 and total scores were calculated. Missing data on the pretest total scores were replaced with the mean scores of each test of the group that the student belongs to. Handling with missing data was reported in detail in chapter 4. Descriptive and inferential statistics used to interpret the raw data. The mean, median, mode, standard deviation, minimum and maximum scores, skewness and kurtosis of both pre and post test scores of the students on CDRAT, CDRDiT, and SPST were calculated. These calculations were used to describe the data and to check some assumptions that are necessary to perform inferential analysis.

Multivariate analysis of covariance (MANCOVA) was performed to test the hypotheses of this study. The variables were checked for any violation of the assumptions underlying the MANCOVA analysis before running it. If the assumptions were met, MANCOVA is a suitable statistical method for the studies which have more than one dependent variable because it adjusts for type I error while comparing groups (Pallant, 2007). MANCOVA was performed with three dependent variables (post-CDRAT scores, post-CDRDiT scores and post-AC scores), two independent variables (treatment, gender) and one confounding variable (SPST scores). In order to interpret the effect of independent variables on each dependent variable separately, follow-up ANCOVAs were done. In addition to these analysis percentages of students' four different scores -total scores, alternative conception scores, lack of knowledge scores, certainty scores- obtained via pre and post-CDRDiT were calculated to investigate differences between LCI and CCI group students before and after the implementation period.

The qualitative data obtained from semi-structured interviews with 12 students were transcribed and categorized under themes. During the interviews, students were asked to draw their representation of cell divisions and explain the phases of mitosis and meiosis. Students were labelled with letters A to L (A,B,C,D,E,F for the CCI group students and G,H,I,J,K, and L for LCI group students). Drawings of the students were categorized under 5 levels conceptual understanding themes with the help of a scoring system developed by Dikmenli (2010). Besides the researcher, a PhD. candidate on biology education categorized transcripts and analyzed the drawings by using the scoring system. The results were consistent with each other. In order to report the results, CCI and LCI group students' responses to interview questions were compared and their sample sentences and representations of the cell divisions were reported in the Chapter 4.

The data collected to verify treatment via classroom observation checklists by researcher and a research assistant majoring science education were compared whether there is consistency between them.

3.10 Power Analysis

Before the study, necessary sample size which is required for obtaining pre-established power needs to be calculated. This calculation was performed by using the following formula which was proposed from Cohen, Cohen, West and Aiken (2003).

$$n = \frac{L}{f^2} + k_A + k_B + k_C + 1$$

n: sample size

L: function of determinants of the population hypothesis and error matrices

f^2: effect size

k_A: number of covariates

k_B: the number of independent variables

k_C: the number of interaction terms

The L value of this study, which is 9.64, is found from the L table at Cohen et al. (2003, p.651) based on pre-determined alpha level (.05). Effect size of this study (f^2) was also established as medium which is .15 according to the criteria of Cohen et al. (2003). k_A is 1 since there is one covariate in this study (SPST scores), k_B is 2 (treatment and gender), and the number of interaction terms (k_C) is 2. When these values were placed to the equation, the minimum sample size was calculated as 70.26. After missing data analysis, the data of 227 students were used to make inferential analysis, therefore medium or large effect might be found.

3.11 Assumptions and Limitations

Assumptions of the study were;

- There is no difference between two teachers' implementations of the lesson plans in CCI and LCI groups.
- Teachers followed only the lesson plans developed by the researcher and did not favor any group during the implementation period.

- Instruments (CDRAT, CDRDiT, and SPST) of this study were administered under standard conditions for each group.
- All of the participants answered the items of the instruments honestly.
- Interviews were conducted under standard condition with each participant.
- Participants answered interview questions sincerely.

Limitations of the study were;

- The results of this study are limited to 241 10th grade Anatolian High school students.
- The results of this study are limited to cell division and reproduction unit.
- Random sampling was not able to provided.
- Implementation period was limited to 10 weeks (20 class hours).
- The quantitative data was limited from four multiple-choice tests (CDRAT, CDRDiT, and SPST) and their contents.
- The qualitative data was limited to 12 students.
- Students' achievement and understanding on cell division and reproduction concepts might be affected by other factors that are not controlled in this study (such as training courses or supplementary lessons) during the implementation.
- Students might gain different alternative conceptions than those that are revealed by CDRDiT from different sources during the implementation period.

CHAPTER 4

RESULTS

The results of this study were reported under four titles; missing data analysis, statistical analysis of pre-test scores and post-test scores, students' interviews results includes their drawings and ideas on 5E learning cycle instruction, and the summary of the results.

4.1 Missing Data Analysis

A total of 241 students took at least one of the instruments in this study. In other words, some of the participants were missing during the administration of the tests. Missing values on each variables of this study were summarized in Table 4.1.

Table 4.1 Missing values for the raw data

Variable	**Present (N)**	**Missing (N)**	**Missing (%)**
Pre-CDRAT	239	2	0.8
Pre-CDRDiT	233	8	3.3
Pre-AC	233	8	3.3
SPST	238	3	1.2
Post-CDRAT	236	5	2.1
Post-CDRDiT	231	10	4.1
Post-AC	231	10	4.1
Gender	241	0	0

Note. N: Number of the subjects

Before conducting data analysis, the raw data needs to be checked for the missing values, since "missing data is one of the most pervasive problems in data analysis" (Tabachnick & Fidell, 2007, p.62). The pattern of the missing data is very important to handle it. If missing values distributed randomly through a data set, it would lead less serious problems (Tabachnick & Fidell, 2007). Since the percentages of missing participants were under 5% for all of the instruments, it can be assumed that these missing values were scattered randomly through the data (Tabachnick & Fidell, 2007). However, missing data in independent variables and dependent variables should be treated differently. The missing participants in the post-tests (13 students) were excluded from the data because these missing values are in the dependent variables of the study. Therefore, 228 students who answered all of the post-tests were used to perform inferential statistics. One student of them did not take pre-CDRAT and six students did not take pre-CDRDiT. These missing pre-test scores were replaced with the mean scores of the groups that the participants belong to (Tabachnick & Fidell, 2007).

4.2 Statistical Analysis of Pre-tests Scores

After the missing data analysis, descriptives of each variable were calculated. In addition, independent samples t-tests were performed to examine whether there is difference between LCI and CCI groups; regarding to their achievement, conceptual understanding on cell division and reproduction concepts, alternative conceptions and science process skills before the treatment. For this purpose, pre-CDRAT, pre-CDRDiT, Pre-AC and SPST scores were used as dependent variables to run independent samples t-tests with SPSS 17 Program. The data collected by the administration of Cell Division and Reproduction Diagnostic test as a pre-test was transported to MS Excel to calculate percentages of correct responses abbreviated as Pre-CDRDiT and alternative conceptions scores abbreviated as (Pre-AC) by taking into account the students' answers to all three tiers of the test.

4.2.1 Statistical Analysis of Pre-tests and SPST Scores

Descriptive statistics for pre-CDRAT, pre-CDRDiT, pre-AC, and SPST scores of LCI and CCI groups were summarized at Table 4.2. According to the table, there were differences between means of the CCI and LCI groups on pre-tests.

Table 4.2 Descriptive statistics for pre-CDRAT, pre-CDRDiT, pre-AC and SPST scores across groups

Tests	Groups	N	Mean	SD	Min.	Max.	Skewness	Kurtosis
Pre-CDRAT	CCI	114	13.97	4.07	4.0	23.0	-.079	-.169
	LCI	114	13.62	3.69	3.0	25.0	-.198	.494
	Total	228	13.79	3.88	3.0	25.0	-.116	.106
Pre-CDRDiT	CCI	114	1.43	1.60	0.0	6.0	1.158	.784
	LCI	114	1.75	1.82	0.0	9.0	1.293	1.924
	Total	228	1.59	1.71	0.0	9.0	1.257	1.597
Pre-AC	CCI	114	7.21	2.79	0.0	13.0	-.673	.356
	LCI	114	7.48	3.00	0.0	15.0	-.299	-.066
	Total	228	7.35	2.90	0.0	15.0	-.453	.126
SPST	CCI	114	19.03	6.34	4.0	33.0	-.228	-.555
	LCI	114	22.35	5.09	8.0	33.0	-.476	.008
	Total	228	20.68	5.97	4.0	33.0	-.448	-.262

Note. CCI: Conventional Classroom Instruction, LCI: Learning Cycle Instruction

The mean score of pre-CDRAT for CCI group was 13.97 and for LCI group was 13.62. Pre-CDRAT measure students' prior knowledge on cell division and reproduction concepts, therefore high score indicates having high level of prior knowledge. Since the mean scores of the CCI and LCI groups were very close to each other, it can be said that these students have similar level of prior knowledge on these concepts before the implementation. In addition, it can be said that the prior knowledge of both groups were low when compared to the maximum score of CDRAT which is 35.

When the descriptives of pre-CDRDiT investigated, the mean score of CCI group (1.43) and LCI group (1.75) were very close to each other. CDRDiT is a diagnostic test and aims to determine students' conceptual understanding levels and identify their alternative conceptions on cell division and reproduction concepts. The possible total score on CDRDiT is 20 and the mean scores of both groups were close to one. This means that their conceptual understanding levels on these concepts were similar and very low before the implementation.

Similar to pre-CDRDiT scores, the mean alternative conceptions scores of the groups were very close to each other before the treatment. The mean score of pre-AC was 7.21 for CCI group and 7.48 for LCI group. When compared to the possible maximum alternative conception score (20), these numbers indicated that besides the students' low understanding scores; they held some alternative conceptions on cell division and reproduction concepts before training on these concepts.

The mean score of SPST was 19.03 for CCI group and 22.35 for LCI group. There was a slight difference between groups according to their mean scores. This difference means that the LCI group students have more science process skills than the CCI groups students before the implementation.

The percentages of correct responses of the students based on first tiers, first two tiers and all three tiers of pre-CDRDiT were showed in Table 4.3. As expected, when the tiers of the question increased, the percentages of the correct answers decreased. If the mean percentages were examined, it can be seen that the numbers were close to each other. In addition, the percentages of all three tiers indicated that there is no differences among CCI and LCI groups in the items 2, 7, 9, 14 and small differences (range between 1-4 percentages) in 14 items of the pre-CDRDiT. In other words, there is no difference between students' understanding of cell division and reproduction concepts before the implementation. The percentages of item 4 and item 5 were higher than the others and very close to each other, the easiest question for CCI group was item 5 and it was item 4 for LCI group. The most difficult question for both groups was item 6 with 25% and 27% percentages of only first tiers for CCI and LCI groups respectively. In addition to that for CCI group item 3 and for LCI group item 1 were difficult questions. The results of the item 13 and 19 emphasize the usefulness of collecting data on students' understanding with multi-tier test items. Although 72% of students from CCI group and 89% of the students from LCI group selected the correct answer for the first tier of the item 13, 59% and 69% of them did not gave the correct reason of their responses in CCI and LCI groups respectively. Similarly, the results of item 19 was interesting, 46% of CCI and LCI group students answered the first tier of the item 19 correctly, however, 40% of them from CCI group and 42% of them from LCI group could not select the correct reason in the second tier of item 19.

Table 4.3 Percentages of the correct responses of students on pre-CDRDiT

CDRDiT items	**Only First Tier**		**First Two Tiers**		**All Three Tiers***		**Confidence Level**		**Lack of knowledge**	
	CCI	**LCI**	**CCI**	**LCI**	**CCI**	**LCI**	**CCI**	**LCI**	**CCI**	**LCI**
1	37	29	8	11	2	4	30	43	64	50
2	46	34	11	10	5	5	36	47	58	48
3	28	41	3	7	0	4	25	33	72	63
4	74	82	32	38	19	29	51	60	37	32
5	72	77	41	43	22	23	36	44	45	36
6	25	27	4	4	1	0	22	27	75	69
7	55	34	11	8	4	4	30	30	63	66
8	45	38	22	16	8	11	32	45	54	51
9	52	60	11	21	6	6	20	23	75	62
10	37	38	18	21	7	9	34	41	55	46
11	39	47	12	11	2	1	22	23	68	68
12	46	60	18	31	11	22	36	45	56	46
13	72	89	13	20	9	11	55	65	40	26
14	66	71	25	29	17	17	47	53	45	35
15	53	49	23	19	7	5	22	24	62	62
16	53	51	18	12	8	5	29	30	61	63
17	49	43	16	9	3	4	21	24	66	71
18	48	37	17	17	6	8	39	46	50	46
19	46	46	6	4	1	0	52	54	43	42
20	34	53	25	33	8	9	37	29	46	46
MEAN	49	50	17	18	7	9	34	39	57	51

Note. CCI: Conventional Classroom Instruction, LCI: Learning Cycle Instruction, *All three tiers corresponds to Total Score (Pre/Post CDRDiT).

Independent samples t-tests were conducted to investigate whether there are statistically significant differences between CCI and LCI groups based on their scores on pre-CDRAT, pre-CDRDiT and SPST. The assumptions of t-test - normality, independence of observations, and equality of variances- were checked before performing the analysis. Descriptives of the pre-test scores provides information on distribution of the scores. The desired skewness and kurtosis values for normal distribution should be in the range of -2 and +2 (George & Mallery, 2003). When the skewness and kurtosis values were checked from the Table 4.2, all skewness and kurtosis values are in the range of -2 and +2. In this study, all of the instruments were answered independently, therefore the assumption of independence of observation was assumed to be met. The equality of variances assumption was checked from the results of Levene's test for equality of variance (Table 4.4).

Table 4.4 Levene's test of equality of variances

	F	**p**
Pre-CDRAT	1.359	.245
Pre-CDRDiT	.606	.437
Pre-AC	1.059	.305
SPST	6.989	.009

The results indicates that variances of scores on pre-CDRAT, pre-CDRDiT and pre-AC for CCI and LCI groups are equal, however; the assumption was violated for the scores of CCI and LCI group on SPST. However, SPSS program provides alternative t-value, which compensates the difference between the variances. Since the assumptions were met, the results of the independent samples t-test were examined to find out whether there are significant differences between groups. Table 4.5 indicates the results of t-tests.

Table 4.5 Independent-samples t-tests for Pre-CDRAT, Pre-CDRDiT, Pre-AC and SPST

	t	df	p
Pre-CDRAT	.682	226	.496
Pre-CDRDiT	-1.390	226	.166
Pre- AC	-.684	226	.495
SPST	-4.360	215.85	.000

According to the table 4.5, there was no significant difference between CCI (M= 13.97, SD= 4.07) and LCI (M= 13.62, SD= 3.69) groups based on their pre-CDRAT scores [t (226) = .682, $p > 0.05$]. When the results of pre-CDRDiT examined, it can be concluded that there was no significant mean difference across CCI (M= 1.43, SD= 1.60) and LCI (M= 1.75, SD= 1.82) groups [t (226) = -1.390, $p > 0.05$]. In addition, there was no statistical significant difference between groups (M= 7.21, SD= 2.79 for CCI and M= 7.48, SD= 3.00 for LCI) based on their alternative conception scores (pre-AC) derivated from the students' answers to pre-CDRDiT [t (226) = -.684, $p > 0.05$]. However, the difference in SPST scores for CCI (M= 19.03, SD= 6.34) and LCI (M= 22.35, SD= 5.09) were significant [t (215.85) = -4.360, $p < 0.05$]. Under the condition that the requirements of being a covariate was met, SPST scores can be assigned as a covariate to control this pre-existing difference between the groups while conducting analysis on post-CDRAT, post-CDRDiT and Post-AC scores of CCI and LCI groups.

4.3 Statistical Analysis of Post-test Scores

First, descriptives of post test scores were calculated. Then, the assumptions of multivariate analysis of covariance (MANCOVA) were checked to detect any violations to perform it for testing the hypotheses of this study. MANCOVA was preferred because of the statistically significant difference between SPST scores of CCI and LCI groups before the implementation. Post-CDRAT, post-CDRDiT and post-AC scores were used as dependent variables, SPST scores were covariate and teaching method and gender were independent variables. SPSS 17 Program was used to conduct MANCOVA at .05 significance level.

4.3.1 Statistical Analysis of Post-tests Scores

The Table 4.6 and Table 4.7 give the descriptive statistics of post-test scores according to the independent variables; teaching method and gender respectively.

Table 4.6 Descriptive statistics for Post-CDRAT, Post-CDRDiT and Post-AC scores across groups

Tests	Group	N	Mean	SD	Min.	Max	Skewness	Kurtosis
Post-CDRAT	CCI	114	26.66	4.17	13.0	35.0	-.480	.120
	LCI	114	27.08	5.58	7.0	35.0	-1.729	3.152
	Total	228	26.87	4.92	7.0	35.0	-1.353	2.584
Post-CDRDiT	CCI	114	6.73	3.35	0.0	16.0	.041	.250
	LCI	114	10.38	4.52	0.0	20.0	-.072	-.856
	Total	228	8.56	4.37	0.0	20.0	.273	-.414
Post-AC	CCI	114	6.47*	2.07	2.0	13.0	.330	.345
	LCI	114	4.84*	2.42	0.0	10.0	.317	-.371
	Total	228	5.65*	2.39	0.0	13.0	.126	-.160

Note. CCI: Conventional Classroom Instruction, LCI: Learning Cycle Instruction
*The higher the score the more alternative conceptions that the students' hold.

There were 114 students in each treatment group. The number of the male (110) and female (118) participants was nearly same. When the distributions of gender in groups were examined, there were 52 males and 62 females in CCI group and 58 males and 56 females in LCI group. The mean post-CDRAT and post-CDRDiT scores of the LCI group were higher than the score of CCI group. In harmony with these results, alternative conceptions scores of the LCI group were lower than CCI group. When a distribution is normal, skewness and kurtosis values of this distribution are zero (Tabachnick & Fidel, 2013, p. 79). However, the distributions have the range of these values between -2 and +2 can be accepted as normal distribution (George & Mallery, 2003). In the present study, most of the skewness and kurtosis values were in the range of -2 and +2 and it can be interpreted that the distributions did not deviate to much from normal distribution. Even though the kurtosis values of post-CDRAT scores of the LCI group were slightly higher than the desired, these values will not result in underestimation of variance since the sample size of the present study is more than 100 (Tabachnick & Fidel, 2013, p. 80). Therefore, it can be assumed that the normality assumption is not violated.

Table 4.7 Descriptive statistics of Post-CDRAT, Post CDRDiT and Post-AC for gender

Tests	Group	Gender	N	Mean	SD	Min	Max	Skewness	Kurtosis
Post-CDRAT	CCI	M	52	26.34	4.16	13.0	35.0	-.410	.848
		F	62	26.93	4.19	17.0	33.0	-.560	-.298
	LCI	M	58	26.74	6.49	8.0	35.0	-1.473	1.448
		F	56	27.49	4.47	7.0	34.0	-.694	1.808
Post-CDRDiT	CCI	M	52	6.40	3.53	.0	16.0	.395	.075
		F	62	7.01	3.20	.0	16.0	-.294	.856
	LCI	M	58	10.08	4.56	.0	18.0	-.091	-.888
		F	56	10.69	4.50	2.0	20.0	-.049	-.818
Post-AC	CCI	M	52	6.65*	2.21	2.0	13.0	.390	.901
		F	62	6.32*	1.94	3.0	11.0	.201	-.483
	LCI	M	58	4.82*	2.55	0.0	10.0	.591	-.342
		F	56	4.85*	2.29	0.0	10.0	-.061	-.373

Note. CCI: Conventional Classroom Instruction, LCI: Learning Cycle Instruction, M: Male, F: Female. *The higher the score the more alternative conceptions that the students' hold.

As seen from the table 4.7, the mean post-CDRAT and post-CDRDiT scores of females were higher than males in both groups. When the post-AC scores were examined, the female students in LCI group have slightly higher mean score than male students. In order to examine whether these differences significant or not, the results of MANCOVA were reported in the following pages. The skewness and kurtosis values for all post-test scores were in the range between -2 and +2, it can be assumed that the distributions did not deviate to much from normal distribution (George & Mallery, 2003).

Table 4.8 Percentages of the correct responses of students on post-CDRDiT

CDRDiT items	Only First Tier		First Two Tiers		All Three Tiers*		Confidence Level		Lack of knowledge	
	CCI	LCI	CCI	LCI	CCI	LCI	CCI	LCI	CCI	LCI
1	68	67	46	60	36	55	69	88	20	8
2	18	48	9	39	6	35	68	81	29	15
3	39	63	5	35	4	33	65	82	34	16
4	89	97	73	75	65	65	82	84	10	6
5	81	86	69	73	44	58	65	75	10	11
6	32	57	9	42	7	39	68	84	31	12
7	50	66	14	39	9	31	68	78	27	14
8	87	93	74	86	58	82	70	90	14	6
9	79	71	18	38	8	31	41	53	49	40
10	65	80	62	77	49	72	69	80	18	15
11	57	76	39	61	33	58	68	89	26	7
12	85	91	73	81	56	71	65	83	18	7
13	96	99	75	80	63	77	81	92	8	5
14	94	95	50	51	38	42	67	78	21	13
15	68	77	46	64	38	61	68	80	23	18
16	80	95	33	47	25	39	52	72	39	19
17	53	37	8	16	3	15	46	70	49	29
18	40	48	30	40	24	33	70	75	24	18
19	86	90	67	75	57	70	75	85	15	11
20	82	83	71	80	52	71	67	81	18	11
MEAN	67	76	44	58	34	52	66	80	24	14

Note. CCI: Conventional Classroom Instruction, LCI: Learning Cycle Instruction, *All three tiers corresponds to Total Score (Pre/Post CDRDiT).

The percentages of only first tiers, both two tiers, and all three tiers of the CCI and LCI groups on post-CDRDiT are given at the table 4.8. Compared to the pre-CDRDiT results, all of the percentages increased after ten week implementation for both groups. The results revealed that the students were more successful to find the correct reason for their answers in the first tiers of the questions compared to the pre-test results. All of the percentages of first two tiers were increased except the percentages of item 2 for CCI group.

In terms of post-CDRDiT, item 13 which was related with the source of genetic diversity was the easiest question for CCI group and Item 8 was the easiest question for LCI group with high percentages of the correct responses. For CCI group, Item 2 was the most difficult question with 18% percentage of only first tier responses in addition to that; item 3, 6 and 17 were difficult questions. For LCI group, item 17 was the most difficult question with the smallest percentages compared to the other items (37%, 16% and 15% for only first tiers, first two tiers, and all three tiers respectively).

In the CCI group, the difference between the percentages of first two tiers and only first tier responses for item 9 was remarkable. Although, 79% percentage of the students gave correct answer to the first tier, only 18% of them found the correct explanation in the second tier. Similar condition can be seen for item 16 in both group, 47% and 48% of the students from CCI and LCI groups respectively, selected correct answer to the first tier, could not selected correct reason to the second tier. The difference between the mean all three tiers percentages on the post- CDRDiT for CCI and LCI groups was 18%. LCI group students have higher percentages for all items than CCI group students except item 4 in which the percentages were same. Item 4 which is about asexual reproduction was one of the easy questions for CCI group. The most significant difference was on item 6 with 32% and this item followed by the items 2 and 3 with 29% percentage differences.

4.3.2 Assumptions of MANCOVA Analysis

The variables were checked for any violation of the assumptions underlying the MANCOVA analysis before testing the hypotheses of this study.

4.3.2.1 Sample Size

The sample size assumption requires that minimum number of the cases in each cell is equal to the number of dependent variables (Pallant, 2007). When Table 4.6 and 4.7 were examined, it is obvious that the number of cases in each cell was more than 3 (the number of dependent variables in this study). Hence, the sample size is large enough to conduct MANCOVA analysis.

4.3.2.2 Normality

The normality assumption was checked from the skewness and kurtosis values of post-CDRAT, post-CDRDiT and Post-AC scores of the students (Table 4.6, Table 4.7). Since the values were in the range of -2 and +2 for each cell, the assumption of normality was satisfied.

4.3.2.3 Outliers

In order to check the outliers assumption, first of all, the data should be examined against the possibility of outlier/s presence. For this purpose, the mahalanobis distance value was calculated and compared with the critical value which is determined by using a critical values of chi-square table, with the number of dependent variables as a degrees of freedom (df) value (Pallant , 2007, p.251). Pallant (2007) gives this critical value for three dependent variables as 16.27. The calculated mahalanobis distance value was 23.97 and exceeded the critical value, in other words there were multivariate outliers in the data set. The procedure given by Pallant (2007, p. 252) was used to find out the outlier/s. Two students' scores were higher than the critical value. One of them (mahal. distance= 23.97) was dropped from data set however the other one (mahal distance= 18.42) was kept because this score was not too high.

4.3.2.4 Linearity

A straight-line relationship between each pair of dependent variables is needed to assure the linearity assumption and it can be checked by generating scatterplots between each pair of dependent variables Pallant (2007). After splitting data by teaching method and gender respectively, scatter plots were generated and examined. All of the scatter plots showed linear relationship between dependent variables therefore; assumption of linearity was met.

4.3.2.5 Homogeneity of Regression

The SPSS syntax for tests of homogeneity of regression was generated to check this assumption with the help of sample syntax given by Tabachnick and Fidell (2007, p. 282). The Figure 4.1 displays the syntax. After the syntax was run, the output of this test was examined according to the explanations of Tabachnick and Fidell (2007, p.281)

```
MANOVA SPST,PostCDRAT,PostCDRDiT,PostAC by Treat,Gender(0,1)
/PRINT=SIGNIF(BRIEF)
/ANALYSIS=PostCDRAT,PostCDRDiT,PostAC
/DESIGN=SPST,Treat,Gender,Treat by Gender,SPST by Treat by Gender
/ANALYSIS=PostCDRAT
/DESIGN=SPST,Treat,Gender,Treat by Gender,SPST by Treat by Gender
/ANALYSIS=PostCDRDiT
/DESIGN=SPST,Treat,Gender,Treat by Gender,SPST by Treat by Gender
/ANALYSIS=PostAC
/DESIGN=SPST,Treat,Gender,Treat by Gender,SPST by Treat by Gender.
```

Figure 4.1 The syntax to test for homogeneity of regression

Non-significant results for both overall and step-down tests show the establishment of homogeneity of regression assumption. The p values of the tests were checked across alpha level of .01 to provide robustness (Tabachnick & Fidell, 2007).The results were as follows; F (3, 219) = 1.40, p = .243, Wilks' Lambda = .981 for

MANCOVA, *F* (1, 221) = .01, *p* = .912 (post-CDRAT), *F* (1, 221) = 3.58, *p* = .060 (post-CDRDiT), and *F* (1, 221) = .79, *p* = .375 (post-AC) for follow-up ANCOVAs. Therefore; the results indicated sufficient homogeneity of regression to perform MANCOVA and follow-up ANCOVAs.

4.3.2.6 Multicollinearity and Singularity

Moderate correlations among dependent variables assure that there is no multicollinearity or singularity problem to perform MANCOVA. According to Mayers, "However, that correlation should not be too strong. Ideally, the relationship between them should be no more than moderate where there is negative correlation (up to about r = -.40); positively correlated variables should range between .30 and .90" (2013, p. 323). Table 4.9 shows correlations among dependent variables and covariate of this study. According to the values in the table, it is obvious that multicollinearity and singularity assumption was satisfied.

Table 4.9 Correlations among dependent variables and covariate

	Post-CDRAT	**Post-CDRDiT**	**SPST**
Post-CDRDiT	.437*		
SPST	.202*	.225*	
Post-AC	-.319*	-.503*	-.109

*. Correlation is significant at the 0.01 level (2-tailed).

4.3.2.7 Homogeneity of Variance-Covariance Matrices

This assumption was checked through the Box's M test of equality of covariance and significant result was found [*F* (18, 170347.24) =1.645, p = .041]. Although, the significant result indicates violation of the assumption, according to Tabachnick and Fidell, "if sample sizes are equal, robustness of significance tests is expected; disregard the outcome of Box's M test, a notoriously sensitive test of homogeneity of variance-covariance matrices" (2007, p. 252). For this study, the sample size in each cell (Table 4.6 and 4.7) were very close to each other. Therefore; the homogeneity of variance-covariance matrices assumption was assumed to be met.

4.3.2.8 Reliability of Covariates

Reliability of covariates plays a crucial role on the power of the MANCOVA results. Therefore, measuring covariate without an error is an important issue. In order to choose a reliable measuring tool, Pallant (2007) suggested checking the Cronbach alpha value that should be at least .70. In this study, the reliability of the SPST scores was .82 which indicates that science process skills scores of the students were reliable and can be used as a covariate.

4.3.3 Results of Multivariate Analysis of Covariance Analysis

Multivariate Analysis of Covariance was performed by three dependent variables (post-CDRAT scores, post-CDRDiT scores and Post-AC scores), two independent variables (teaching method and gender), and one covariate (SPST scores) since no serious violations of the assumptions were noted. The results were organized in Table 4.10.

Table 4.10 MANCOVA results

Source	**Wilks' Lambda**	**F**	**Hypoth. df**	**Error df**	**Sig. (p)**	**Eta-Squared**	**Observed Power**
Intercept	.279	188.789	3	220	.000	.721	1.000
Teach.method	.812	16.980	3	220	.000	.188	1.000
Gender	.993	.547	3	220	.651	.007	.161
SPST	.964	2.739	3	220	.044	.036	.659
Teach.method * Gender	.998	.136	3	220	.938	.002	.075

The results of the MANCOVA were investigated for the evidences to test null hypotheses 1, 2 and 3 of this study.

4.3.3.1 Null Hypothesis 1

The first null hypothesis was 'There is no statistically significant main effect of teaching methods (5E learning cycle instruction and conventional instruction) on the population mean of collective dependent variables of 10^{th} grade science major public Anatolian high school students' posttest scores of achievement and conceptual understanding in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills".

When the main effects were examined, the results (see Table 4.10) showed that there are statistically significant mean differences between LCI and CCI groups on the combined dependent variables of post-CDRAT, post-CDRDiT and Post-AC scores after adjusting for pre-existing difference in students' science process skills [$F(3, 220) = 16.980$, Wilks' Lambda = .812, $p = .000$]. Therefore, the null hypothesis 1 is rejected and this difference can be attributed to the different teaching methods on cell division and reproduction concepts between groups. The partial eta squared value is .188 and this effect size can be interpreted that approximately 19% of the variance in dependent variables can be explained by teaching methods. The observed power value indicates the probability of making correct decision. Observed power value at .05 level is 1.000 for the main effect of teaching method. Therefore, the attribution of the difference on dependent variables between groups to different teaching methods is reasonable.

4.3.3.2 Null Hypothesis 2

The second null hypothesis was "There is no statistically significant main effect of gender on the population mean of collective dependent variables of 10^{th} grade science major public Anatolian high school students' posttest scores of achievement and conceptual understanding in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills."

The results (see Table 4.10) indicated that there are no statistically significant mean differences between male and female students on the combined dependent variables of post-CDRAT and post-CDRDiT after adjusting for pre-existing difference in students' science process skills [F (3, 220) = .547, Wilks' Lambda = .993, p = .651]. So, the null hypothesis 2 is failed to reject. Thus, the result showed that girls and boys had roughly equal achievement and understanding of cell division and reproduction concepts regardless teaching method.

4.3.3.3 Null Hypothesis 3

The third null hypothesis was "There is no statistically significant effect of interaction between teaching methods and gender on the population mean of collective dependent variables of 10th grade science major public Anatolian high school students' posttest scores of achievement and conceptual understanding in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills".

The interaction effect is examined to find evidence to reject the null hypothesis 3 however, it is obvious from the Table 4.10 that the teaching method by gender interaction is not statistically significant [F (3, 220) = .136, Wilks' Lambda = .998, p = .938, partial eta squared =.002]. Therefore, the null hypothesis 3 is failed to reject since there is no statistically significant evidence for the interaction effect of teaching methods and gender on combined dependent variables.

In addition to these results, when fourth line of the Table 4.10 examined, it can be seen that the contribution of science process skills scores of the students to the collective dependent variables of CDRAT, post-CDRDiT and Post-AC scores is statistically significant [F (3, 220) = 2.739, Wilks' Lambda = .964, p = .044, partial eta squared = .036].

Although, MANCOVA results indicated that there are main effects of teaching method and gender on collective dependent variables, the multiple univariate

ANCOVAs needs to be performed to examine the particular effect of independent variables on each dependent variable. The follow-up ANCOVA results are presented in the Table 4.11.

Table 4.11 Results of follow-up ANCOVAs

	Dependent Variable	**df**	**F**	**Sig. (p)**	**Eta Squared**	**Observed Power**
Teach.method	Post-CDRAT	1	.017	.896	.000	.052
	Post-CDRDiT	1	37.242	.000*	.144	1.000
	Post-AC	1	25.829	.000*	.104	.999
Gender	Post-CDRAT	1	.592	.442	.003	.119
	Post-CDRDiT	1	1.573	.211	.007	.239
	Post-AC	1	.417	.519	.002	.099
Teach.method* Gender	Post-CDRAT	1	.065	.800	.000	.057
	Post-CDRDiT	1	.001	.977	.000	.050
	Post-AC	1	.222	.638	.001	.076

* Test is significant at the .017 level.

The null hypotheses 4 to 12 stated in the introduction chapter of this study could be tested by checking these follow up ANCOVA results. Before checking the p values, a Bonferroni type adjustment is applied to alpha value as suggested by Tabachnick and Fidell (2007, p. 270) to decrease Type I error in separate univariate tests. New adjusted alpha level is calculated by dividing .05 by the number of dependent variables (3). Thus, .017 is compared to the p values in the Table 4.11 to check significance of the tests. Any p value that is less than .017 shows significant results (see asterisks in Table 4.11).

4.3.3.4 Null Hypothesis 4

The fourth null hypothesis was "There is no statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of the groups exposed to learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills".

According to the Table 4.11, there is no evidence to reject the null hypothesis 4 (F =.017, p = .886). It can be concluded that there is no statistically significant mean difference between CCI and LCI groups based on their post-CDRAT test scores (M=26.66 for CCI and M=27.08 for LCI). Even there is a slight difference between groups' post-CDRAT scores in favor of LCI group, the estimated marginal means (see table 4.12) are more close to each other since the mean adjustment applied in covariate analysis. According to the analysis, the difference between groups is neither statistically nor practically significant (partial eta squared= .000)

Table 4.12 Estimated Marginal Means for the post-CDRAT scores in terms of treatment

				95% Confidence Interval	
Dependent Variable	Treatment	Mean	Std. Error	Lower Bound	Upper Bound
Post-CDRAT	CCI	26.981	.456	25.993	27.788
	LCI	26.977	.456	26.078	27.876

4.3.3.5 Null Hypothesis 5

The fifth null hypothesis was "There is no statistically significant mean difference between posttest achievement scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills".

According to the Table 4.11, there is no evidence to reject the null hypothesis 5 (F = .592, p = .442). It can be concluded that there is no statistically significant mean difference between male and female students based on their post-CDRAT test scores. When the estimated marginal post-test CDRAT means of the groups were checked from Table 4.13, they are M=26.691 for male and M=27.177 for female students, the difference is very small but in favor of female students. However, the difference in these estimated mean scores was not statistically significant as the null hypothesis 5 was accepted.

Table 4.13 Estimated Marginal Means for the post-CDRAT scores in terms of gender

Dependent Variable	Gender	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Post-CDRAT	Male	26.691	.455	25.794	27.588
	Female	27.177	.438	26.314	28.039

4.3.3.6 Null Hypothesis 6

The sixth null hypothesis was “There is no statistically significant effect of interaction between teaching methods and gender on students’ posttest scores of achievement in ‘cell division and reproduction concepts’ after adjusting for pre-existing difference in students’ science process skills”.

The interaction effect is examined to find evidence to reject the null hypothesis 6 however, it is obvious from the Table 4.11 that the teaching method by gender interaction is not statistically significant [F = .065, p = .800].

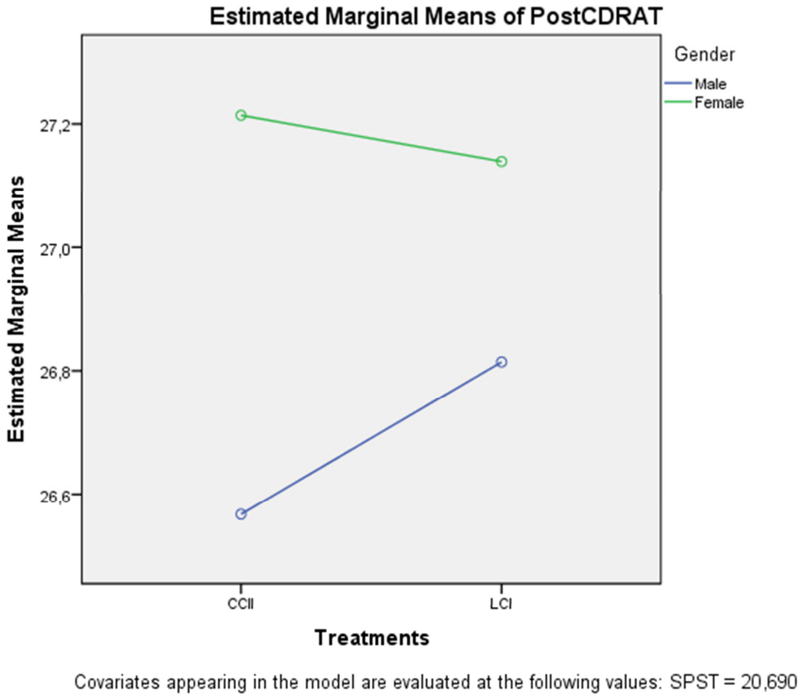


Figure 4.2 Line graph of estimated marginal means of post-CDRAT scores in terms of gender as categorized in two different treatments.

Therefore, the null hypothesis 6 is failed to reject since there is no statistically significant evidence for the interaction effect of teaching methods and gender on post-achievement scores of the students. Figure 4.2 shows the line graph of post-CDRAT scores in terms of gender as categorized in two different treatments and indicates that there is no interaction between gender and treatments when post-CDRAT scores of the students considered.

4.3.3.7 Null Hypothesis 7

The seventh null hypothesis was "There is no statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of groups exposed to learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills".

The values in the second row of the Table 4.11 indicated that the test is significant (F = 37.242, p = .000). Therefore, there is a statistically significant evidence to reject the null hypothesis 7. It can be concluded that there is significant mean difference between CCI and LCI groups' conceptual understanding on cell division and reproduction concepts because of different teaching methods. When the estimated marginal post-test CDRDiT means of the groups were controlled from table 4.14 (M=6.852 for CCI and M=10.195 for LCI), the difference is in favor of LCI group. The partial eta squared was found 0.144 and eta squared was calculated as 0.136; which is very close to large effect size according to the accepted criteria of Cohen (1988). This large effect size indicated the practical significance of the result and high power value (observed power = 1.000) showed the high probability of the correct decision for the null hypothesis 7.

Table 4.14 Estimated Marginal Means for the post-CDRDiT scores in terms of treatment

				95% Confidence Interval	
Dependent Variable	Treatment	Mean	Std. Error	Lower Bound	Upper Bound
Post-CDRDiT	CCI	6.852	.380	6.104	7.600
	LCI	10.195	.380	9.446	10.944

In addition to the significant result of MANCOVA analysis, the percentages of the total scores (correct, correct and certain), lack of knowledge scores and certainty scores of the CCI and LCI group students provide evidence of the difference between their conceptual understandings after the treatment on cell division and reproduction concepts.

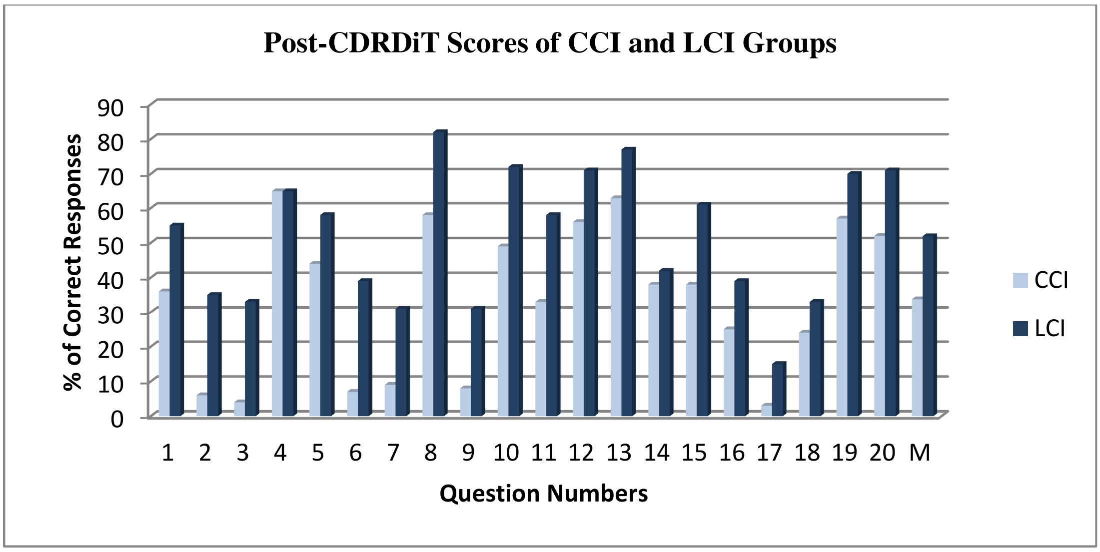


Figure 4.3 The percentages of total scores of CCI and LCI groups on post-CDRDiT.

Figure 4.3 shows that the difference between the mean percentages of CCI and LCI groups on the post-CDRDiT was 18%. LCI group students have higher percentages for all items than CCI group students except item 4 in which the percentages were same. Item 4 which is about asexual reproduction was one of the easy questions for CCI group. The most significant difference was on item 6 with 32% and this item followed by the items 2 and 3 with 29% percentage differences.

CDRDiT as a three tier diagnostic test provides more information on students' understanding than one-tier multiple choice tests by giving chance to calculate different scores related to students' understandings. Figure 4.4 presented graphs of confidence level (certainty score) percentages of CCI and LCI groups on post-CDRDiT. Before the implementation, mean confidence level percentages were moderate in both groups with close values (34% and 39%). LCI group students were slightly more confident with their answers than CCI group students. After ten weeks implementation, confidence levels increased in both groups however; this increment was higher in LCI group than CCI group.

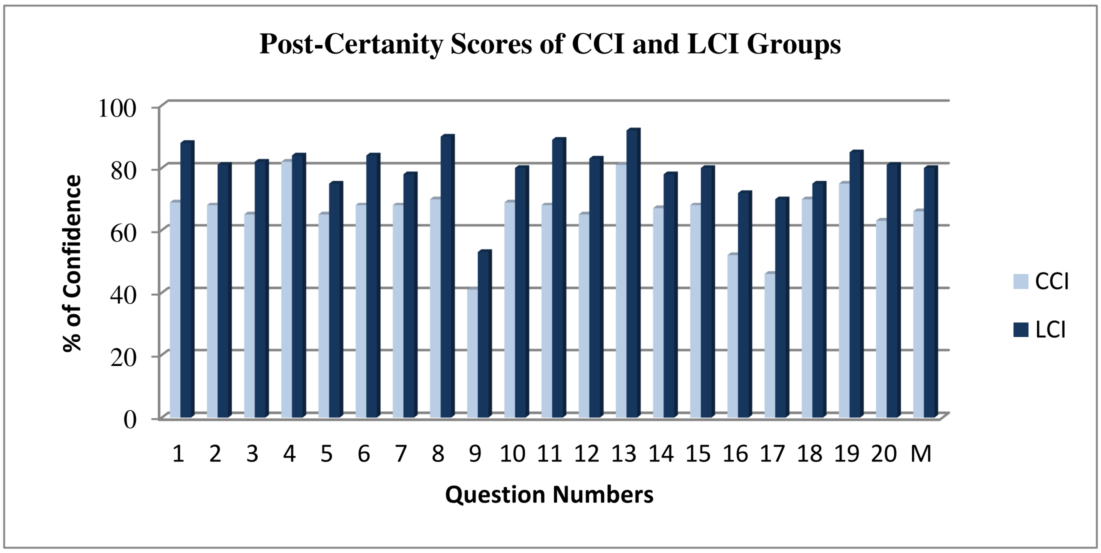


Figure 4.4 The percentages of confidence levels of CCI and LCI groups on post-CDRDiT.

The mean difference between confidence level percentages on pre and post-CDRDiT was 41% and 32% for LCI and CCI groups respectively. When post-test scores compared, there is 14% difference between the mean confidence level percentages of CCI and LCI groups in favor of LCI.

In addition to confidence levels, lack of knowledge score, the condition of being uncertain regardless of correct or incorrect responses to the first and/or second tiers, can be calculated. As explained in detail at Chapter 3 under the title of instruments, answer combinations of “correct/incorrect/uncertain”, “incorrect /correct/uncertain”, and “incorrect/incorrect/uncertain” were coded as lack of knowledge. Figure 4.5 represents the lack of knowledge percentages of CCI and LCI groups on post-CDRDiT.

When pre-CDRDiT results examined, the mean lack of knowledge percentages were not significantly different from each other; 57% for CCI and 51% for LCI group. The highest lack of knowledge percentage of CCI group was on item 6 which ask for differentiating meiosis from mitosis and on item 9 which asks for the role of organelles during the mitosis. Item 17, which is related with sister chromatids and homologous chromosomes, has the highest lack of knowledge percentage for LCI group on pre-CDRDiT. After the implementation, the mean percentages of lack of knowledge were decreased in both groups as expected. But this decrease was higher in LCI group (37%) than CCI group (32%). Although there were differences between groups in favor of LCI group before the implementation, these differences increased on most of the items. There is only one item (item 5) that the mean percentages of lack of knowledge of CCI group was lower than LCI group but the difference was quite small (1%).

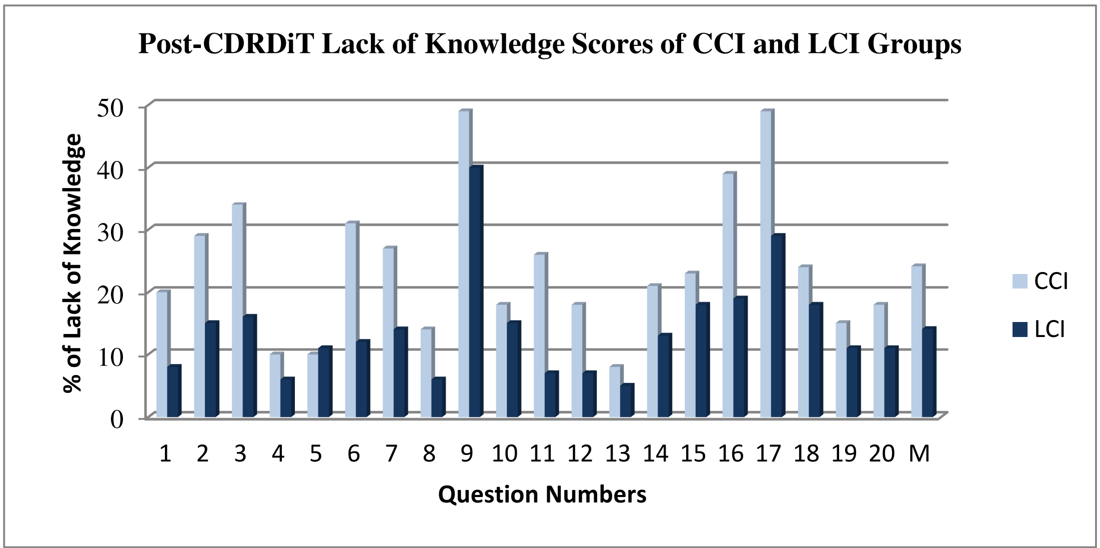


Figure 4.5 The percentages of lack of knowledge scores of CCI and LCI groups on post-CDRDiT.

4.3.3.8 Null Hypothesis 8

The eighth null hypothesis was "There is no statistically significant mean difference between posttest understanding scores in 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills".

The null hypothesis 8 is failed to reject when the values of post-CDRDiT in table 4.11 examined (F = 1.573, p = .211). It can be concluded that there no statistically significant mean difference between male and female students when their post-

CDRDiT test scores were considered. Table 4.15 shows that the estimated marginal means of male and female students on post-CDRDiT were close to each other.

Table 4.15 Estimated Marginal Means for the post-CDRDiT scores for gender

Dependent Variable	Gender	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Post-CDRDiT	Male	8.193	.379	7.446	8.941
	Female	8.853	.365	8.135	9.572

4.3.3.9 Null Hypothesis 9

The nineth null hypothesis was "There is no statistically significant effect of interaction between teaching methods and gender on students' posttest understanding scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills".

The univariate ANCOVA result shows that there is not sufficient evidence to reject the claim that there is no interaction between teaching methods and gender on students' post understanding scores ($F = .001$, $p = .977$). Figure 4.6 shows an overview for post-CDRDiT scores in terms of gender as categorized in two different treatments.

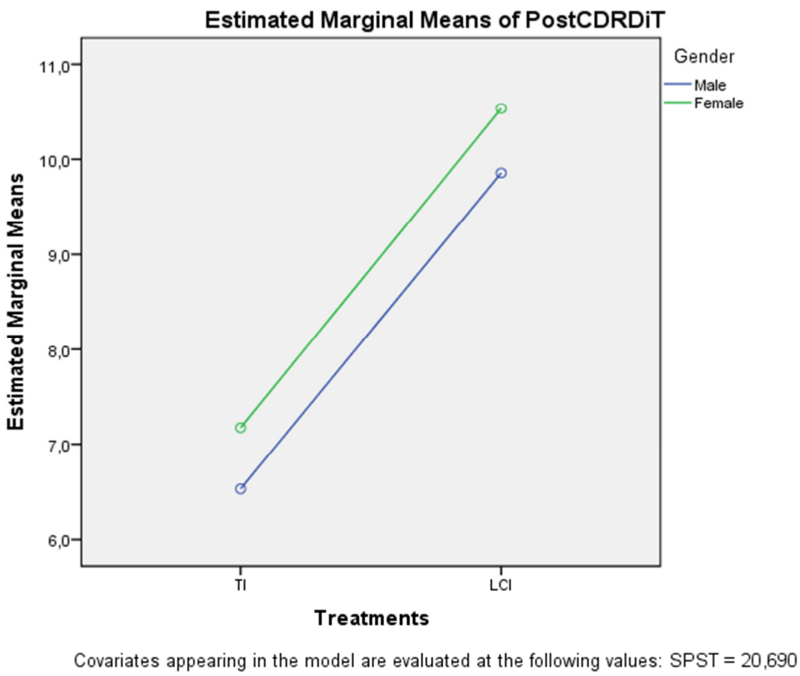


Figure 4.6 Line graph of post-CDRDiT scores in terms of gender as categorized in two different treatments.

4.3.3.10 Null Hypothesis 10

The tenth null hypothesis was "There is no statistically significant mean difference between posttest alternative conceptions scores about 'cell division and reproduction concepts' of groups exposed to 5E learning cycle and conventional classroom instruction after adjusting for pre-existing difference in students' science process skills".

The null hypothesis 10 is rejected when the values of post-AC in table 4.11 examined (F = 25.829, p = .000). Therefore, there is statistically significant evidence that the mean post-AC scores of CCI and LCI groups are different from each other when SPST scores were controlled. In other words, students in CCI group held more alternative conceptions than LCI group students after ten weeks implementation on cell division and reproduction concepts. The estimated marginal means can be seen from table 4.16 (M= 6.47 for CCI and M= 4.89 for LCI).

Table 4.16 Estimated Marginal Means for the post-AC scores in terms of treatment

Dependent Variable	Treatment	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Post-AC	CCI	6.477	.216	6.052	6.902
	LCI	4.896	.216	4.471	5.321

In addition to the significant result of MANCOVA analysis, the percentages of the post-AC scores of the CCI and LCI group students for each alternative conception provide evidences of the difference between their alternative conceptions after the treatment. As seen in Figure 4.7, the percentages of the alternative conceptions of the CCI groups students is higher than LCI groups students in approximately all of the alternative conceptions and there was a significant difference in the percentages of alternative conceptions numbered with 2, 4, 5, 7, 9, 16, 19, 29, 40, 45, 47 and 49 between the CCI and LCI groups.

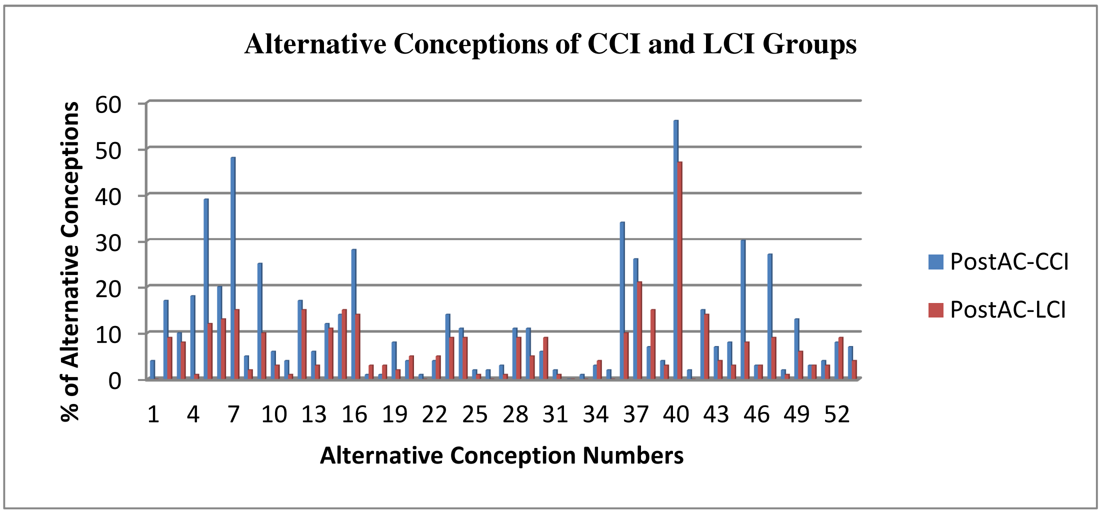
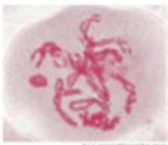
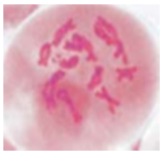
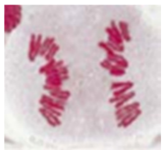


Figure 4.7 The percentages of post-AC scores of CCI and LCI groups.

When the questions of CDRDiT related to these alternative conceptions analyzed, the percentages of students' responses to each alternative of the questions 1, 3, 4, 7, 10, 12, 18, and 20 makes the results more clear. Table 4.17 shows the percentages of students' responses to Question 1.

Table 4.17 The Percentages of Students' Responses to Question 1

Question 1	**Percentages of students' responses (%)**	
	CCI	**LCI**
 X Cell-Prophase  Y Cell-Prophase  Z Cell-Anaphase		
1.1. The above figures represents the phases of mitosis in different cells of one organisms. According to this, the amount of chromosomal DNA is same in each cell.		
A. Correct*	66.4	68.1
B. Incorrect	33.6	31.9
1.2. Because;		
A. The amount of chromosomal DNA is doubled at interphase and is constant to the end of the mitosis.*	52.1	77.0
B. The amount of chromosomal DNA is different in different phases of mitosis.	3.5	1.8
C. The amount of chromosomal DNA is doubled at prophase and stays same to the end of the mitosis.	14.9	7.6
D. The amount of chromosomal DNA is doubled at interphase and is halved in anaphase.	10.5	9.1
E. The amount of chromosomal DNA is never change in any phase of mitotic cycle.	19.0	4.5
1.3. I am		
A. Certain	69.5	87.6
B. Uncertain	30.5	12.4

*Correct alternative

Both alternative conceptions 2 and 4 were calculated from the students' responses to question 1. The alternative C in the second tier of the Question 1 along with either correct or wrong response to the first tier indicates AC-2 (alternative conception 2) which is "DNA replication occurs during prophase". Approximately 15% of the CCI students selected alternative C and 7.6% of the LCI students selected it. The difference in AC-4 which is related with alternative E is more than AC-2, 19% of the students of CCI group chose alternative E and 4.5% the LCI students chose it. In other words, 19% of CCI group students thought that the amount of chromosomal DNA does not change during the stages of mitosis.

In the second tier of 3th question, AC-5 which is 'the number of chromosome is fixed and remains unchanged during the stages' is placed. AC-5 selected by 39% of CCI group students and 12% of LCI group students. Most of the CCI group students could not realize that the chromosome number duplicated when chromatids separated from each other in anaphase of cell division.

Table 4.18 The Percentages of Students' Responses to Question 7

Question 7	**Percentages of students' responses (%)**	
	CCI	**LCI**
7.1. A diploit animal cell (2n= 6) undergoes mitosis. The chromosome number of this cell will be 12 in prophase.		
A. Correct	50.0	34.5
B. Incorrect*	50.0	65.5
7.2. Because;		
A. DNA is replicated in interphase, the chromosome number is doubled and this number is same in prophase.	53.6	28.8
B. DNA is replicated in prophase and so the chromosome number is doubled.	1.8	7.2
C. Prophase is resting and preparation phase and the chromosome number has not doubled yet.	5.4	3.7
D. The sister chromatids have not separated yet and the chromosome number is same with the parent cell.*	14.3	41.6
E. The chromosome number of a cell is same in all phases of mitosis	25.0	18.7
7.3. I am		
A. Certain	67.5	78.6
B. Uncertain	32.5	21.4

*Correct alternative

Both alternative conceptions 7 and 9 were calculated based on the students' responses to question 7. Table 4.18 shows the percentages of students' responses to Question 7.

The alternative A in the second tier of the Question 7 along with wrong response to the first tier indicates AC-7 which is “The chromosome number is doubled in interphase and stays same during the stages”. Alternative A is one of the challenging distracter for CCI students, 53.6% of the students selected it on the contrary 28.8% of the LCI students selected it. Before the implementation the percentage of AC-7 was 24% for CCI groups, and 34% for LCI groups, there is an increased in the percentages of AC-7 in CCI groups however, a decreased in LCI groups.

The alternative E in the second tier of the Question 7 along with correct response to the first tier indicates AC-9 which is “The number of the chromosomes is same during the all phases of mitosis”. Among the alternatives, alternative E is also one of the challenging distracter for CCI students, 25.0% of the students selected it on the contrary 18.7% of the LCI students selected it. There is a difference between groups in favour of LCI groups.

In the 10^{th} question, alternative A and B of the second tier includes AC-16 which is “Spindle fibers are only formed by centrosomes”. 28.9% of the CCI group students selected this alternative conception; however 14.2% of the students from LCI groups selected it. Before the implementation the percentage of AC-16 was 28% in both groups, it stayed same in CCI group but halved in LCI groups.

AC-19 “Only single-celled organisms can reproduce by mitosis” placed in the alternative A of second tier of the 4^{th} question. In the post-CDRDiT, 19.8% of the CCI group students chose it and 4% of the LCI group students chose the same choice. These percentages were 10% and 7% for CCI and LCI groups respectively before the imlementation.

In the 12^{th} question, both alternative A and D along with the wrong response to the first tier represents AC-29 which is “all diploid cells can undergo cell division by both mitosis and meiosis”. When the table 4.19, showed the percentages of students’ responses to Question 12, is checked, the total of the percentages A and D is 18.9%

for CCI group and 6.3% for LCI groups can be found. These percentages were 11% and 15% for CCI and LCI groups respectively before the implementation.

Table 4.19 The Percentages of Students' Responses to Question 12

Question 12	**Percentages of students' responses (%)**	
	CCI	**LCI**
12.1. Which of the following/followings can undergo both mitosis and meiosis?		
A. Pollen mother cell*	85.8	92.0
B. Liver cell	6.2	2.7
C. Both of them	8.0	5.3
12.2. Because;		
A. Both of them are diploid and all dipoid cells can undergo both mitosis and meiosis.	10.1	5.4
B. Mitosis may occur in both cells however meiosis can be just seen in pollen mother cell.*	74.1	85.0
C. Mitosis may occur in both cells however meiosis can be just seen in haploid cells and the pollen mother is haploid.	7.0	8.7
D. Mitosis may occur in both cells however meiosis can be just seen in diploid cells and the pollen mother is diploid.	8.8	0.9
12.3. I am		
A. Certain	65.5	83.9
B. Uncertain	34.5	16.1

*Correct alternative

Alternative conception 40 (AC-40) which is stated that "sexual reproduction must involve mating" was the most common alternative conception for both groups with 56% and 47% for CCI and LCI groups respectively. The high percentages of AC-40 might be resulted in not enough focusing on the role of mating in sexual reproduction during the instruction in both groups.

Both AC-45 and AC-47 were based on students' knowledge on homologous chromosomes. The post-AC results shows that 30% of the CCI students held AC-45 which is stated as "Homologous chromosomes placed only in the daughter cells after meiosis", however, 8% of LCI group students held AC-45. When the percentages of the students held AC-47 (Homologous chromosomes are produced by DNA replication) compared, it was 27% for CCI group and 9% for LCI group.

In the 20th question, alternative C of the second tier includes AC-49 which is "homologous chromosomes and sister chromatids are essentially the same thing". Table 4.20 shows the percentages of students' responses to Question 20. 8.2% of the CCI group students selected this alternative conception; however 1.8% of the students from LCI groups selected it. Before the implementation the percentage of AC-49 was very similar 14% for CCI and 15% for LCI groups, even there is a decrase in both groups, it is more in LCI groups than CCI groups.

Table 4.20 The Percentages of Students' Responses to Question 20

Question 20	**Percentages of students' responses (%)**	
	CCI	**LCI**
 20.1. There are four homologous chromosomes in the figure.		
A. Correct	17.7	16.0
B. Incorrect*	82.3	84.0
20.2. Because; A. The chromosomes of the diploid parent cell produced four homologous chromosomes by replicating.	9.6	8.9
B. The chromosomes of the diploid parent cell produced two homologous chromosomes include two chromatids by replicating.*	74.5	85.7
C. Sister chromatids and homologous chromosomes are essentially the same and there are four homologous chromosomes in the figure.	8.2	1.8
D. The homologous chromosomes are being connected with each other from their centromeres and there are four homologous chromosomes in the figure.	7.5	3.6
20.3. I am A. Certain	67.5	81.3
B. Uncertain	32.5	18.7

*Correct alternative

The percentages of alternative conceptions that the students held before and after the implementation were summarized in Table 4.21. According to table, it can be seen that nearly all of the percentages of alternative conceptions that LCI students held decrased after 5E LC instruction. However, in CCI group even some of them decreased, 12 of the alternative conceptions increased after instruction.

Table 4.21The percentages of alternative conceptions that the students held

Alternative Conceptions	CCI Pre	CCI Post	LCI Pre	LCI Post
1. In mitosis, the amount of chromosomal DNA is different in different stages.	9	4	16	0
2. DNA replication occurs during prophase.	25	17	34	9
3. In mitosis, the amount of chromosomal DNA is halved in anaphase.	18	10	18	8
4. In mitotic cycle, the amount of chromosomal DNA does not change.	12	18	5	1
5. The number of chromosome is fixed and remains unchange during the stages.	29	39	18	12
6. The number of chromosome is halved in the anaphase of mitosis.	25	20	23	13
7. The chromosome number is doubled in interphase and stay same during the stages.	24	48	18	15
8. Prophase is the resting and preperation phase of the mitosis.	15	5	9	2
9. The number of chromosomes is same during the stages of the mitosis.	18	25	5	10
10. Homologous chromosomes seperate from each other during mitosis.	18	6	30	3
11. Sister chromatids seperate from each other only during mitosis.	11	4	11	1
12. All of the organelles dissolve and dissappear during mitosis.	19	17	14	15
13. Golgi aparatus can be monitored during the mitosis.	13	6	18	3
14. Both golgi and mitochondria can be monitored during the mitosis.	12	12	11	11
15. There is no need for the organelles during the mitosis since preperation is done in the interphase.	3	14	4	15
16. Spindle fibers are only formed by centrosomes.	24	28	28	14
17. There are centrosomes in plant cells.	11	1	13	3
19. Only single-celled organisms can reproduce by mitosis.	10	8	7	2
20. All single-celled organisms & multicellular organisms who have regeneration ability can reproduce by mitosis.	18	4	17	5
21. The number of chromosome remains unchanged after meiosis.	9	1	2	0
22. Both homologous chromosomes and sister chromatids seperate and the number of chromosomes halves in two times.	20	4	24	5

(Table 4.21 continued)

Alternative Conceptions	CCI Pre	CCI Post	LCI Pre	LCI Post
23. Homologous chromosomes seperated in meiosis I and they are sent to daughter cells without a change.	2	14	6	9
24. The number of chromosome remains unchange in meiosis I and halves in meiosis II.	16	11	26	9
25. Doughter cells have diploid chromosome number.	4	2	4	1
26. Sister chromatids seperate from each other only during meiosis.	16	2	20	0
28. DNA needs to be replicated after meiosis I.	23	11	18	9
29. All diploid cells can undergoe cell division by mitosis and meiosis.	11	11	15	5
30. Only haploid cells can undergoe mitosis.	16	6	15	9
33. Changes in the number of chromosomes provides genetic diversity.	8	1	4	0
34. Plants reproduce by only asexual reproduction.	17	3	15	4
35. Plants reproduce by pollination which is a kind of asexual reproduction.	6	2	4	0
36. Non-flowering plants reproduce by asexual but flowering plants reproduce by sexual reproduction.	17	34	20	10
37. Fertilization occurs during parthenogenesis.	25	26	36	21
38. Reproduction is not possible without fertilization.	11	7	9	15
39. Diploit gametes can develop without fertilization.	4	4	9	3
40. Sexual reproduction must involve mating..	35	56	48	47
42. Centrioles are located in the nucleus of the cell but move to cytoplasm after the nucleus wall dissolves.	12	15	11	14
43. Gamete mother cells are haploid.	5	7	10	4
44. Gametes are diploid.	16	8	20	3
45. Homologuos chromosomes placed only in the daughter cells produced after meiosis.	20	30	15	8
47. Homologous chromosomes are produced by DNA replication.	34	27	29	9
48. Homologous chromosomes are formed only in meiosis.	15	2	15	1
49. Homolog chromosomes and sister chromatids are the same thing.	15	13	14	6
50. Homolog chromosomes are tied each other from their centromeres.	6	3	5	3
51. Highly organized animals have more regeneration ability compared to primitive ones.	2	4	5	3
52. Animals with large bodies has much regeneration ability.	21	8	23	9
53. Genetic diversity can be provided by regeneration.	4	7	4	4

Getting instruction on a certain topic might be one of the sources of alternative conceptions, the increase in the percentages of alternative conceptions that the CCI group students held after ten weeks implementation on cell division and reproduction concepts with conventional instruction might be attributed to the teaching method. When CCI group students' alternative conceptions examined, most of them were related with chromosome structure, replication and separation. For instance, nearly half of the students thought that 'The chromosome number is doubled in interphase and stay same during the stages', 30% of them selected AC-45 that is 'Homologuos chromosomes placed only in the daughter cells produced after meiosis' and 27% of them believed that 'Homologous chromosomes are produced by DNA replication'.

On the contrary, 9 of the alternative conceptions of LCI group is in the range of 0-1% percentages after implementation which shows that these alternative conceptions remediated after 5E LCI instruction. Even the prevalence of 52 alternative conceptions decreased, some of the LCI group students held alternative conceptions after 5E LC instruction. Especially AC-40 which is stated 'Sexual reproduction must involve mating' shows the highest percentage among the ACs. The lack of emphasize in lesson plans might be the primary reason of this situation.

4.3.3.11 Null Hypothesis 11

The eleventh null hypothesis was "There is no statistically significant mean difference between posttest alternative conceptions scores about 'cell division and reproduction concepts' of male and female students after adjusting for pre-existing difference in students' science process skills". The values in the sixth row of Table 4.11 indicates that the null hypothesis 11 is failed to reject (F = .417, p = .519). In other words, there is no statistically significant mean difference between male and female students' alternative conception scores on cell division and reproduction concepts. When table 4.22 checked for the estimated marginal means of the groups, it is M= 5.78 for CCI and M= 5.59 for LCI groups. The partial eta squared value, .002 showed that this result is not pratically significant too.

Table 4.22 Estimated Marginal Means for the post-AC scores in terms of gender

Dependent Variable	Gender	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Post-AC	Male	5.783	.215	5.359	6.208
	Female	5.590	.207	5.182	5.998

4.3.3.12 Null Hypothesis 12

The twelveth null hypothesis was "There is no statistically significant effect of interaction between teaching methods and gender on students' posttest alternative conceptions scores in 'cell division and reproduction concepts' after adjusting for pre-existing difference in students' science process skills".

This hypothesis is accepted because of the fact that the related values (F = .222, p = .638, partial eta squared= .001) from the Table 4.11 do not provide evidence to reject this claim. This result is neither statistically nor practically significant according to p and partial eta squared values. Figure 4.8 gives line graph of post-AC scores in terms of gender as categorized in two different treatments and indicates that there is no interaction between gender and treatments on students' post alternative conceptions scores.

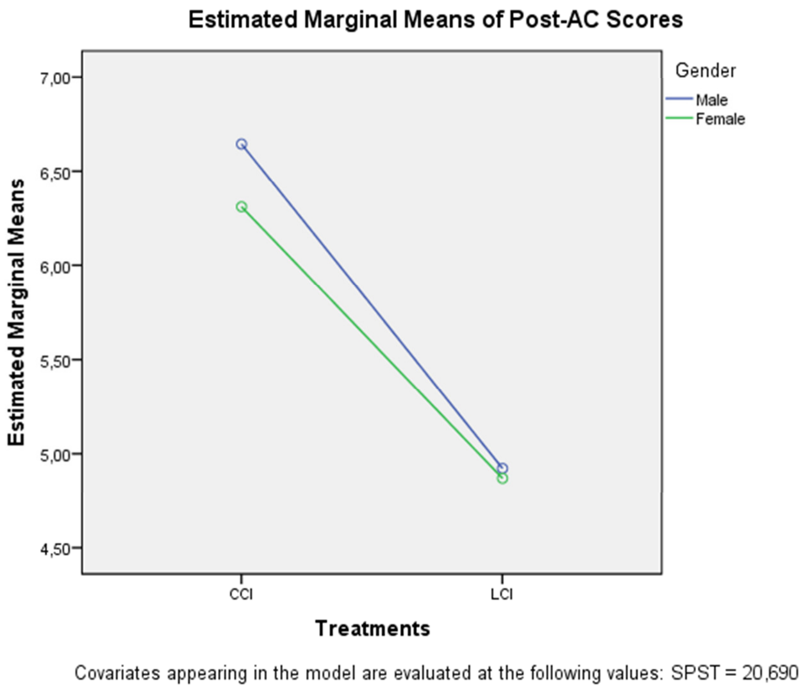


Figure 4.8 Line graph of post-AC scores in terms of gender as categorized in two different treatments.

4.4 Students Interviews on Cell Division and Reproduction Concepts

After treatment period, semi-structured interviews were conducted to gain detailed data on students' understandings on cell division and reproduction concepts. 6 CCI group students and 6 LCI group students (total 12) were semi-structurally interviewed. Interview sessions were 20-30 minutes in duration. Students were asked to draw the phases of mitosis and meiosis while explaining these process and additional questions were directed. All interviews were tape recorded and transcribed word for word and analyzed. A PhD candidate on biology education analyzed the transcripts by using rubric and the drawings besides the researcher and the results were consistent with each other. The findings indicated that the LCI group students demonstrated higher understanding and held less alternative conceptions on cell division and reproduction concepts when compared to CCI group students. Results were categorized under 6 sub-topics of the unit; cell division, mitosis, meiosis, comparison of mitosis and meiosis, sexual reproduction, asexual reproduction. In addition, students' answers to the questions under each subtopic were categorized as; no response (N), alternative conceptions (A), incorrect response (I), partially correct response (P), correct response (C). If a student refused to answer or said that s/he did not know this response categorized under "no response". When student's explanation includes a specific misconception and s/he insisted on their response or repeated it more than one, it was categorized under "alternative conceptions". However, sometimes students just said wrong answer but did not insist on their response when the researcher directed probing questions. These responses categorized as "incorrect response" since they are neither "no response" nor "alternative conception". If student answered the question partially even the researcher's probing questions, it is categorized under "partially correct response" theme. When the student's response was comprehensive and included the whole answer of the question, it was categorized as "correct response". The percentages of the students' answers were summarized in table 4.23 and sample sentences and drawings of the students were given in the following sections. The results in table 4.23 shows that the CCI group students have lower understanding and held more alternative conceptions on cell division and reproduction concepts than LCI group students.

The students in both the CCI and LCI groups were directed conceptual questions about cell division in general, mitosis, meiosis, asexual and sexual reproduction specifically. When the responses to general questions (first four questions) about cell division examined, in CCI group maximum 3 students (50%) answered correctly however, in LCI group minimum 3 students (50%) answered correctly. For instance, when researcher directed question "what happens to the parent cell after cell division?" all students in the experimental group (100%) and three students (50%) in the control group answered the question correctly. Moreover, two of the rest of the students held a specific alternative conception that "Parent cell remains after cell division". Both of the students insist on their answers and stated that "After cell division, two daughter cells produced and parent cell still exists so, there will be three cells at the end of the process". The excerpt below belongs to Student C from the CCI group shows alternative conception of the student and the source of it:

Researcher : What do you think what happens to the parent cell after cell division?

Student C : In the beginning there is one cell, and at the end of the cell division process two new cells produced.

Researcher : So?

Student C : The parent cell was already there. I mean, there will be three cells at the end.

Researcher : At the end of the cell division there will be three cells, right?

Student C : Of course. The presentation of mitosis in our book shows it very clear, the parent cells remains and there will be three cells.

Similar excerpt below belongs to Student F from the CCI group indicates how similar ideas that these students held:

Researcher : What do you think what happens to the parent cell after cell division?

Student F : ...... I do not understand.

Researcher : I mean, What happens to the cell that exists at the beginning of the cell division?

Student F : It stands.

Researcher : What you mean by saying “it stands”.

Student F : In other words, at the end of the cell division process, the main cell does not die, it is still alive. I know that the genetic information is copied to the new cells but the parent cell stays.

Researcher : Do you mean, one of the sister cells becomes mother cell at the end?

Student F : No. The parent cell still exist, isn’t it?

Researcher : .....

Student F : I know that, there will be two new cells from mother cell.

Researcher : So, you mean that at the end there will be three cells, right?

Student F : Yes.

Table 4.23 The percentages of the students' responses to interview questions

	CCI Group					LCI Group				
	N	**A**	**I**	**P**	**C**	**N**	**A**	**I**	**P**	**C**
Cell Division										
Does every cell divide?	0 (0%)	0 (0%)	2 (33.3%)	1 (16.7%)	3 (50%)	0 (0%)	0 (0%)	2 (33.3%)	0 (0%)	4 (66.7%)
Why do cells divide?	1 (16.7%)	1 (16.7%)	0 (0%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	2 (33.3%)	3 (50%)
What happens to a parent cell?	1 (16.7%)	2 (33.3%)	0 (0%)	0 (0%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (100%)
What are the meaning of n and 2n?	1 (16.7%)	3 (50 %)	0 (0%)	0 (0%)	2 (33.3%)	0 (0%)	1 (16.7%)	0 (0%)	1 (16.7%)	4 (66.7%)
Mitosis										
What is the aim of mitosis?	0 (0%)	0 (0%)	0 (0%)	2(33.3%)	4 (66.7%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	5 (83.3%)
When does DNA replication occur?	1 (16.7%)	2 (33.3%)	1 (16.7%)	0 (0%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	5 (83.3%)
Which cells undergoes mitosis?	2 (33.3%)	1 (16.7%)	0 (0%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (100 %)
Do parent cell and daughter cells differ?	0 (0%)	0 (0%)	1 (16.7%)	2 (33.3%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)	2 (33.3%)	4 (66.7%)
Do daughter cells differ?	0 (0%)	1 (16.7%)	0 (0%)	2 (33.3%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)	2 (33.3%)	4 (66.7%)
Meiosis										
What is the aim of meiosis?	1 (16.7%)	0 (0%)	1 (16.7%)	2 (33.3%)	2 (33.3%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	5 (83.3%)
Which cells undergoes meiosis?	1 (16.7%)	2 (33.3%)	0 (0%)	1 (16.7%)	2 (33.3%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	5 (83.3%)
What is the reason of decrease in chromosome #?	0 (0%)	0 (0%)	2 (33.3%)	0 (0%)	4 (66.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (100 %)
Is it advantageous to delete one pair of each homolog chromosomes?	3 (50 %)	0 (0%)	1 (16.7%)	0 (0%)	2 (33.3%)	0 (0%)	0 (0%)	1 (16.7%)	1 (16.7%)	4 (66.7%)

Notes: CCI = Conventional Classroom Instruction, LCI= Learning Cycle, N= No response, A= Alternative conception, I= Incorrect response, P= Partially correct response, C= Correct response.

(Table 4.23 continued)

	CCI Group					LCI Group				
	N	**A**	**I**	**P**	**C**	**N**	**A**	**I**	**P**	**C**
Comparison of mitosis and meiosis										
What are the similarities between mitosis and meiosis?	0 (0%)	0 (0%)	1 (16.7%)	2 (33.3%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)	3 (50 %)	3 (50%)
What are the differences between mitosis and meiosis?	0 (0%)	0 (0%)	0 (0%)	5 (83.3%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	5 (83.3%)
What is the reason of the need for two different types of cell division?	2 (33.3%)	0 (0%)	1 (16.7%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	5 (83.3%)
Asexual reproduction										
What are the types of asexual reproduction?	1 (16.7%)	0 (0%)	0 (0%)	2 (33.3%)	3 (50%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	5 (83.3%)
Which organisms reproduce asexually?	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	5 (83.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (100%)
Sexual reproduction										
Which organisms reproduce sexually?	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	5 (83.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (100%)
Is it possible to reproduce by both sexually and asexually?	1 (16.7%)	1 (16.7%)	1 (16.7%)	2 (33.3%)	1 (16.7%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	5 (83.3%)
What are the similarities between asexual and sexual reproduction?	1 (16.7%)	0 (0%)	2 (33.3%)	3 (50 %)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (83.3%)	1 (16.7%)
What are the differences between asexual and sexual reproduction?	1 (16.7%)	0 (0%)	0 (0%)	4 (66.7%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	4 (66.7%)	2 (33.3%)

Notes: CCI = Conventional Classroom Instruction, LCI= Learning Cycle, N= No response, A= Alternative conception, I= Incorrect response, P= Partially correct response, C= Correct response.

When the meaning of the abbreviations “n” and “2n” were asked to the students, 4 students (66%) of experimental group and 2 students (33%) of control group answered correctly. For instance one of the experimental group students (Student G) stated that “n is used for haploid organisms and 2n is used for diploid organisms”. The excerpt below belongs to Student G:

…….

Researcher : What you mean by the words “haploid and diploid organisms”?

Student G : The diploid organisms have two sets of chromosomes and the haploids have one set of chromosomes.

Researcher : What is the meaning of “two sets”?

Students G : There are two chromosomes carry genes for same traits. Each inherited from one parent, one from mother and one from father.

Researcher : So, One set means?

Student G : Haploids have one set chromosome. Therefore; haploids are the ones that have just one allele for each trait however, diploids carry two alleles.

The response which included explanation that “n is used for haploid organisms; 2n is used for diploid used for diploid organisms” categorized as partially correct and one of the experimental group student stated this answer. There were two alternative conceptions aroused from students’ responses to the fore-mentioned question. These alternative conceptions were “2n is used for the cells that have sister chromatids and “n” is used for the cells that have one chromosome” and “The cells that undergo meiosis are diploid and the cells that undergo mitosis are haploid”. In total, three CCI group students (50%) and one LCI group student (16.7%) held alternative conception about n/2n concept. One of those CCI group student’s (Student D) excerpt is below:

Researcher : Do you know, what are the meaning of the terms n and 2n?

Student D : 2n is diploid cells and n is haploid cells.

Researcher : What you mean by the words diploid and haploid cells?

Student D : Only mother gamete cells contain 2n, somatic cells contain n.

Researcher : Could you explain more?

Student D : 2n cells can undergo meiosis but n cells can only undergo mitosis. Hmmm, I am little confused. I think it was vice versa.

Researcher : So?

Student D : I think.........., My first explanation is the correct one.

Researcher : Are you sure?

Student D : Yes, ofcourse, I am. The cells which can undergo mitosis are called as haploid and which can undergo meiosis are called as diploid. It is very easy, I have studied these concepts and I solved many questions.

Even Student D confused while talking about the haploidy and diploidy, s/he was very sure about the last answer that contained alternative conceptions. The decision of the Student D did not change that s/he held alternative conceptions on these concepts indeed since both of the answers were totally wrong. I was clear that s/he does not have the idea of being hapliod or diploid cell depends on having homologuos chromosomes.

When the answers of the students to the questions related with mitosis examined, it is obvious that most of the experimental group students gave correct answer; at least 4 students (66.7%) stated scientific explanations and none of them gave incorrect response and none of them held alternative conceptions. However, in the control group maximum 4 students (66.7%) answered the questions correctly, some of them gave incorrect responses and some of them held alternative conceptions. For instance, two of the control group students held one of the common alternative conceptions that ‘DNA replication occurs during prophase’. The excerpt below belongs to Student C (from CCI group):

Researcher : How do the chromosomal changes that occur during mitosis?

Student C :The chromosomes are replicated and shared by daughter cells therefore, chromosome number stay same in generations.

Researcher : Dou you remember, which stage of cell division these events occur?

Student C : Hmmm, there are five stages of mitosis, I memorized them by the fist letters of the stages "IPMAT". Sooo, interphase, prophase, metaphase, anaphase and telophase. There are not much things happened during interphase but the prophase is the preparation phase, chromosomes started to be formed and DNA replication occurs. These chromosomes seperated in anaphase and are shared in telophase.

Researcher : What you mean by saying "not much things happened during interphase"?

Student C : I mean, there is no chromosomal changes occur. Cell becomes larger, organels are replicated, necessary things for cell division produced and...... thats all.

Researcher : What about the DNA?

Student C : It is replicated in order to keep constant the chromosome number between generations.

Researcher : So, when does DNA replicated?

Student C : In prophase. I know like this.

When the question of which cells undergoes mitosis is directed, one of the control group student stated that "Somatic cells undergoes mitosis, but nerve cells and gamete mother cells cannot divide by mitosis". If the students just stated that the somatic cells as an answer and could not gave response to the question of 'which cells do not undergo mitosis', these answers categorized under partially correct answers. The last question related to mitosis was "do daughter cells differ", 4 of the experimental students (66.7%) and 3 of the control group students (50%) gave correct answer that the daughter cells might be different in size, the amount of cytoplasm and the number of organelles. Two of the students from each group gave partially correct answer, which means they did not stated all of the parameters that might be differ in daughter cells. One of the control group students stated that 'there might be differences in daughter cells like size, the number of organelles, and DNA amount'. Even after the researcher directed question that do you think the DNA amount differ across daughter cells. The student insisted on his/her answer and stated that 'Chromosome number has to be same but the DNA amount might be change'.

This response indicated that the student have same alternative conceptions related to the structure and the role of DNA.

The general interpretations to the questions related to the meiosis can be done as experimental group students have higher conceptual understanding and held less alternative conception than control group students. Most of the LCI students answered all of the four questions correctly and one of them held alternative conceptions. This student stated that ‘n cells undergo only mitosis and 2n cells undergo only meiosis”. The student is the same student that confused the meaning of the n and 2n cells. When the answers of the control group students were examined, their responses were distributed to the categories. For instance, 2 students gave correct answer, 2 students gave partially correct answer, one student gave incorrect answer and one student did not give response to the first question of meiosis; “what is the aim of meiosis”. One of those students (Student E) stated scientifically correct answer as following:

> ……The main aim of the meiosis is to decrease the chromosome number and enable fertilization which is very important to provide genetic diversity and maintain evolution.

Two students just said similar sentences like “the aim is to decrease chromosome number’ and could not give further explanation even the researcher directed probing questions. One of control group student stated that “the aim of the meiosis is produce new organisms”. The second question was which cells undergoes meiosis answered by 5 of the experimental group students (83.3%) whereas 2 control group students (33.3%) gave correct answer. In addition, 2 of the control group students held alternative conception that is “the gametes undergo meiosis”.

Although, the answers to the questions related to the comparison of the processes of mitosis and meiosis showed that most of the students of both groups know the differences and similarities between these processes, there were more partially correct answers in CCI group than LCI group since the students in the CCI group could not mentioned all of the differences just said two or three of them. When the second of the comparison question was examined the difference between the percentages of correct and partially correct answer among groups can be realized easily.

The percentages of correct responses to the questions related the asexual reproduction increased in CCI group however the superiority of LCI group continued. The question, which organisms reproduce asexually, answered correctly by all of the LCI group students and 5 of the CCI group students. The transcripts showed that one of the CCI students held a common alternative conception among students and s/he stated that “Plants reproduce by only asexually since it is impossible for them to copulate”. All of the interviewees answered correctly the question of which organisms reproduce sexually except the student who though that plants can not reproduce sexually. When the question about the posibility of reproducing both asexually and sexually was directed to the students, a new alternative conception aroused. One of the CCI group students (Student A) and one of the LCI group students (Student H) stated similar alternative conceptions. Their expressions are in the following:

> Student A: Human can reproduce by both sexually and asexualy. …..I mean, somatic cells of human can reproduce asexually and gonads reproduce by sexually (After the researcher asked what s/he mean).

> Student H: ….. Human is a good example for the organisms that reproduce by both sexually and asexually since the autosomes reproduce via mitosis which is asexual reproduction and allosomes reproduce by meiosis which is sexual reproduction.

It is obvious from the above expressions, these students confused the terms mitosis with asexual reproduction and meiosis with sexual reproduction.

Alternative conceptions that are identified in interviews are listed in Table 4.24. Some of these alternative conceptions were corresponding to the AC's of the CDRDiT and were identified before but some of them revealed during the interview sessions since the students who held AC insist on their answers even the probing questions directed. Table 4.24 indicated that CCI group students held more alternative conceptions than the LCI group students.

Table 4.24 The percentages of the alternative conceptions revealed in interviews

Alternative Conceptions	CCI	LCI
- Cell nucleus cannot control the passage of molecules through cell membrane then divide.	1 (16.6%)	0 (0%)
- Parent cell remains after cell division.	2 (33.3%)	0 (0%)
- 2N means that having sister chromatids (AC-49).	1 (16.6%)	0 (0%)
- The cells that undergo meiosis are diploid and the cells that undergo mitosis are haploid (AC-30).	2 (33.3%)	1 (16.6%)
- DNA replication occurs during prophase (AC-2).	2 (33.3%)	0 (0%)
- Gamete mother cells cannot divide by mitosis.	1 (16.6%)	0 (0%)
- Daughter cells can have different DNA amount.	1 (16.6%)	0 (0%)
- Gametes undergo meiosis.	2 (33.3%)	0 (0%)
- 2N cells undergo only meiosis.	0 (0%)	1 (16.6%)
- Plants reproduce by only asexually (AC-34).	1 (16.6%)	0 (0%)
- Human autosomes reproduce by asexually and allosomes reproduce by sexually.	1 (16.6%)	1 (16.6%)

Note. Abbreviations at the end of the sentences show the alternative conception numbers included in cell division and reproduction diagnostic test (CDRDiT), were listed in Table 3.6

4.4.1 Students' Representations of Cell Divisions

During the interviews, students were asked to draw and explain the phases of mitosis and meiosis. The researcher wanted them to label each component of their drawings. Some of the students show an inability to draw well but this is not the matter and the researcher assured them on that issue. Drawings of the LCI group students were more complex and include more elements of the cell structure than CCI group students' drawings. All of six LCI group students drew the phases of the mitosis completely. Four of them drew the phases of meiosis; one of them drew just the first part of meiosis completely and stated that there is no need to draw second part since it is similar with mitosis, the difference is that the sister chromatids will separate instead of homolog chromosomes in anaphase II. The other LCI group student did not want to draw meiosis by stating that it is too long and she drew just a sketch of gametogenesis. When drawings of the CCI group analyzed, four of six CCI group students drew the phases of mitosis, two of those drew the phases of meiosis completely. One of those CCI group students did not drew the phases of meiosis one by one and drew a gametogenesis. One other CCI group student drew prophase, metaphase and telophase of mitosis and did not draw meiosis. One other CCI group student did not want to draw anything and stated that she can't draw, she said the names of the phases without and order, could not explain them verbally too and she just write the words that she remembered for each cell division types.

In order to analyze students' drawings deeply and categorize them, a pre-existing scoring system adapted to the concepts of photosynthesis and respiration in plants by Kose (2008) from Reiss and Tunnicliffe (2001) and then modified to cell division concepts by Dikmenli (2010) was used. Scoring system consists of five well-defined conceptual understanding levels. Table 4.25 shows each level and their explanations.

Table 4.25 The scoring system to analyze drawings of the students

Level	Theme	Explanation
Level 1	No Drawing	- No response or "I don't know"
Level 2	Non-Representational Drawings	- Includes identifiable elements of cell division. - Diagrams or formulations instead of the drawings.
Level 3	Drawings with Misconceptions	- Includes some elements of cell division but also demonstrated some alternative conceptions.
Level 4	Partial Drawings	- Includes partial understanding of the concepts and elements of the cell division like prophase, metaphase, anaphase, telophase, etc.
Level 5	Comprehensive Representation Drawings	- The most competent and realistic diagrams of cell division. - Includes a sound understanding and contained seven or more elements of cell division processes.

Note. Table is adapted from Dikmenli, 2010.

Students' drawings of mitosis and meiosis were analyzed and categorized with the help of the above mentioned scoring rubric and the results were summarized in Table 4.26. As seen from the table, students' drawings reveal that LCI group students show high level conceptual understanding than CCI group students. In addition to that the claim that the understanding of mitosis could facilitate the understanding of meiosis might not be unrealistic since the results indicated that the student who have high level conceptual understanding in mitosis, have high level of conceptual understanding in meiosis, and the vice versa is also valid. Among CCI group students' drawings, three of them include some alternative conceptions about mitosis and two of them include some alternative conceptions about meiosis. However, only two of the LCI group students' drawings includes alternative conceptions about mitosis. Therefore it can be said that learning cycle instruction helps to avoid alternative conceptions mostly but there were still some of the students held alternative conceptions in the LCI groups even after ten weeks treatment period.

Table 4.26 Categorization of the students' drawings

CCI Group			LCI Group		
Students	**Mitosis**	**Meiosis**	**Students**	**Mitosis**	**Meiosis**
Student A	Level 3	Level 3	Student G	Level 5	Level 5
Student B	Level 3	Level 1	Student H	Level 3	Level 4
Student C	Level 4	Level 2	Student I	Level 3	Level 2
Student D	Level 1	Level 1	Student J	Level 5	Level 5
Student E	Level 4	Level 2	Student K	Level 4	Level 4
Student F	Level 3	Level 3	Student L	Level 5	Level 5

There are example drawings were given below to make clear the categorization process.

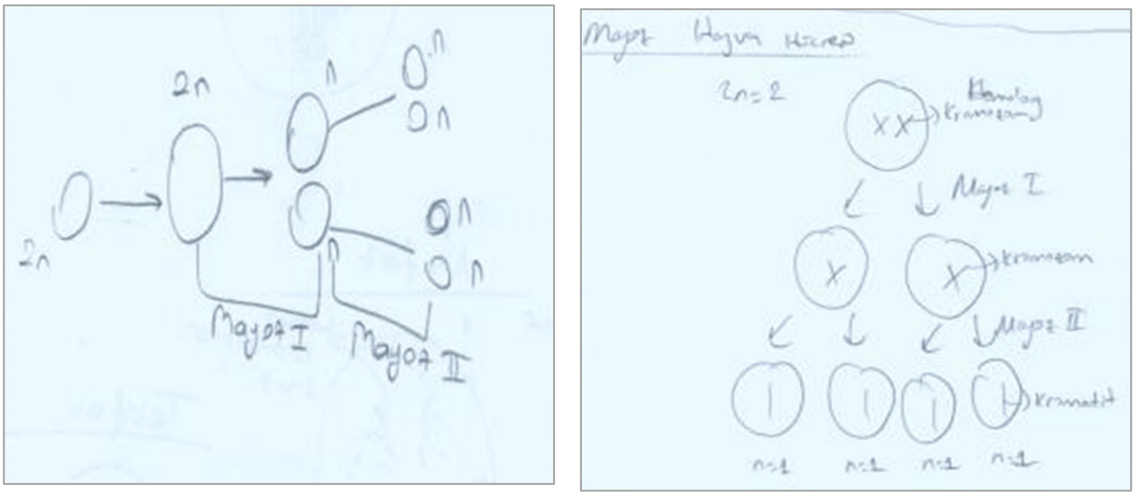


Figure 4.9 Drawings of the Students E and I (Examples of Level 2)

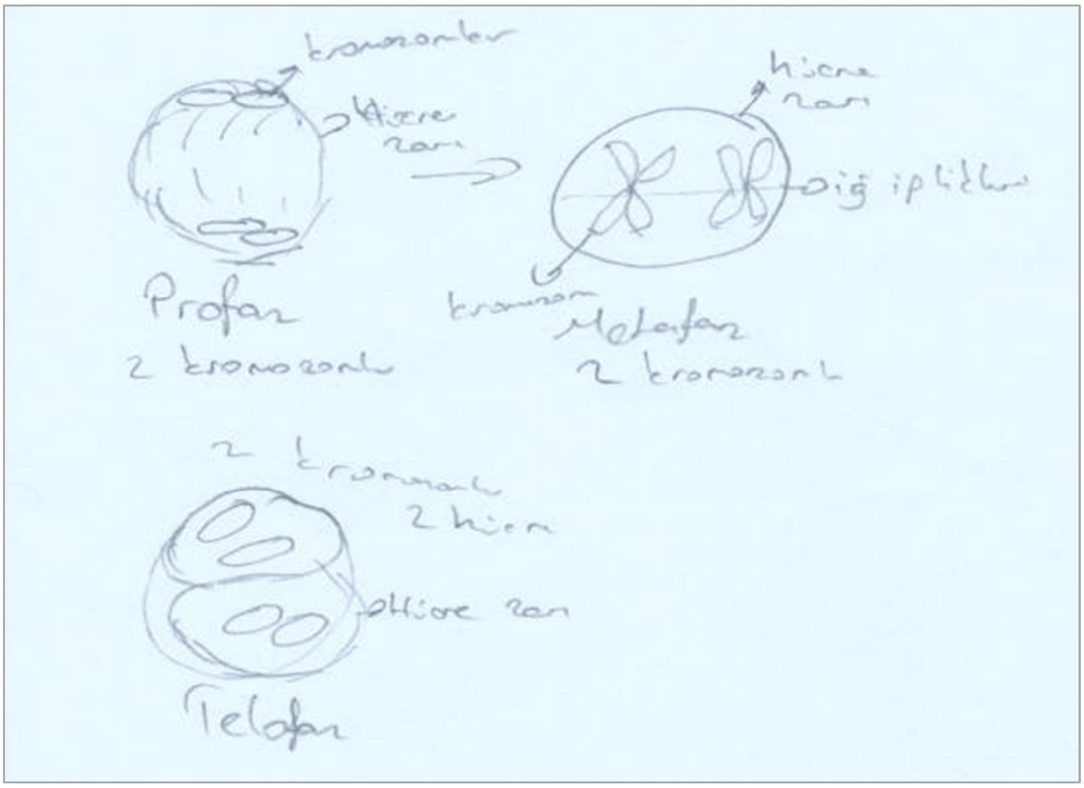


Figure 4.10 Drawing of the Student B (Example of Level 3- DNA replication occurs during prophase)

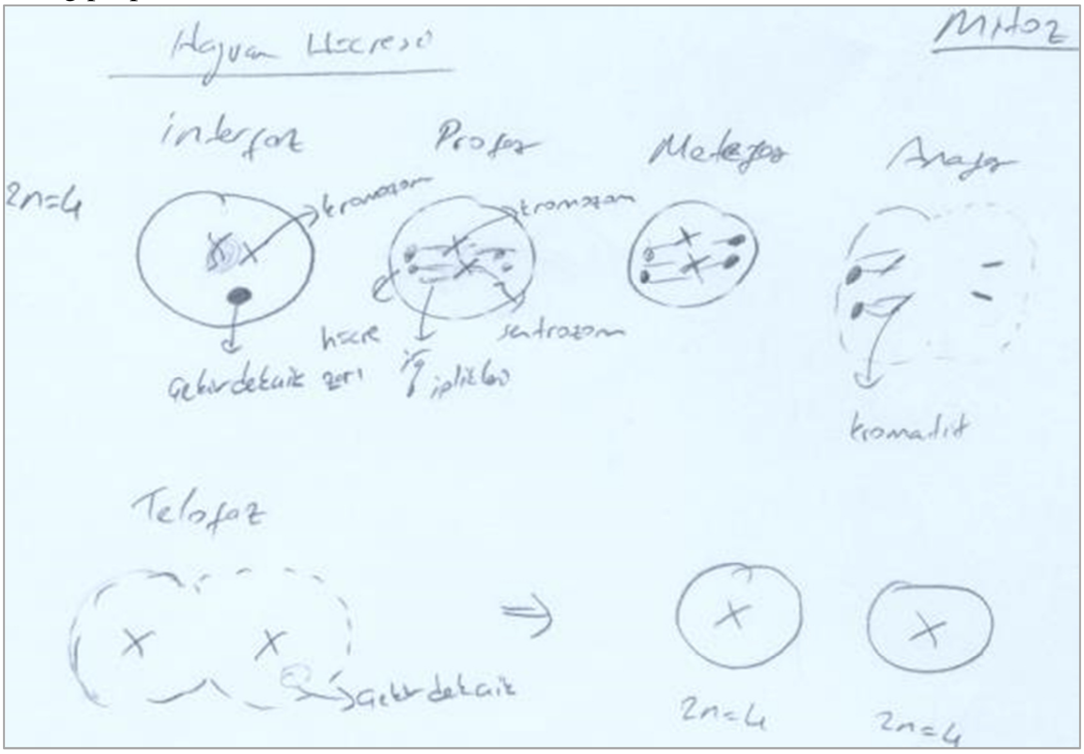


Figure 4.11 Drawing of the Student I (Example of Level 3- Chromosomes have two sister chromatids in telophase)

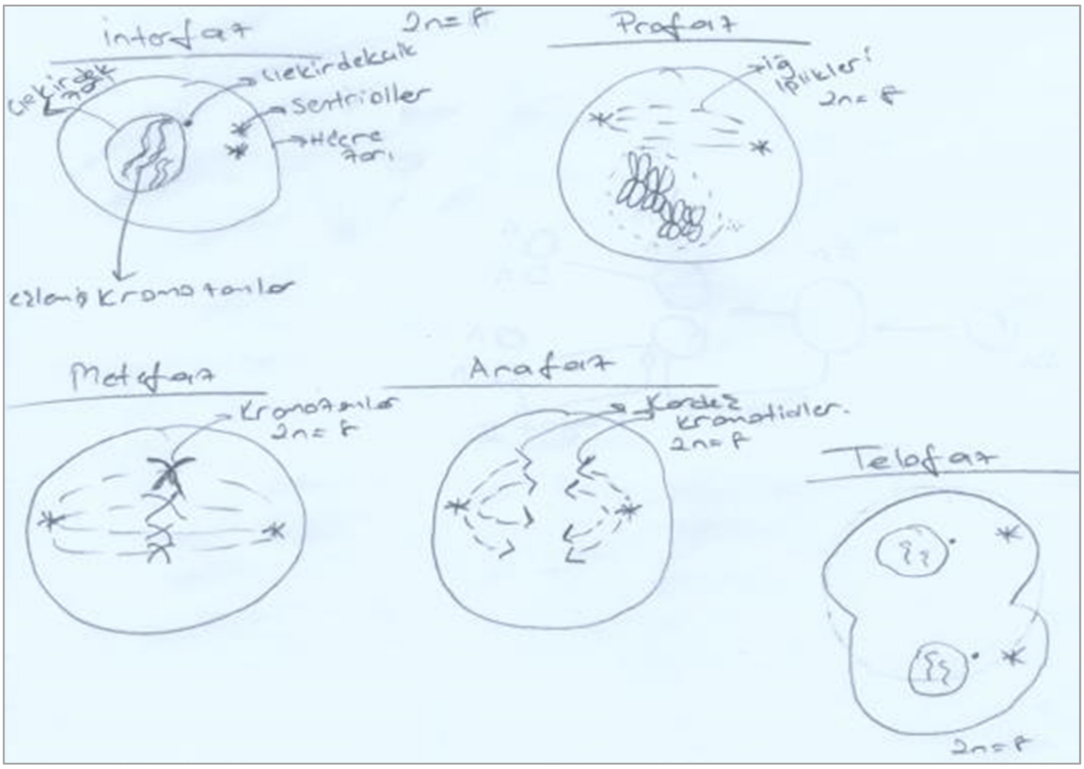


Figure 4.12 Drawing of the Student E (Example of Level 4)

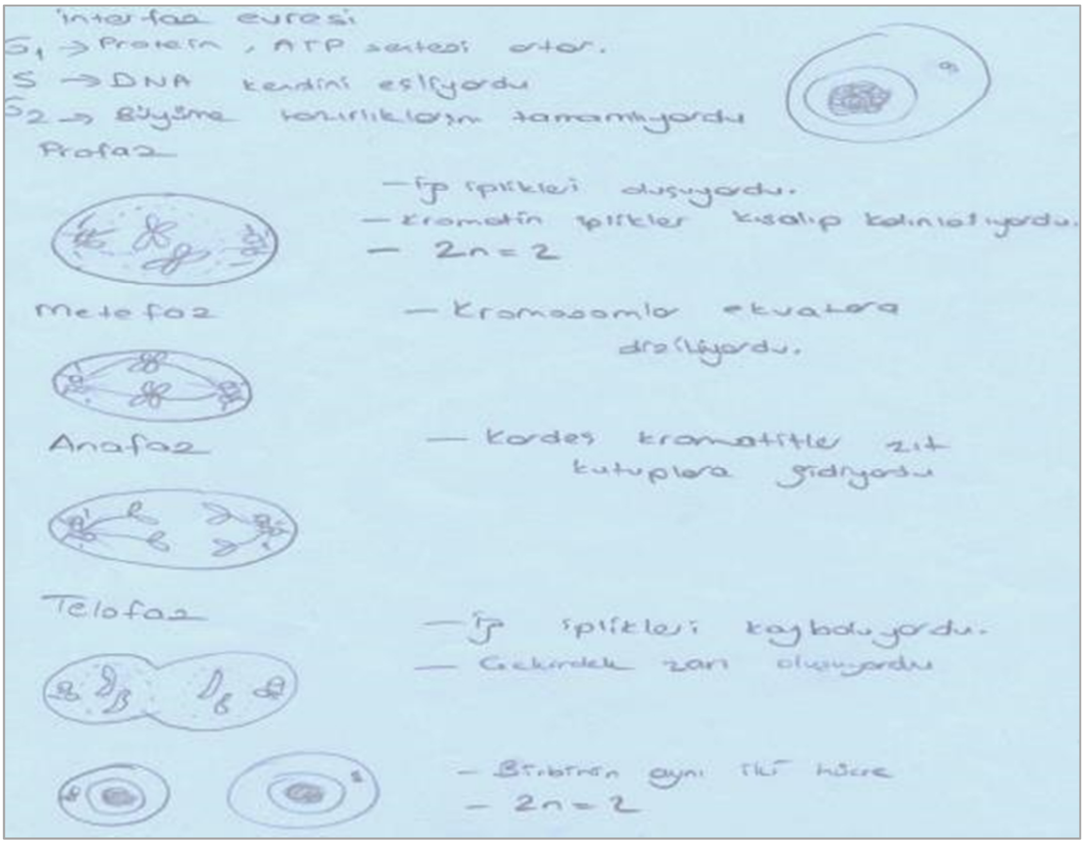


Figure 4.13 Drawing of the Student G (Example of Level 5)

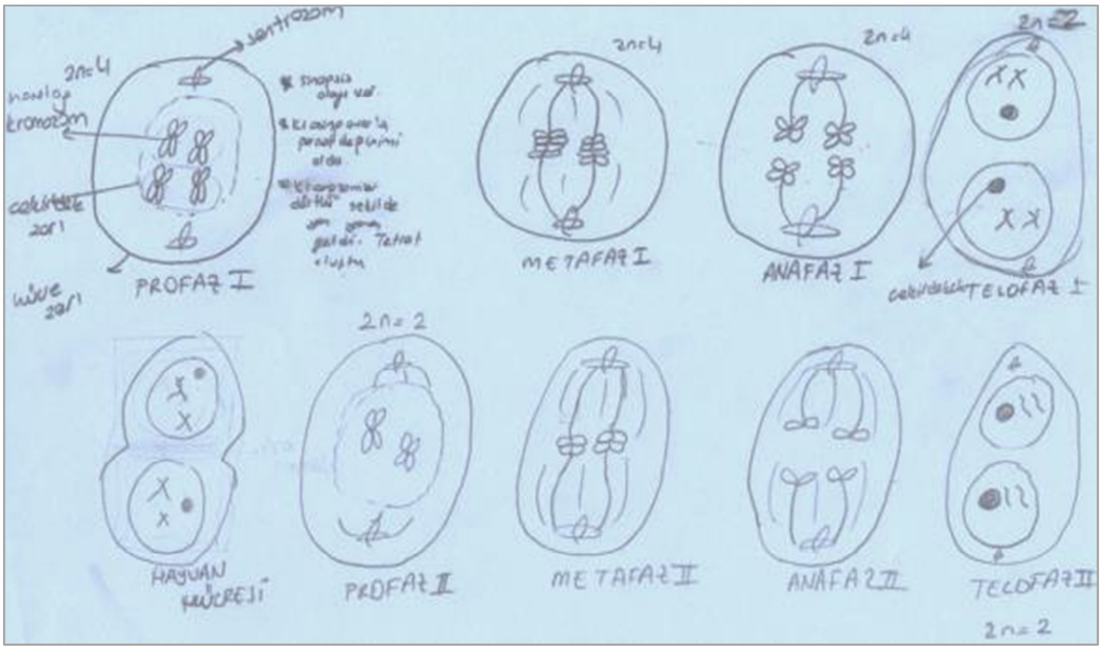


Figure 4.14 Drawing of the Student L (Example of Level 5)

When students' drawings and explanations were detected to identify alternative conceptions, CCI group students' drawings and explanations includes more alternative conceptions than LCI group students'. The alternative conceptions are listed in Table 4.27.

Most of the alternative conceptions identified from students' drawings and explanations of the processes were consistent with the identified alternative conceptions from three-tier diagnostic test (CDRDiT) on cell division and reproduction concepts and interview. Students usually confused the number of chromosomes that the cell havein different stages of cell division, structure of chromosomes, replication and separation of the chromosomes during mitosis and meiosis.

Table 4.27 The alternative conceptions revealed in drawings and explanations

Alternative Conceptions	Group
Chromatin is placed in cytoplasm in eukaryotes.	CCI
In mitotic cycle, the amount of chromosomal DNA does not change (AC-4).	CCI
The number of chromosome is fixed and remains unchanged during the stages (AC-5).	CCI, LCI
Homolog chromosomes are actually sister chromosomes* (AC-49).	CCI
DNA replication occurs during prophase (AC-2).	CCI
Prophase is the preparation phase of cell cycle* (AC-8).	CCI
Cells have two centrosomes.	LCI
Nucleus and nucleolus disappear in interphase.	CCI
Spindle fibers formed chromosomes by condensing and being shorten*.	CCI, LCI
Centrosome is replicated during prophase.	LCI
Chromatids are replicated during mitosis and chromosomes are replicated during meiosis*.	CCI
Chromosome number is duplicated in interphase*(AC-7).	CCI
Genetic diversity is just depends on crossing over* (AC-31).	CCI
DNA is replicated before meiosis II*(AC-28).	CCI
The cell that undergoes mitosis doesn't have homologous chromosomes*.	CCI
Gametes are produced by meiosis I and the number of them is increased by meiosis II*.	LCI
Chromosomes have two sister chromatids in telophase of mitosis.	CCI

Note. * shows the detected alternative conceptions from students' explanations. Abbreviations at the end of the sentences show the alternative conception numbers included in cell division and reproduction diagnostic test (CDRDiT), were listed in Table 3.6

There are some example of alternative conceptions identified from students' drawings can be seen below.

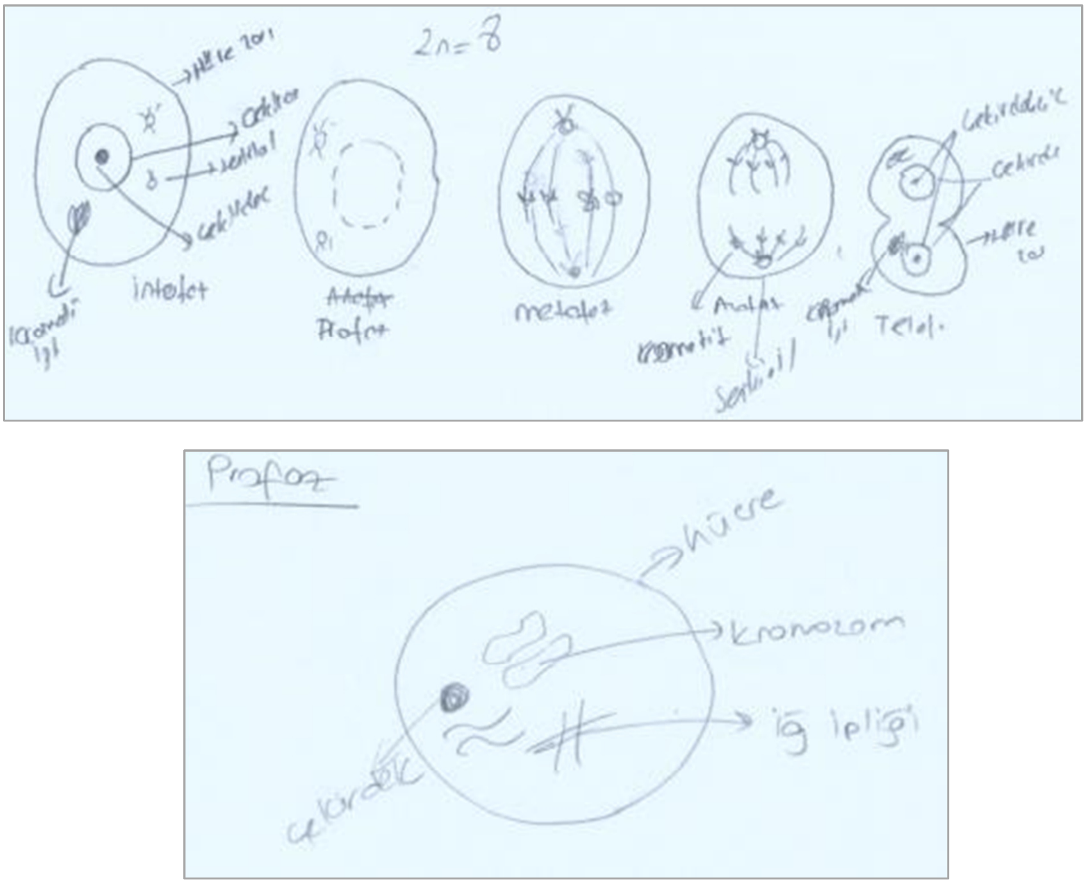


Figure 4.15 Chromatin is placed in cytoplasm in eukaryotes (Example of Level 3)

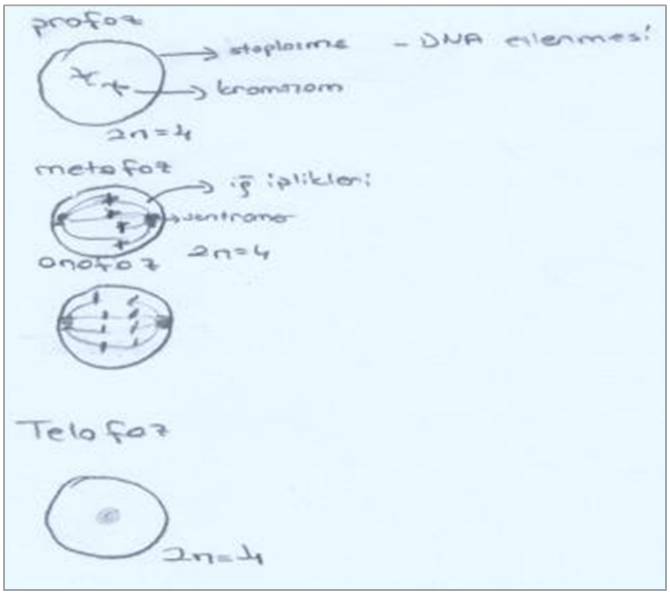


Figure 4.16 DNA replication occurs during prophase (Example of Level 3)

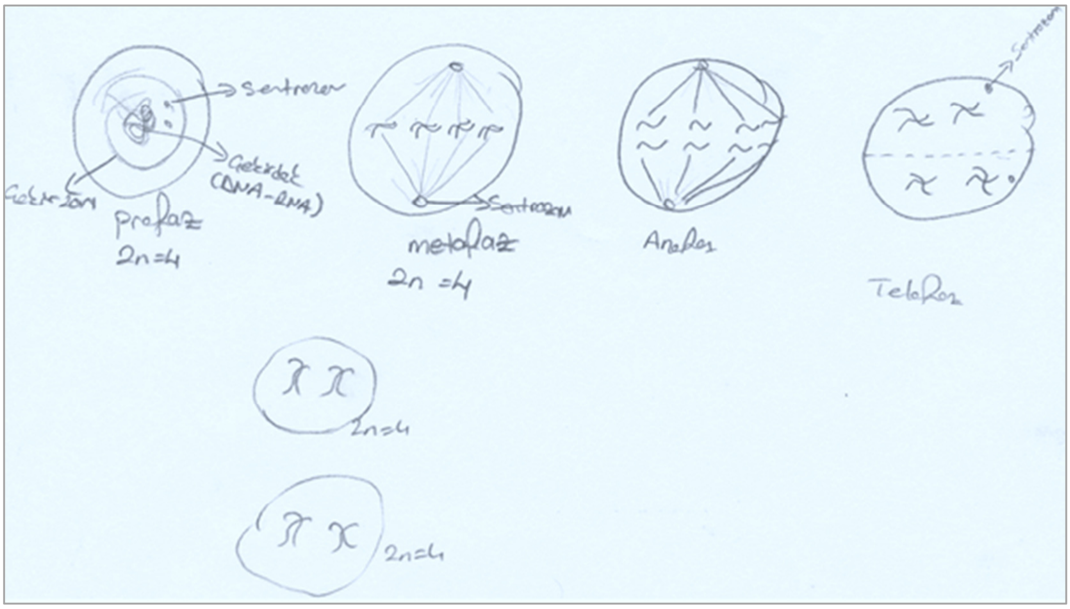


Figure 4.17 Chromosomes have two sister chromatids in telophase of mitosis (Example of Level 3)

In addition to these alternative conceptions, the most frequent confusion for the students was the chromosome number of the cells. When researcher asked students to write the chromosome number of the cell that they were drawn in the beginning and at the end of cell division, although most of them said that the chromosome number will stay same in mitosis and will be halved in meiosis, four of the six CCI group students and one of the LCI group student confused about the numbers and wrote different chromosome number than they drawn.

4.4.2 Students' Reflections on 5E Learning Cycle

Six questions related with teaching method were directed only LCI group students during the interview sessions. LCI group students` ideas on the implementation of the 5E learning cycle model were investigated. Same process with the previous interview data were applied to the collected data, dialogs were transcribed word by word, coded, and categorized under themes. The results revealed in interviews are summarized in Table 4.28.

Table 4.28 LCI Group Students' Ideas on 5E Learning Cycle

Codes	Number of students (%)
Comparison of the Methods (5E LCI vs. CCI)	
- Active engagement	3 (50%)
- Daily life connected	6 (100%)
- Experiments and activities	5 (83.3%)
- More enjoyable	6 (100%)
- Preferable	6 (100%)
- More visual	2 (33.3%)
Helpful Activities	
- Surprise with sockosomes	4 (66.6%)
- Modeling mitosis with play dough	5 (83.3%)
- Watching video	3 (50%)
- Bajema strategy	3 (50%)
Daily Life Connection	
- Cancer	6 (100%)
- Grafting	4 (66.6%)
- Animal life	3 (50%)
- Fertilization	6 (100%)
- Egg	5 (83.3%)
Changes in Students	
- Increase attention	3 (50%)
- Improve retention	6 (100%)
- Increase comprehension	5 (83.3%)
- Increase motivation towards biology	3 (50%)
- Increase curiosity on biology	1 (16.6%)
Problems	
- Noise	2 (33.3%)
- Lab environment	2 (33.3%)

The entire six LCI group students were aware of the different instructional method implemented by their teacher from the one used in the previous semester and all of them said that they liked this instructional method because it is more enjoyable than conventional classroom instruction. In addition, all of them would prefer 5E learning cycle instruction if they have a chance to select. The students who preferred the 5E LC over conventional classroom instruction thought that the 5E learning cycle gained their interest more and keep them engaged in activities and the topics that have been studied. Students used sentences such as "I like the way that the teacher do this year, it helped me engage and motivate", "it is more daily life connected", and "learning with this method makes the lessons more fun" indicated their specific reasons why all of the students favored 5E learning cycle instruction.

4.5 Summary of the Results

- 5E Learning cycle instruction provides a better conceptual understanding than conventional classroom instruction on cell division and reproduction concepts.
- 5E Learning cycle instruction is better to remedy students' alternative conceptions than conventional classroom instruction on cell division and reproduction concepts.
- 5E Learning cycle instruction does not caused higher achievement than conventional classroom instruction on cell division and reproduction concepts.
- 5E Learning cycle instruction does not interact with gender, that means males and females did not affected by the instruction on cell division and reproduction concepts differently either in understandings and achievement.
- LCI group students held less alternative conceptions and used more scientific terms in explaining the cell division processes than CCI group students during the interviews.
- Drawings of the LCI group students show higher conceptual understanding levels than the drawings of the CCI group students.
- CCI group students' drawings include more alternative conceptions than the drawings of the LCI group students.
- LCI group students liked learning cycle instruction because it is more enjoyable than conventional classroom instruction. In addition, all of them would prefer 5E learning cycle instruction if they have a chance to select.
- LCI group students claimed that learning cycle instruction increase attention [3 (50%)]; improve retention [6 (100%)]; increase comprehension [5 (83.3%)]; increase motivation towards biology [3 (50%)].

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

As a final chapter of this study; chapter five included five sections; discussion and interpretations of the results is the first section. Secondly, possible validity threats and the ways that utilized to prevent these threats were presented. Afterwards, the generalization of the study was given. Finally, implications of the results and suggestions for future studies were presented.

5.1 Discussion of the Results

The purpose of the study was investigate effectiveness of 5E learning cycle instruction (LCI) and conventional classroom instruction (CCI) on 10th grade students' conceptual understanding and achievement in cell division and reproduction concepts, and their alternative conceptions on these concepts. The design of this study was twofold: (1) administering pretests and post-tests regarding students' achievement on cell division and reproduction concepts (CDRAT) and conceptual understanding on these concepts to determine students' alternative conceptions (CDRDiT), (2) conducting semi-constructed interviews with 12 students and get them to draw and explain the cell division processes in order to support quantitative results. In other words, the focus of the study was to remediate students' alternative conceptions on cell division and reproduction concepts by improving their conceptual understanding with the help of 5E learning cycle instructional model that let students to participate in more hands-on and minds-on activities embedded with real world compared to the conventional classroom instruction. Learning cycle instruction group spent their time in biology laboratory and performed experiments whereas conventional classroom instruction group listened their teacher, follow textbooks and take notes most of the class time. Before the implementation, both CCI and LCI groups took pre-tests on students' achievement on cell division and reproduction concepts (CDRAT), their conceptual understanding of these concepts (CDRDiT), and science process skills test (SPST). After checking for the descriptives of the pre-CDRDAT, independent sample t-tests were performed in order to compare the groups before the treatments.

The independent sample t-test result is indicated that prior knowledge on cell division and reproduction concepts of the students was not different across the CCI and LCI groups. When the mean scores were checked, the control group students' mean score was 13.97, and it was 13.62 for experimental group students. The maximum score on CDRAT was 35 therefore; these low mean scores showed that both groups had limited prior knowledge of the cell division and reproduction concepts before the implementation period. Statistically insignificant t-test results also support the idea that the groups were assumed to be equal in terms of their prior knowledge. As Ausubel (1968) emphasized, the prior knowledge plays a critical role in knowledge construction, so conducting study with groups had similar prior knowledge would be better for experimental studies. Blurton (1985) reported that prior genetics knowledge significantly predicted the performance of the students' on a genetics posttest. Similarly, the prior knowledge help students interiorize more effective study strategies to achieve in college physics and biology classes (Hegarty-Hazel & Prosser, 1991). Since there is no difference is found between CCI and LCI groups before the treatment, the effectiveness of the instructional methods on students' achievement cannot be attributed to the students' prior knowledge differences.

Students understanding scores obtained from pre-CDRDiT were not also statistically different from each other. The mean scores of the control and the experimental groups were 1.43 and 1.75 respectively. Since the maximum score on CDRDiT is 20, it could be said that both groups had very low understanding level before the implementation period. The main reason under these low scores is that the students had not come across with most of the concepts included in CDRDiT before, because of the curriculum advised to just mention the processes as overall without even spelling the names of the phases in 6th grade level. The second reason of getting low score might be originated the nature of the CDRDiT. The CDRDiT is a three-tier diagnostic test, the first tiers of CDRDiT directs regular multiple choice question with two/three alternatives, the second tier items contain the reason of the answer to the first tier, and the third tier asks whether the participant certain or not. Most of the alternatives in the second tiers were formed by alternative conceptions that are reported as common in the literature. Correct answers to the first two tiers along with being certain were classified as scientific knowledge. If a student guess the answer of the first tier, it would be hard to find the correct reason in the second tier of the question, and in the third tier, the percentage of the being certain become less. Therefore, CDRDiT provides a chance to obtain more accurate data on students' understandings of cell division and reproduction concepts. Even two-tier diagnostic tests are undeniably superior than multiple choice tests to detect alternative conceptions, the likelihood of guessing in these tests might overestimate students' knowledge and misconception levels therefore, these tests could not differentiate alternative conceptions from lack of knowledge (Arslan, Cigdemoglu, & Moseley, 2012; Caleon & Subramaniam, 2010a; Pesman & Eryilmaz, 2010). In order to overcome this weakness of two-tier diagnostic tests, a third-tier (confidence tier) which asks that the subjects were confident or not about their responses were added to each items of CDRDiT. Researchers developing diagnostic tests with certainty indices tend to treat all of the uncertain responses as lack of knowledge (Hasan et al., 1999; Odom & Barrow, 2007; Pesman & Eryilmaz, 2010). Similar approach is followed and the percentage of mean lack of knowledge scores were calculated based on students responses to pre-CDRDiT as 57% for control and 51% for experimental group. These percentages also shows that along with the low understanding scores, most of the students were not confident about their knowledge on the cell division and reproduction concepts before the treatment, in order words they have similar lack of knowledge percentages on these concepts. Therefore, the possible difference on students' post-CDRDiT scores after the implementation could not be aroused from the prior differences of the control and experimental groups' understanding levels.

In addition to the above mentioned scores, pre-alternative conception scores (pre-AC scores) were calculated based on students responses to pre-CDRDiT by taking into account the alternative sets that coded each alternative conceptions. In general, incorrect responses to one of the first two tiers or both of them with certainty give alternative conceptions. The mean alternative conception score of control group was 7.21 and experimental group was 7.48 out of 20. The more the score that the students have, the more alternative conceptions they hold. Therefore, the experimental groups' students have slightly more alternative conceptions than the control groups before the treatment. However, independent sample t-test results indicated that this small mean difference was not statistically significant. In other words, there is no statistically difference between students' alternative conceptions before the treatment. Therefore, the effectiveness of the instructional methods on the elimination of students' alternative conceptions about cell division and reproduction concepts cannot be attributed to the differences of alternative conceptions that the students held among control and experimental groups before the treatment.

The independent sample t-test was also performed for the students' mean scores on Science Process Skills Test (SPST) before the treatment; the result showed that the control and the experimental groups had statistically significant mean differences. The mean score of the experimental groups (22.35) is higher than the mean score of control group students (19.03). In their study, Krajcik et al. (1998) investigated middle school students' processes of questions generation, investigation designs, apparatus construction and procedures; data analysis, conclusions, and findings presentations when problem-based learning was employed as an inquiry method. They attributed the failure of students on scientific inquiry to the missing aspects of understanding and skills. Therefore, the difference between science process skills of the groups might affect the effectiveness of 5E learning cycle instruction since the students had more skills might gain more than the student had low skills. To eliminate this probability and also reduce the probability of making type I error, MANCOVA was performed with the presence of SPTS scores as a covariate to test the hypotheses.

After 10 weeks implementation period with conventional classroom instruction and 5E learning cycle instruction, both control and experimental groups took post-tests on students' achievement on cell division and reproduction concepts (CDRAT), and their conceptual understanding of these concepts (CDRDiT). After checking for the descriptives of the post-CDRDAT, post-CDRDiT and post-AC scores and the assumptions of the MANCOVA, it was performed with three dependent variables; post-CDRDAT, post-CDRDiT and post-AC, two independent variables; treatments and gender and one covariate; SPST scores.

The result revealed that the effect of 5E learning cycle instruction on students' post achievement scores is not statistically more than conventional classroom instruction. In other words, conventional classroom instruction was as affective as learning cycle instruction in terms of improving students' achievement scores. The learning cycle literature does not point out unambiguous results on the effectiveness of learning cycle on content achievement (Abraham, 1998). Although some of the studies, compared the effectiveness of learning cycle instruction with traditional instruction, reported significant results in favour of learning cycle (Balci, 2009; Cakiroglu, 2006; Ercan, 2009; Sadi & Cakiroglu 2010; Saunders & Shepardson, 1987; Schneider & Renner, 1980), as Bybee and his colleagues reviewed; some of the studies found no differences in achievement between students who experienced learning cycles and those who received traditional instructional formats (Campbell, 1977; Davis, 1978; Horn, 1980; Vermont, 1984 all in cited in Bybee et al., 2006). More recently, the results of a study conducted by Keskin (2008) indicated that there is no statistical difference between the groups instructed with 5E learning cycle and traditional method in terms of their achievement in simple harmonic motion. The main reason under the result of the present study might be aroused from the characteristics of achievement test (CDRAT). There were conceptual questions in the test and most of the items were similar to those that the students were familiar from question banks, textbooks and questions of entrance exam to university. Since the university enrollment requires taking exam in Turkey, most of the participants might do personal efforts even by their selves or by enrolling training centers. Most of these students try to receive a high score via learning testing techniques that help them just focus to find the correct alternative in multiple choice test items even they might not know exactly the logic of the answer. As a result of these efforts, control and experimental group students might receive approximately similar post-achievement scores (26.66 and 27.08 respectively). It is nearly impossible to control the effect of these extraneous variables. Furthermore, John Henry effect (Hake, 1998) might be occur since the experimental group and control group student were in interaction during break times and they might hear about the activities in LCI group and receiving no treatment might triggered them to study hard and so affect their performance. Therefore; they might tried to do their bests to take higher scores than experimental groups in order to prove their selves. Although, John Henry effect is tried to minimized by getting CCI group students to read the same readings and watched the same videos on grafting and fertilization with the LCI groups, these efforts might not be enough for the control group students and John Henry effect might cover the real effect of leaning cycle instruction on students' achievement in cell division and reproduction concepts.

Although, statistically insignificant result is found about the effectiveness of the learning cycle in promoting students' achievement on cell division and reproduction concepts compared to conventional classroom instruction, the follow-up ANCOVA results showed that 5E learning cycle instruction improved students' understanding of cell division and reproduction concepts more than CCI. Experimental groups students compared to control groups students achieved significantly greater post-CDRDiT scores (M= 10.38 and M= 6.73 respectively). When the gain mean scores compared, it is 5.30 for CCI and 8.63 for LCI groups. Even there was an increase in understanding level of both groups, the control group students could not gain as many scores as the experimental group students when the mean scores on pre-CDRDiT and post-CDRDiT compared. Therefore, experimental groups' students have higher-level conceptual understanding of cell division and reproduction concepts after the implementation period. The comparison of the percentages of the correct responses to each post-CDRDiT item showed improvement in LCI group students' more than CCI group students since LCI group students have higher percentages for all of the CDRDiT items than CCI group students except item 4 in which the percentages were same. Item four which is about asexual reproduction was one of the easy questions for CCI group. The most significant difference was on item 6 with 32% and this item followed by the items 2 and 3 with 29% percentage differences in favor of LCI group. Therefore, it can be said that experimental group students showed higher understanding level about the processes of mitosis and meiosis especially chromosome duplication, separation and the chromosome numbers of the parent and daughter cells. In addition to the percentages of the correct responses, the confidence levels before the implementation were moderate in both groups with close values (34% in CCI groups and 39% in LCI groups). After ten weeks implementation, confidence levels increased in both groups however; this increment was higher in LCI group than CCI group. The mean difference between confidence level percentages on pre and post-CDRDiT was 41% and 32% for LCI and CCI groups respectively. When post-test scores compared, there is 14% difference between the mean confidence level percentages of CCI and LCI groups in favor of LCI. Furthermore, the mean lack of knowledge percentages also provides evidence about the effectiveness of the 5E LC on students' understanding. The mean percentages of the lack of knowledge scores were not significantly different from each other; 57% for CCI and 51% for LCI group before the treatment. After the implementation, the mean percentages of lack of knowledge were decreased in both groups as expected. However, this decrease was higher in LCI group (37%) than CCI group (32%). In addition to the quantitative results, the qualitative results of the present study also provides evidence supporting this findings that LCI group students constructed more meaningful learning than CCI group students according to both their explanations and drawings of the cell division processes. All of these findings supported the results of MANCOVA analysis that the 5E learning cycle instruction is statistically more effective to improve students' understanding on cell division and reproduction concepts than conventional classroom instruction. The results provides further empirical support for the studies reported significant results about the effectiveness of 5E LC instruction over traditional instruction on students' understandings levels in several biology concepts (Balci, Cakiroglu, & Tekkaya, 2006; Bulbul, 2010; Haras, 2009; Kaynar, 2007; Lord, 1999; Musheno, Cowan, & Cavallo, 1994; Musheno & Lawson, 1999; Saka & Akdeniz, 2006; Saygın, Atılboz, & Salman, 2006; Yılmaz, 2010). Bybee stated that "Each phase has a specific function and contributes to the teacher's coherent instruction and the students' formulating a better understanding of scientific and technological knowledge, attitudes, and skills" (2009, p. 4). The effectiveness of LCI may be attributed to nature of inquiry approach that provide opportunities for students to active engagement in investigations, test their hypothesis, collects and analyze the data, and interpret the results. During the implementation in experimental groups, students constructed their understanding of cell division and reproduction concepts by doing activities, sharing their ideas, asking questions and discussing with both their teacher and friends. Rather than present concepts through teacher centered lectures, daily life contexts were put forward within the discussion in order to engage students, after students explore concepts, students were prompted to explained and discuss their understanding of concepts. These efforts in experimental groups might foster conceptual understanding of the students on cell division and reproduction concepts.

Corresponding to the improvements of students' understanding of cell division and reproduction concepts, there is a decrease in their alternative conceptions related to these concepts in both groups. The mean pre-AC scores were 7.21 for the control group and 7.48 for the experimental group before the treatment. When the mean post-AC scores were checked, it is 6.47 for control and 4.84 for the experimental group. Since the lower the AC score, the less alternative conceptions that the students hold, the comparison of the mean post-AC score of the groups showed that the students received 5E learning cycle instruction held less alternative conceptions than the students received conventional classroom instruction. The decrease in CCI groups was very small (0.74) however, it was 2.64 in LCI groups. Furthermore, the follow-up ANCOVA results indicated that there is statistically significant difference between CCI and LCI group students' post-AC scores. Therefore, it can be concluded that 5E learning cycle instruction in cell division and reproduction concepts provides experiences in which students are allowed to confront their alternative conceptions and develop understandings on these concepts and eliminate alternative conceptions. Lawson claimed in his study entitled with “A better way to teach biology” that the correct use of the learning cycle provides students the opportunity to reveal prior conceptions/misconceptions and the opportunity to argue and test them, and thus become "disequilibrated" and develop more adequate conceptions and reasoning patterns to debate and test them (1988, p. 273). In addition to this claim, Bybee, et al. (2006) emphasized that the extended version of three phase learning cycle, 5E instructional model is especially designed to facilitate the progress of conceptual change. The result of the present study is consistent with the studies investigated the effectiveness of LC on alternative conceptions over more traditional instruction and reported that LC instruction is more effective in bringing about conceptual change (Marek, Cowan, & Cavallo, 1994; Saygin, 2009; Stepans et al., 1988). According to Marek, et al. (1994) teaching via the learning cycle is one important way to eliminate alternative conceptions and to help students develop meaningful understandings of the concepts. On the other hand, Balci (2009) emphasized that more traditional approaches in teaching science fail to improve students’ conceptual understanding and leave many alternative conceptions unchanged therefore more student-centered instructional methods than the traditional ones is necessary to overcome alternative conceptions and promote meaningful learning. The interview results of the present study were also consistent with these findings that CCI group students held more alternative conceptions in both their explanations and drawings of the cell division processes than LCI groups. Both groups held still some alternative conceptions even after the implementation, this result might be an evidence to support the claim that the alternative conceptions are very robust and resistant to change (e.g. Novak, 1988; Taber, 2001).

The interviews and drawings of the students help to clarify students’ understanding and identify alternative conceptions. Interview results showed that the alternative conceptions detected with three-tier diagnostic test (CDRDiT) were consistent with those observed during interview sessions. Most of these alternative conceptions related to chromosome structure, numbers, replication, separation of chromosome during cell division processes and fertilization. The results provided evidence to the previous studies identified alternative conceptions on cell division and reproduction concepts (Atılboz, 2004; Banet & Ayuso; Dikmenli, 2010; Kinfield; 1991; Lewis & Wood-Robinson, 2000; Quinn, Pegg, & Panizzon, 2009; Smith, 1991; Stewart, et al., 1990; Yılmaz, 1998). Most of the CCI group students and some of the LCI group students could not support their answers if "why" questions directed, they tend to just memorize the cell division processes happening at the microscobic level without conceptual understanding. They also held some common alterative conceptions even after ten weeks implementation on these subjects. For instance, when researcher directed question "what happens to the parent cell after cell division?" all students in the experimental group (100%) but three students (50%) in the control group answered the question correctly. Two of the rest of the students held a specific alternative conception that "Parent cell remains after cell division". Both of the students insist on their answers and stated that "After cell division, two daughter cells produced and parent cell still exists so, there will be three cells at the end of the process". These students used their prior understanding related to reproduction in which an adult gives birth to an offspring and both parent and offspring exist at the end. This alternative conception might be strengthened by typical textbook diagrams used in which a parental cell is connected by two arrows to two daughter cells so that all three cells appear to be exist (Smith, 1991). In CCI group, the teacher usually used these kinds of representations of mitosis and meiosis to explain these processes. The results of the study supported the idea that the representation/ diagrams of chromosomes play an important role on conceptual understanding on cell processes. Another remarkable finding appeared when the researcher asked students to write the chromosome number of the cells that they were drawn in the beginning and at the end of cell division, although most of them said that the chromosome number will stay same at the end of the mitosis and will be halved in meiosis, four of the six CCI group students and one of the LCI group student confused about the numbers and wrote different chromosome number than they drawn. The CCI group students struggled to count the number of chromosomes since they did not understand the distinction between chromosome and chromatid, did not improve their knowledge via conventional classroom instruction. Smith emphasized the confusion to understand the distinction between chromosome and chromatid is damaging since “telling a student that the chromosome number is halved in meiosis is of no value if the student does not know how to count the chromosomes” (1991, p. 30). According to Yip (1998b), large number of alternative conceptions for certain topics particularly those that are concerned with more complex or abstract phenomena such as cell division caused by ineffective learning or poor teaching in the classroom rather than the the personal experiences of the students. Therefore, conventional instruction might be one of the source of alternative conceptions. In this study, experiments, hands-on activities such as; modelling mitosis, playing with sockosomes (chromosomes from socks) and class discussions in 5E LC instruction enhanced LCI group students’ understanding of both cel division processes and the structure of the chromosomes. These students answered more questions correctly and drew higher level drawings of cell division processes than CCI group students.

Another purpose of this study is to investigate whether the effectiveness of teaching methods differ in terms of gender. In other words, is there any interaction between gender and teaching methods related to students’ achievement, understanding and alternative conceptions. The results of the study revealed that the effectiveness in promoting achievement, understanding and dispelling alternative conceptions of either 5E LC instruction or CCI instruction statistically do not differ across gender. During the implementation, the daily life contexts used for engagement phase such as; cancer, yeasts and bees and the materials used in the activities like playdough, socks, and cheese might not favor neither males nor females. Therefore, it can be concluded that the male and female students would gain the benefits of 5E LC equally. The results consistent with the studies investigated the effectiveness of learning cycle across gender and found no interaction between gender and LC (Bektas, 2011; Bulbul, 2010; Cakiroglu, 2006; Cetin-Dindar, 2012).

When students’ responses to the interview questions related with their reflections on 5E LC investigated all of the students said that they liked this instructional method because it is more enjoyable than conventional classroom instruction. They would prefer 5E LC to CCI if they have a chance to select the method of instruction. The students who preferred the 5E LC over conventional classroom instruction thought that the 5E learning cycle gained their interest more and keep them engaged in activities and the topics that have been studied. In addition to that, 50% of the students claimed that learning cycle instruction had increased their attention, 100% of them said that LC had improved retention of the concepts and 83.3% of them thought that it had promoted their comprehension. The findings are supported with the related literature (Balci, 2009; Billings, 2001; Saygin, 2009). Saygın reported that most of the students in the learning cycle group enjoyed the activities that performed in learning cycle instruction and they learned better with learning cycle. Similary, Billings (2001) collected written responses related to views on learning cycle instruction and found that 75% of the students enjoyed using learning cycle and 66% had a favorable response to learning cycle.

5.2 Internal Validity

'Internal validity refers to the degree to which a research design rules out explanations for a study's findings other than that variables involved appear to be related because they are in fact related' (Slavin, 2007, p. 200). There may be other reasons under the results of the study rather than the manipulated independent variables and these reasons impact the conclusion of the researcher. These reasons obstructed legitimate interpretations are called threats to internal validity. There are some possible *Subject Characteristics* such as; age, gender, intelligence, prior knowledge that might affect the validity of the study. Students in CCI and LCI groups were in the same grades, same age ranges, from the same types of schools. If students' prior knowledge is considered, their pre-CDRAT, pre-CDRDiT and SPST scores were collected and compared. There were no differences found between their achievement and understanding scores on cell division and reproduction concepts before ten weeks implementation period. However, there is a statistical significant difference between CCI and LCI groups in terms of their science process skills in favor of LCI group. Therefore, SPST scores of the students were used as a covariate in multivariate analysis to control the possible effects of student's science process skills on the observed difference in dependent variables.

Mortality that losing subjects is another threat of internal validity; mortality cause decrease in subject number so, it will limits the generalizability of the study. To avoid this threat, the sample of this study was higher than needs to make generalization. Some of the participants were not in their classes during data collection process, the percentages of these missings were calculated and they were below 5 percent. Missing data on pre-test scores were replaced with mean scores however this replace may cause a bias like if those subjects differ from whom the data is obtained. In order to remedy this situation, statistical evidence that missing data is random needs to be found, in other words there should be no difference between students who attend the tests and students who are absent. A dummy variable was created by giving 0 and 1according to presence of the students in pre-tests and their post-test scores were compared whether difference exist among them or not. There were no difference was observed between absent and present students' post-test scores. In addition to these missings in pre-tests, there were also missings in post-tests. Thirteen students who do not have score on any post-tests were removed from the data since replacing these missing values with mean scores is not suitable way for the dependent variables. These actions help to eliminate mortality as an internal validity threat for this study.

Location of the test administration may affect outcome of the study, the particular locations in which data are collected may cause difference in scores of the students. Therefore, the location of the data collection was kept constant for each school by organizing tests in classes that biology lectures are given to CCI and LCI groups regularly. These classes have approximately equal conditions in each school therefore the location is controlled for this study.

There are three important threats of instrumentation; *instrument decay, data collector characteristics* and *data collector bias*. All of them might affect the results of the study and cause invalid interpretations. In instrument decay, scoring procedure change in some way, the person who evaluates the data may lead difference between students. All of the tests; CDRAT, CDRDiT and SPST; consisted of objective type items therefore; the scoring procedure did not contain any bias. However, the evaluation of the data obtained via interviews may contain bias. To avoid that, A PhD. candidate on biology education analyzed the transcripts and the drawings by using rubric besides the researcher and the results were consistent with each other. Data collector characteristic is another threat for the study, all of the data were collected by the researcher under standard procedures with the biology teacher of each class. The *testing* threat occurs in the presence of pre-test, in this study the pre-tests and post-test were same, therefore the students might remember the questions in the pre-test and work for the items that s/he was not able to answer in the pre-test and so, take higher score in the post test. In this study, the treatment conducted for ten weeks so, the time was long enough to get students to forget the questions and distracters. In addition, both CCI and LCI group students might be influenced by testing effect, therefore; it could be concluded that this threat was minimized.

History threat that unplanned events can be in any groups (Fraenkel & Wallen, 2000), this unplanned events might make students to remember the subject that is covering during the events. The observations were done by the researcher for all lessons and by a research assistant majoring science education for 2 weeks of the lessons to obtain accurate data for treatment verification. During these class observations, there is no unplanned events that might affect students' understanding were reported. In addition, using control group design minimizes the history threat since the chance of unplanned event happening is equal in each group.

Maturation is not among the intenal validity threats for this study because, the control group design helps to control maturation threat. If the observed difference between groups takes root from the maturation, the control group students maturated too. The way in that subjects' view about the study and their role in the study can create an attitude of subjects' treat (Fraenkel & Wallen, 2000). The students and/or teachers might have different views. For instance, according to the Hawthorne effect; the students in LCI group may have higher achievement and understanding scores than CCI group because of the novelty effect of teaching method. Hawthorne effect was tried to be controlled by conducting experiments before the intended unit, therefore conducting experiments in biology courses is become less novel. Another one is John Henry effect, the students in CCI might think if the LCI group perform more activities than them, they should study hard and take higher scores than LCI group students. Although, CCI group students did not make any activities performed in the LCI groups, CCI and LCI group students were in interaction during break times and they might hear about the activities in LCI group and receiving no treatment might affect their performance either in negative or positive manner. In order to avoid this effect, CCI group students read the same readings and watched the same videos on grafting and fertilization with the LCI groups. In addition to that, the teachers might be affected from John Henry effect too. They might plan extra activities in CCI group in order to protect his/her method of instruction. Observations helped to control this threat by detecting whether the teacher have John Henry effect or not.

There is no *regression* threat in this study since the regression threat may occur when the subjects of the study were extremely low or high performers (Fraenkel & Wallen, 2000). In this study, the students were not selected on the basis of extremely low or high scores. Both of the schools were Anatolian high school and students' achievement levels were almost same. *Implementation* is not a threat in this study due to the teachers of CCI and LCI groups were same in each school. In other words, there were two teachers and each teacher has two experimental and two control groups. In addition to that, teachers were trained for application of learning cycle, how they should follow lesson plans and use teaching materials. Researcher reminded teachers the important points of lesson plans approximately one hour in every week before the each class session.

5.3 External Validity

External validity means applying results of a study to new settings, people, or samples (Frankel & Wallen, 2000). The results of the present study revealed that there are statistically significant mean differences between LCI and CCI groups on dependent variables of post-CDRDiT and post-AC scores after adjusting for pre-existing difference in students' science process skills in favor of 5E learning cycle instruction group. The number of the subject in this study was 241 and it corresponds to approximately 12% of the accessible population. Even the sample size is large; it does not guarantee the representativeness of the intended population. However, there were five Anatolian high schools in the district and two of them were selected in the study. Therefore, the findings of this present study might only be generalized to the students from Anatolian high schools in the accessible population of the study. Similar study can be conducted in general high schools or different kind of schools.

5.4 Implications

The following suggestions can be done according to the findings of this study:

- 5E Learning cycle instruction should be used to improve students' conceptual understanding of cell division and reproduction concepts rather than conventional classroom instruction. Therefore, the results of this dissertation may contribute to Turkish National Biology education by integrating 5E learning cycle model to the curiculum. The developed lesson plans and findings might serve as sample chapter for teachers, textbook writers, curriculum developers and also researchers for designing biology courses.

- 5E LC is found more effective than conventional classroom instruction on preventing alternative conceptions. In addition, 5E LC seems to have potential to eliminate alternative conceptions. Teachers should be used 5E LC to avoid alternative conceptions.

- Pre-test results indicated that students held alternative conceptions on cell division and reproduction concepts and their understanding levels are very low. Therefore, learners' pre-conceptions as well as their pre-alternative conceptions should be considered before the instruction period.

- Most of the students have difficulties in understanding chromosome numbers and movements during each phase of cell division either mitosis or meiosis therefore, teachers should emphasize these concepts, detect alternative conceptions and discuss them with students.

- Three-tier diagnostic tests should be used to measure students' conceptual understanding and to identify alternative conceptions. The developed three-tier test might be used for cell division and reproduction unit.

- The representation of abstract concepts of the cell in textbooks needs to be improved according to students' detected alternative conceptions.

5.5 Recommendations for Further Study

- The effectiveness of 5E learning cycle instruction can also be investigated with different biology topics.

- The effectiveness of 5E learning cycle instruction on affective domain such as; students' attitudes and motivation; can also be investigated.

- The effectiveness of 5E learning cycle instruction on the durability of the related concepts should be investigated by collecting data with retention tests.

- Further study can be conducted to explore the effect of 5E learning cycle model on scientific literacy.

- 5E Learning cycle instruction can be implemented to different type of schools and grade levels in order to increase the generalization of the current study.

- The way in that teachers' view about the 5E learning cycle model and their motivation to use the model in their classes should be investigated.

- The effectiveness of learning cycle instruction on teacher/pre-service teacher training in several biology concepts by organizing courses, short-term workshops or online activities.

- Three-tier diagnostic test can be administered to biology teacher to identify their alternative conceptions on cell division and reproduction concepts.

- Three-tier diagnostic tests on different biology concepts should be developed.

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APPENDIX A

OBJECTIVES OF THE UNIT

1. Related to mitosis, the students will;

    1.1 Explain phases of mitosis in schema.
    1.2 Compare mitosis in plant and animal cells.
    1.3 Explain the importance of mitosis for single-cell and multi cellular organisms.
    1.4 Explain the control of the mitosis and the importance of it for living beings.

2. Related to asexual reproduction, the students will;

    2.1 Explain the types of asexual reproduction by giving examples.
    2.2 Explain the importance of asexual reproduction in agricultural production.

3. Related to meiosis, the students will;

    3.1 Explain sexual reproduction in single-cell organisms by giving examples.
    3.2 Explain main phases of meiosis in schema.
    3.3 Explain the importance of meiosis in sexual reproduction.
    3.4 Explain oogenesisi and spermatogenesis in schema.
    3.5 Explain the events happened in fertilization.
    3.6 Explain parthenogenesis by giving examples.

APPENDIX B

TABLE OF SPECIFICATION

Table B.1 Table of specification for Cell Division and Reproduction Achievement Test (CDRAT)

Objectives / Content	Knowledge	Comprehension	Application	Analysis	Total	%
Cell Cycle	1 (10)			1 (9)	2	5,7
Mitotic Division	3 (1,3,7)	5 (2,4,5,8,13)			8	22,9
Asexual Reproduction		3 (15,16,18)	3 (11,12,14)		6	17,1
Meiotic Division	1 (34)	3 (22,23,33)			4	11,4
Sexual Reproduction	2 (19,21)	4 (27,31,32,35)		1 (20)	7	20,0
Spermatogenesis and Oogenesis		3 (24,25,29)			3	8,5
Comparison of mitosis and meiosis		2 (6,17)			2	5,7
Fertilization	1 (30)	2 (26,28)			3	8,5
Total	8	22	3	2	35	100
Percentage	22,9 %	62,9 %	8,5 %	5,7 %		

APPENDIX C

CELL DIVISION AND REPRODUCTION ACHIEVEMENT TEST

I.Ad- Soyad:__________
II. Sınıf: _____
III. Cinsiyet: □ Kız □ Erkek
IV. Doğum yılı: ______
V. Annenizin mesleği ________________
VI. Annenizin Eğitim Durumu
□ Hiç okula gitmemiş □ İlkokul □ Ortaokul
□ Lise □Üniversite □ Yüksek lisans
VII. Babanızın mesleği_________________
VIII. Babanızın Eğitim Durumu:
□ Hiç okula gitmemiş □ İlkokul □ Ortaokul
□ Lise □Üniversite □ Yüksek lisans

1. Şekilde verilen mitoz evresinde gerçekleşen olaylar yanda maddeler halinde verilmiştir.

- Çekirdek zarı ve endoplazmik retikulum zarı erir.
- Kromozomlar kısalır ve kalınlaşır.
- Sentrozomlar zıt kutuplara hareket eder.
- Kutuplardan merkeze iğ iplikleri oluşur

Bu evre aşağıdakilerden hangisidir?

a) Profaz b) Metafaz c) Sitokinez d) Interfaz e) Anafaz

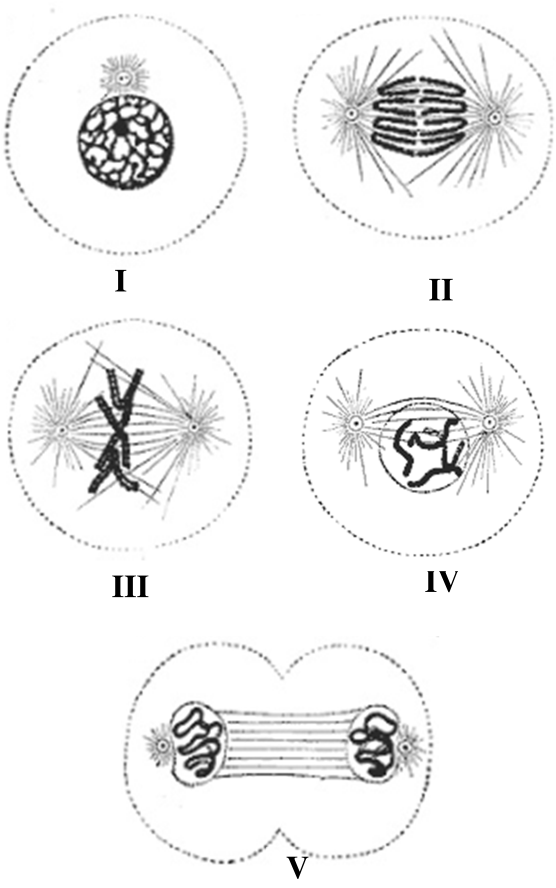
2. Mitoz bölünme ile ilgili aşağıdakilerden hangisi <u>hem bitki hem de hayvan</u> hücresinde gözlemlenir?

a) Sentriollerin eşlenmesi
b) Sitoplazmanın boğumlanarak bölünmesi
c) Sitoplazmanın orta lamel oluşumu ile bölünmesi
d) İğ ipliklerinin bir organel tarafından oluşturulması
e) Kinetekorların iğ ipliklerine tutulması

3. Tek hücreli canlılarda hangisi mitoz sayesinde gerçekleşir?

a) Çoğalma
b) Büyüme
c) Gelişme
d) İyileşme
e) Çeşitlilik

4.



Bir biyoloji öğretmeni mitoz bölünme evrelerine ait hazır preperatları 5 ayrı mikroskoba (I, II, III, IV, V) yukarıda şematize edildiği şekilde yerleştirir. Öğrencilerinden bu evreleri isimlendirmelerini istediğinde aşağıdaki cevaplardan hangisini beklemektedir?

	I	II	III	IV	V
a)	Metafaz	Telofaz	Profaz	Anafaz	İnterfaz
b)	İnterfaz	Profaz	Anafaz	Metafaz	Telofaz
c)	Profaz	Telofaz	Anafaz	Profaz	İnterfaz
d)	**İnterfaz**	**Anafaz**	**Metafaz**	**Profaz**	**Telofaz**
e)	Metafaz	Anafaz	Profaz	Telofaz	İnterfaz

5. Aşağıda verilenlerden hangileri, mitoz bölünme geçiren tüm canlılarda ortak değildir?

a) Kromozom sayısının sabit kalması
b) İğ ipliklerinin sentriollerden oluşumu
c) Bir hücreden iki hücre oluşumu
d) DNA'nın kendini eşlemesi
e) Çekirdek zarının erimesi

6. Çağdaş, okulda canlıların büyümesi için mitoz bölünme geçirmesi gerektiğini öğrendiğinde "ama köpeğim ile çiçeğimin hücrelerinin bölünmesinde farklar olması lazım" diye düşünür. Hem ortak noktaları, hem de farkları listelemeye karar verir. Aşağıdakilerden hangisi Çağdaş'ın listesinde olabilir?

	Ortak olanlar	Farklı olanlar
a)	DNA'nın kendini eşlemesi	Kinetokorların iğ ipliklerine tutunması
b)	**İğ ipliklerinin oluşması**	**Sitoplazmanın boğumlanarak bölünmesi**
c)	Çekirdek zarının erimesi	İğ ipliklerinin oluşması
d)	Sentrozomun kendisi eşleme sayısı	Kromatidlerin kutuplara çekilmesi
e)	Ara lamel oluşumu	Sentriollerin eşlenmesi

7. Aşağıdakilerden hangisi insan vücudunda mitoz bölünme ile olmaz?

a) Yıpranan organların tamir edilmesi.
b) Üst derinin sürekli yenilenmesi.
c) Kanserli dokuların büyümesi.
d) Kırılan bir kemiğin onarılması.
e) Sperm hücrelerinin oluşumu

8. Arda, odasına giren kertenkeleyi yakalayıp atmak isterken kuyruğunun koptuğunu fark eder. Günler sonra kertenkeleyi tekrar gördüğünde kuyruğu yerindedir. İkisinin aynı kertenkele olmadığına karar verir, daha sonra durumu biyoloji öğretmenine anlatır. Öğretmeni muhtemelen kertenkelenin kopan kuyruğunu yenilendiğini ve bu süreçte gerçekleşen olayları anlatır. Öğretmen aşağıdakilerden hangisinden bahsetmiş olamaz?

a) Kromozomların ekvator bölgesine yerleşmesi
b) Çekirdek zarının erimesi
c) Homolog kromozomların zıt kutuplara çekilmesi
d) İğ ipliklerinin kaybolması
e) DNA nın eşlenmesi

9. Mitoz sırasında hücre döngüsü G1, G2 ve M kontrol noktalarında denetlenir ve bir sorun tespit edildiğinde dur sinyali ile mitoz bölünme durdurulur. Bu mekanizmanın bozulması aşağıdakilerden hangisine sebep olamaz?

a) Kanserli dokuların gelişmesi.
b) DNA hasarlı hücrelerin çoğalması.
c) Down sendromu görülmesi.
d) Anormal hücre sayısında artış.
e) Kontolsüz hücre bölünmesi.

10. Kanser hücreleriyle ilgili olarak verilenlerden hangileri doğru değildir?

a) Komşu hücrelerle olan bağlantıları kesilir ve yığılma gösterirler.
b) Doku kültüründe üretildiklerinde 20-50 defa bölünürler.
c) Hücre döngüsünü düzenleyen sinyallere cevap vermezler.
d) Ne zaman bölüneceğini bilme yeteneklerini kaybetmişlerdir.
e) Kan veya lenf yoluna girerek tüm vücuda yayılabilirler.

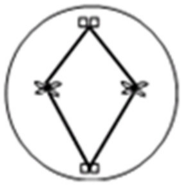
11. Ömer çiftçi olan babasının bazı ağaçların dallarını kestikten sonra aynı tür başka ağaçlardan aldığı dalları kesilen yere eklediğini ve bir bez ile sıkıca sardığını pekçok defa görmüş hatta ona yardım etmiştir. Ancak okulda üreme konusu anlatıldığında babasının ne yaptığını (I) ve amacını (II) anlar. Aşağıdakilerden şıklardan hangisi I ve II'yi içermektedir?

	I	II
a)	**Aşılama**	**Kaliteli ürün üretmek**
b)	Vejetatif üreme	Kestiği ağacın genetik yapısını korumak
c)	Daldırma	Bitkiyi hastalıklardan korumak
d)	Sürünücü gövde	Bitkiyi geniş bir alana yaymak
e)	Eşeyli üreme	Yeni özellikte bitki elde etmek

12. Tohum oluşturabilen bir bitkinin bir dalı kesilerek toprağa dikiliyor. Bu daldan yeni bir bitki oluştuğu gözleniyor. Ata bitki ile yavru bitkide aşağıda sıralanan özelliklerden hangisi kesinlikle aynıdır?

a) Oluşturacakları polenlerdeki DNA dizilişi.
b) Verecekleri meyvelerin büyüklüğü.
c) Sitoplazmalarındaki organel sayısı
d) Yapraklarındaki DNA dizilişi.
e) Birim zamanda bir daldaki uzama miktarı

13. Mitoz bölünmenin bir evresi yandaki şekilde gösterilen hücre ile ilgili aşağıdakilerden hangisi <u>söylenemez</u>?



a) Bölünme tamamlandığında oluşan hücreler iki kromozomludur.

b) Bölünmenin metafaz evresindedir.

c) Bir sonraki evrede iğ iplikleri kısalarak kardeş kromatidler birbirinden ayrılır.

d) Hücrenin toplam 4 kromozomu vardır.

e) Sitoplazma bölünmesi boğumlanarak gerçekleşir.

14. Selin ve annesi bir arkadaşına oturmaya gittiklerinde kırmızı-pembe iki renkli çiçek açan menekşeleri gören annesi arkadaşının annesinden bir yaprak ister. Eve döndüklerinde yaprağın sapını suya koyar, birkaç gün sonra saptan kökler çıkmaya başladığını gören Selin, bu durumun nasıl gerçekleştiğini merak eder ve internette bir araştırma yapmak ister. Selinin bu olayı anlaması için aşağıdakilerden hangisini arama motoruna yazması gerekir?

a) Tomurcuklanma

b) Rejenerasyon

c) Sporla üreme

d) Vejetatif üreme

e) İkiye Bölünme

15. Aşağıdaki olaylardan hangisi eşeysiz üreme örneği değildir?

a) Kertenkelenin kopan kuyruğunun aynı şekilde yenilenmesi.

b) Planaryanın ikiye bölünmesiyle her parçadan yeni bir planarya oluşması.

c) Çileğin sürünücü gövdesindeki göz adı verilen bölgelerden yeni bitkiler oluşması.

d) Plazmodyumun merozitlerinin insan alyuvarlarında çoğalması.

e) Maya mantarında dışarı doğru oluşan çıkıntıdan yeni birey oluşması.

16. Aşağıdakilerden hangisi vejetatif üreme örneğidir?

a) Planaryada kopan bir parçanın kendisini tamamlası ile yeni birey oluşması
b) Muz bitkisinin dalından alınan bir parçanın köklendirilip ekilmesi ile yeni birey oluşması
c) Mantar sporlarının çimlenmesiyle yeni mantarların oluşması
d) Kamçı kuyruklu kertenkelede yumurtanın döllenmeden gelişerek yeni bir bireyi oluşturması
e) Bira mayasında oluşan tomurcukların ana vücuttan kopması ile yeni bireylerin oluşması

17. Diploit kromozomlu bir hücrenin bölünmesi sırasında olan olaylardan aşağıda verilenlerden hangisi bölünmenin mitoz veya mayoz olduğu hakkında fikir <u>vermez</u>?

a) Çekirdek zarının eriyerek kaybolması
b) Homolog kromozomları birbirinden ayrılması
c) Kromozomların dörder kromatitli tetratlar oluşturması
d) Sitoplazma bölünmesi sonucu haploit kromozomlu hücreler oluşması
e) Kromatitlerin niteliğinin krossing overla değişmesi

18. Bazı bitkilerde toprağa yakın yerden çıkan dalın bükülerek yere değen kısmının toprakla örtülmesi ve ucunun toprağın dışına çıkarılması ile yeni bitki üretilebilir. Bu yöntemle ilgili aşağıdakilerden hangisi <u>söylenemez</u>?

a) Bitkilerde eşeysiz üreme örneğidir.
b) Ana bitki ile aynı özellikte bitki elde edilir.
c) Vejetatif üreme olarak adlandırılır.
d) Temeli mitoz bölünmeye dayanır.
e) Tomurcuklanma ile üreme olmuştur

19. Aşağıdakilerden hangisi sıtma etkeni olan plazmodyum isimli tek hücrelinin üremesi ile ilgili doğru bir ifade değildir?

a) Merozoitler bölünerek gametositleri oluşturur.
b) Zigot mayoz geçirerek sporozoitleri oluşturur.
c) Sivrisineğin ısırmasıyla insana geçen sporozoitler karaciğerde çoğalır.
d) Gametositler insan alyuvarında döllenir.
e) Sporozoitlerin bölünmesiyle merozoitler oluşur.

20. Selim ateşlenip, titremeye başladığında doktor sıtma teşhisi koyar. Sıtma hastalığını duymamış olduğundan biyolog olan annesine sorar. Annesi sıtmaya neden olan plazmodyum isimli canlıyı ve hayat döngüsünü anlatır. Selimin anlatılanları doğru anladığı varsayılırsa aşağıdakilerden hangisi / hangilerinin vücudunda gerçekleştiğini düşünmemelidir?

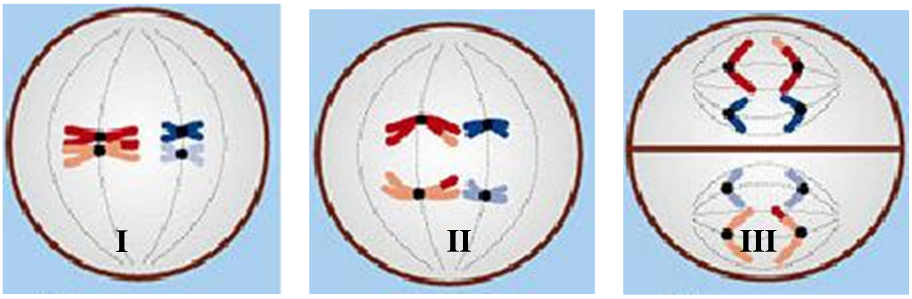
I. Zigot oluşması
II. Merozoitlerin meydana gelmesi
III. Gametositlerin meydana gelmesi

a) Yalnız I b)I ve II c)I ve III d)Yalnız III **e)II ve III**

21. Aşağıdaki üreme çeşitlerinden hangisi kalıtsal çeşitliliğe neden olur?

a) Tomurcuklanma
b) Rejenerasyon
c) Vejetatif Üreme
d) Konjugasyon
e) İkiye bölünme

22. Hücre bölünmesi konusunu anlatmak için hazırlık yapan Pelin öğretmen, laboratuvarda mayoz bölünme evrelerinin hazır preparatlarını bulduğunda çok sevinir. Ancak yıllardır kullanılan preparatların etiketleri sökülmüş, sıralamaları karışmıştır. Yeniden etiketlemek ve düzenlemek amacıyla öncelikle aşağıda şematize edilen 3 tanesini inceler.



Bu preparatların etiketlerini nasıl yapıştırması gerekir?

	I	II	III
a)	Mayoz II- Metafaz	Mayoz II- Anafaz	Mayoz II- Telofaz
b)	Mayoz I- Anafaz	Mayoz II- Metafaz	Mayoz I- Sitokinez
c)	Mayoz I - Profaz	Mayoz I – Anafaz	Mayoz I- Telofaz
d)	**Mayoz I – Metafaz**	**Mayoz I- Anafaz**	**Mayoz II- Anafaz**
e)	Mayoz I –Telofaz	Mayoz II- Anafaz	Mayoz I- Anafaz

23. Cinayet masası dedektifi Başkomiser Özgür ve ekibi, bir seri katili yakalamaya çalışmaktadır. Son cinayet mahallinde bulunan katile ait saç telinin DNA analizi sonucunda katilin 44 XYY kromozom takımına sahip olduğu ortaya çıkar. Başkomiser Özgür bu garipliği anlamak için analizi yapan adli biyoloğa sorar. Biyolog katilin 44 XYY kromozomlu olmasını anlatabilmek için mayoz bölünmeden bahseder. Mayoz ile ilgili aşağıdakilerden hangisinden söylemiş <u>olamaz</u>?

a) Başlangıçtaki kromozom sayısının yarıya inmesi

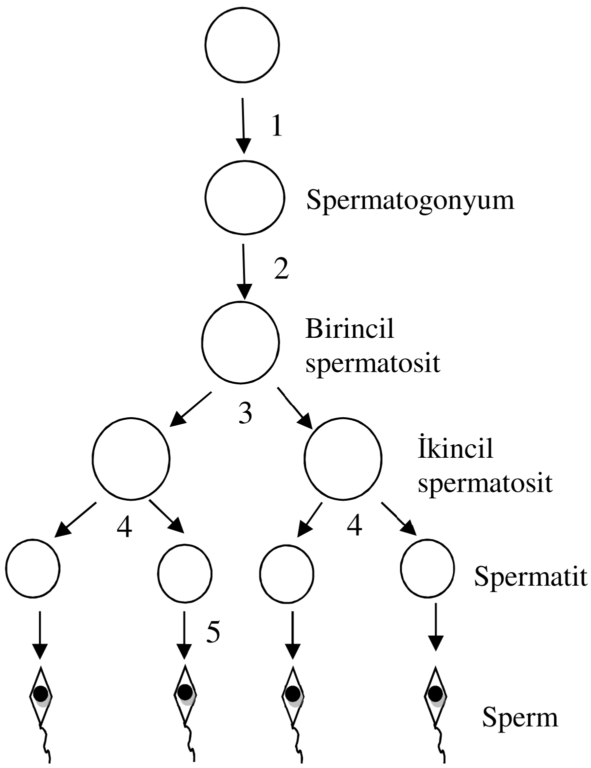
b) Kromatidler arasında parça değişiminin olması

c) Kardeş kromatidlerin zıt kutuplara doğru çekilmesi

d) Homolog kromozomların birbirinden ayrılması

e) Oluşan hücrelerin aynı genetik yapıya sahip olması

24. Aşağıda spermatogenez olayı şematize edilmiştir. Numaralandırılmış olaylardan krosing overın (I) gerçekleşebileceği ve farklılaşmanın olacağı (II) evreler aşağıdaki seçeneklerden hangisinde birarada verilmiştir?



	I	II
a)	1	2
b)	2	3
c)	1	4
d)	2	4
e)	**3**	**5**

25. Aşağıdakilerden hangisi spermatogenez ile oogenez arasındaki temel farkı açıklamaktadır?

a) Yumurta hücresi haploit ancak olgun sperm diploit yapıdadır.

b) Spermatogenez sonunda oogenezden 2 hücre fazla oluşur.

c) Oogenezde bir tane yumurta, spermatogenezde 4 tane olgun sperm oluşur.

d) Oogenezde kromozom sayısı iki katına çıkarken spermatogenezde kromozom eşlenmesi olmaz.

e) Olgun sperm haploitken olgun yumurta diploittir

26. Nilgün ile Mert çocuk sahibi olamadıkları için doktora basvurur. Yumurta ve sperm örneklerinin incelenmesi ile spermlerde hareket yeteneğinin olmadığı tespit edilir. Bu kavramlara yabancı olan çift, doktorun anlattıklarını tam olarak anlayabilmek amacıyla internetten döllenmede gerçekleşen aşağıdaki olayları okurlar. Bu olayların oluş sırası ile hangi seçenekteki gibi okumuş olmalıdırlar?

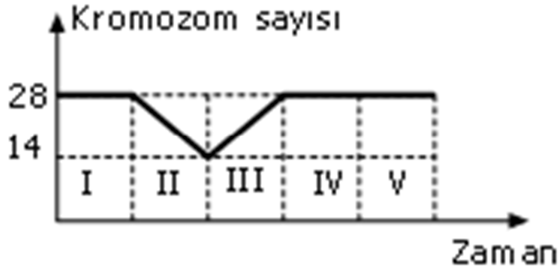
I. Spermlerin yumurtaya doğru hareket etmesi.
II. Spermin akrozomundaki enzimlerin yumurta zarını eritmesi.
III. Spermin yumurtaya tutunması.
IV. Yumurtanın kimyasal bir madde salgılaması.
V. Sperm ve yumurtanın haploit çekirdeklerinin kaynaşması.

a) I, III, V, II, IV.
b) II, III, IV, V, I.
c) IV, I, III, II, V.
d) III, II, I, IV, V.
e) IV, III, II,V, I.

27. Aşağıdakilerden hangisi aynı anne ve babadan doğan kardeşler arasında ortaya çıkan kalıtsal çeşitliliğin nedenleri ile ilgili olarak doğru bilgidir?

a) Ana-babadan çocuğa geçen kromozom sayısının farklı olması
b) Hücrelerinin mitoz bölünme hızlarının farklı olması
c) Hücrelerin sitoplazma miktarlarının farklı olması
d) Mayozda kardeş olmayan kromatidler arasında parça değişimi
e) Farklı besinler ile beslendikleri için büyüme ve gelişmelerinin farklı olması

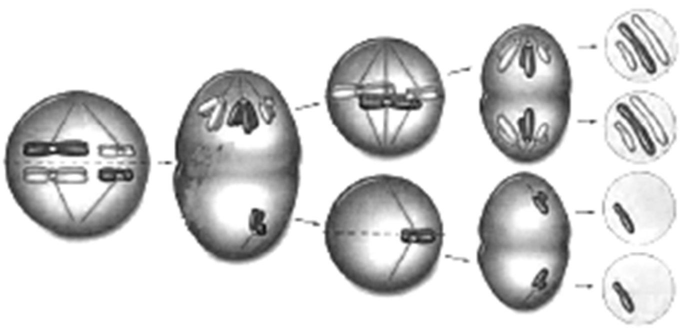
28.



Kromozom sayısı değişimi yukarıda verilen grafikteki gibi olan 2N = 28 kromozomlu memeli hücresi hangi zaman aralığında döllenmiş olabilir?

a) I b) II **c) III** d) IV e) V

29. Doktoru Nevraya hamileliğinin 11. haftasında yapılan test sonucunda bebeğinde kromozom anomalisi olabileceğini ve kesin tanı için yeni bir test daha yapılması gerektiğini söyler. Endişelenen Nevra biyoloji dersinden kromozomlarda ayrılmama olduğunu hatırlar ve bilgi ararken güvenilir bir internet sitesinde spermatogeneze ait aşağıdaki şemayı bulur.



Şemaya göre ayrılmama hangi evrede olmuştur?

a) Metafaz I

b) Anafaz I

c) Metafaz II

d) Profaz II

e) Telofaz I

30. Aşağıda verilenlerden hangisi iç döllenme ile ilgili yanlış bir ifadedir?

a) Sperm ve yumurtanın canlı vücudunda birleşmesiyle gerçekleşir.
b) Sadece karada yaşayan canlılarda görülür.
c) Gametler dış çevrenin zararlı etkilerinden korunur.
d) Omurgalı ve omurgasız hayvanlarda görülebilir.
e) Spermlerin aktarılması için çiftleşme organına ihtiyaç vardır.

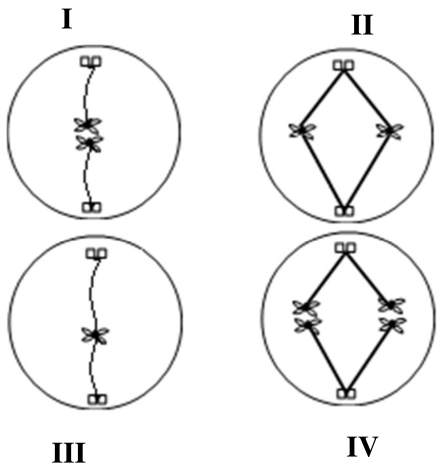
31. Bal arılarında partenogenez ile ilgili olarak verilenlerden hangisi doğrudur?

a) Dişi ve erkek gametler mitoz bölünmelerle oluşur.
b) İşçi ve kraliçe arı oluşumu kalıtsal farklılıklara bağlıdır.
c) Bir dölde oluşan tüm erkek arıların kalıtsal yapısı aynıdır.
d) Erkek arılar homolog kromozom çiftleri bulundurmaz.
e) Tüm dişi arılar yumurta oluşturur.

32. Doğaya meraklı Mehmetali televizyon seyrederken bal arıları ile ilgili bir belgesel dikkatini çeker. Belgeselde bir bal arısı kovanında kraliçe arı, işçi arılar ve erkek arıların yeraldığını ve bunların farklı genetik yapılarda olduklarını öğrenir. Sizce belgeselin devamında bu bireylerin oluşumlarında genetik katkı sağlayan birey/ bireyler aşağıdakilerden hangisindeki gibi verilmiştir?

	Kraliçe arı	İşçi arı	Erkek arı
a)	İşçi arı ve Erkek arı	İşçi arı ve Erkek arı	İşçi arı
b)	**Kraliçe arı ve Erkek arı**	**Kraliçe arı ve Erkek arı**	**Kraliçe arı**
c)	Kraliçe arı	Kraliçe arı	Kraliçe arı
d)	Kraliçe arı ve Erkek arı	İşçi arı ve Erkek arı	Kraliçe arı ve Erkek arı
e)	Kraliçe arı ve Erkek arı	Kraliçe arı ve Erkek arı	İşçi arı ve Erkek arı

33. Aşağıda verilen bölünme şekillerinden hangisi ya da hangileri 2n= 2 kromozomlu bir hücrenin mayoz bölünmesine ait olamaz?



a) Yalnız I b) Yalnız II c)I ve III **d) II ve IV** e) I, II ve IV

34. Aşağıdaki mayoz bölünme evrelerinin hangisinde herbir kromozom iki kromatidli olarak gözlemlenmez?

a) Profaz I
b) Metafaz I
c) Telofaz II
d) Metafaz II
e) Telofaz I

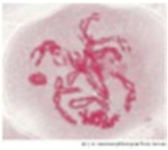
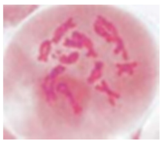
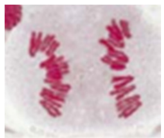
35. Eşeyli üreyen canlılarda gametlerin mayoz bölünme ile oluşması ile ilgili olarak aşağıdakilerden hangisi doğru bir ifadedir?

a) Türün kromozom sayısını sabit tutmayı sağlar.
b) Gametlerin döllenme şansını arttırır.
c) Bireylerin çeşitliliğini etkilemez.
d) Gametlerin DNA ağırlığının farklı olmasını sağlar.
e) Gametlerin kromozom sayısının ana hücrelere eşit olmasını sağlar.

APPENDIX D

CELL DIVISION AND REPRODUCTION DIAGNOSTIC TEST

1.1.

X Hücresi-Profaz Y Hücresi-Profaz Z Hücresi-Anafaz

Yukarıda aynı canlıya ait üç ayrı hücrenin mitoz safhaları görülmektedir. Bu hücrelerin her üçündeki kromozomal DNA miktarı aynıdır.

a) Doğru **b)** Yanlış

1.2. Çünkü

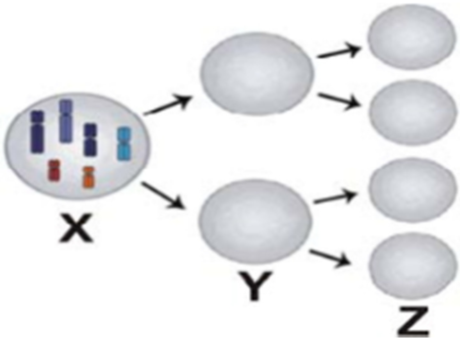
a) Bir hücredeki kromozomal DNA miktarı interfazda iki katına çıkar ve mitoz bölünme sonuna kadar bu miktar sabit kalır.
b) Mitoz bölünmede farklı safhalardaki kromozomal DNA miktarı da farklıdır.
c) Bir hücredeki kromozomal DNA miktarı profaz safhasının sonuna doğru iki katına çıkar ve mitoz bölünme sonuna kadar bu miktarı değişmez.
d) Bir hücredeki kromozomal DNA miktarı interfazda iki katına çıkar ve anafazda yarıya iner.
e) Mitotik hücre döngüsünde kromozomal DNA miktarı hiçbir safhada değişmez.
f) ____.

1.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

2.1.

Şekil 1



Şekil 2

Şekil 1'de 2n = 6 diploid kromozom sayısına sahip bir organizmanın eşey ana hücresi olan X hücresi görülmekte olup bu hücre mayoz bölünme geçirmektedir. Bu bölünme sonucu oluşan Z hücresi ise Şekil 2'deki gibidir.

a) Doğru **b) Yanlış**

2.2. Çünkü

- **a)** Mayoz bölünmede kromozom sayısı değişmeden kalır.
- **b)** Mayoz bölünmede hem homolog kromozomlar hem de kardeş kromatitler ayrılır ve kromozom sayısı iki defa yarıya iner.
- **c) Mayoz bölünmede önce homolog kromozomlar sonrada kardeş kromatitler ayrılarak kromozom sayısı yarıya inmiş olur.**
- **d)** Mayoz bölünmenin birinci aşamasında homolog kromozomlar ayrılır ve ikinci aşamada bu kromozomlar aynen yeni hücrelere aktarılırlar.
- **e)** Mayoz bölünmenin birinci aşamasında kromozom sayısı sabit kalır, ikici aşamada bu sayı yarıya iner.
- **f)** Mayoz bölünme sonucunda oluşan hücreler diploid (2n) kromozom takımına sahiptirler.
- **g)** __________________.

2.3. Yukarıdaki iki soruya verdiğim cevaptan,

- **a)** Eminim.
- **b)** Emin değilim.

3.1. Bir insanın kemik iliği hücresi mitoz bölünme geçirmektedir. Bu hücrenin anafaz safhasında sahip olduğu kromozom sayısı 92'dir.

a) **Doğru** **b)** Yanlış

3.2. Çünkü

a) Mitoz bölünmenin bütün safhalarında kromozom sayısı sabittir ve ana hücrenin kromozom sayısı ile aynıdır.
b) Kromozom sayısı mitoz bölünmenin anafaz safhasında yarıya iner.
c) **Anafazda kardeş kromatitler ayrılır ve her bir kromatit artık bir kromozom sayılır.**
d) Kromozom sayısı interfazda iki katına çıkar ve bu sayı mitozun bütün safhalarında korunur.
e) Anafazdan önce kromozom sayısı iki katına çıkar ancak anafazda sitoplazma bölünmesiyle beraber bu sayı yarıya iner.
f) ____.

3.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

4.1. **I-** Amip **II-** Planaria

Yukarıdaki organizmalardan her ikisi de mitoz bölünme ile çoğalabilir

a) **Doğru** **b)** Yanlış

4.2. Çünkü

a) Yalnızca tek hücreli canlılar mitozla çoğalırlar.
b) Tek hücreli ve çok hücreli canlılardan rejenerasyon yeteneğine sahip olanların tamamı mitoz bölünme ile çoğalırlar.
c) **Her iki bireyde de eşeysiz üreme görülür ve eşeysiz üremede mitoz bölünme rol alır.**
d) ____.

4.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.

b) Emin değilim.

5.1. Interfaz evresindeki bir hücrede sentrioller,

a) Çekirdekte bulunur **b) Sitoplazmada bulunur**

5.2. Çünkü

a) Sentrioller sentrozomu oluşturan yapılardır ve sentrozom daima sitoplazmada bulunur.

b) Mitoz bölünme hücrenin çekirdeğinde gerçekleşir ve sentrioller de çekirdekte bulunur.

c) Sentrioller interfaz evresinde çekirdekte bulunurlar ancak bölünme sırasında çekirdek zarının erimesiyle sitoplazmaya geçerler.

d) Sentrioller çekirdekte bulunurlar ve iğ ipliklerini oluşturmaya başlayınca sitoplazmaya geçip hücrenin zıt kutuplarına giderler.

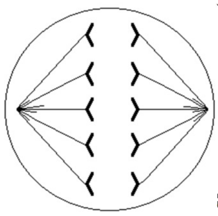
e) ____.

5.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.

b) Emin değilim.

6.1.



Yanda diploid kromozom sayısı 2n = 10 olan bir organizmaya ait hücre görülmektedir. Bu hücre mitoz bölünmenin anafaz safhasını temsil etmektedir.

a) Doğru **b) Yanlış**

6.2. Çünkü

a) Mitoz bölünmenin anafaz evresinde kardeş kromatitler karşılıklı kutuplara çekilirler ve sonuçta 10 kromozomlu hücreler oluşur.

b) **II. Mayozun anafaz evresinde kardeş kromatitler karşılıklı kutuplara çekilirler ve sonuçta 5 kromozomlu hücreler oluşur.**

c) Kardeş kromatitler mitozun anafazında ayrılırlar ve sonuçta 5 kromozomlu hücreler oluşur.

d) Kardeş kromatitler mitoz bölünmede değil, mayoz bölünmede ayrılırlar.

e) Homolog kromozomlar I.Mayozun anafazında ayrılırlar ve sonuçta 5 kromozomlu hücreler oluşur.

f) ____.

6.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

7.1. Diploid kromozom sayısı 2n = 6 olan bir hayvansal hücre mitoz bölünme geçirmektedir. Bu hücrenin profaz safhasındaki kromozom sayısı 12'dir.

a) Doğru **b) Yanlış**

7.2. Çünkü

a) İnterfazda DNA eşlenir, kromozom sayısı iki katına çıkar ve profazda da bu sayı aynıdır.

b) Profazda DNA eşlenir ve dolayısıyla kromozom sayısı da iki katına çıkar.

c) Profaz mitoz bölünmenin dinlenme ve hazırlık evresidir ve kromozom sayısı henüz iki katına çıkmamıştır.

d) **Profazda kardeş kromatitler henüz ayrılmamıştır ve kromozom sayısı ana hücrenin kromozom sayısı ile aynıdır.**

e) Bir hücredeki kromozom sayısı mitoz bölünmenin bütün safhalarında aynıdır.

f) ____.

7.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

8.1. Kromozom sayısı 2n = 4 olan yandaki hücre,

a) Mayoz bölünme geçirmektedir

b) Mitoz bölünme geçirmektedir

8.2. Çünkü

a) Bu hücrede homolog kromozomlar karşılıklı kutuplara çekilmektedir ve homolog kromozomlar mitozda ayrılırlar.

b) Bu hücrede homolog kromozomlar karşılıklı kutuplara çekilmektedir ve homolog kromozomlar mayozda ayrılırlar.

c) Bu hücrede kardeş kromatitler karşılıklı kutuplara çekilmektedir ve kardeş kromatitler sadece mayoz bölünmede ayrılırlar.

d) Bu hücrede kardeş kromatitler karşılıklı kutuplara çekilmektedir ve kardeş kromatitler sadece mitoz bölünmede ayrılırlar.

e) ____.

8.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.

b) Emin değilim.

9.1. **I-** Golgi aygıtı **II-** Mitokondri

Mitoz bölünme geçirmekte olan bir insan deri hücresinde metafaz safhasında, yukarıdaki organellerden her ikisi de tamamen gözlenebilir.

a) Doğru **b) Yanlış**

9.2. Çünkü

a) Mitoz bölünme sırasında bütün organeller eriyerek kaybolur.

b) Mitoz bölünme sırasında gerekli enerji sitoplazmadaki glikoliz reaksiyonları sonucu elde edilir ancak protein ihtiyacı devam ettiği için yalnızca golgi varlığını bölünme boyunca sürdürür.

c) Bölünme sırasında bütün zarlı organeller eriyerek kaybolur ancak enerji ihtiyacı devam ettiğinden dolayı yalnızca mitokondri sürekli gözlenebilir.

d) Bölünme sırasında iğ ipliklerinin oluşumunda golgiye ihtiyaç olduğundan dolayı yalnızca bu organel sürekli olarak gözlenebilir.

e) Devam eden protein gereksinimi için golgiye, bölünme sırasında gerekli olan enerjiyi karşılamak için de mitokondriye ihtiyaç vardır.

f) Bölünme için gerekli bütün maddeler ve enerji interfazda hazırlanır ve bölünme sırasında herhangi bir organele ihtiyaç duyulmaz.

g) ____.

9.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.

b) Emin değilim.

10.1. **X.** Soğan Kök Hücresi **Y.** İnsan Deri Hücresi

I ve II hücrelerinin mitoz bölünmeleri sırasında,

a) Sadece X hücresinde iğ iplikleri oluşur.

b) Sadece Y hücresinde iğ iplikleri oluşur.

c) Hem X hem de Y hücrelerinde iğ iplikleri oluşur.

10.2. Çünkü

- **a)** İğ ipliklerini sentrozom oluşturur ve sentrozom yalnızca bitki hücrelerinde bulunur.
- **b)** İğ ipliklerini sentrozom oluşturur ve sentrozom yalnızca hayvan hücrelerinde bulunur.
- **c) Her iki hücrede de farklı yapılar iğ ipliklerini oluştururlar.**
- **d)** Sentrozom hem soğan kökü hücresinde hem de insan deri hücresinde bulunur ve iğ ipliklerinin oluşumunu sağlar.
- **e)** İnsan deri hücrelerinde iğ ipliklerini sentromer oluşturur ve sentromer bitki hücrelerinde bulunmaz.
- **f)** ____.

10.3. Yukarıdaki iki soruya verdiğim cevaptan,

- **a)** Eminim.
- **b)** Emin değilim.

11.1. Bir hücrenin mayoz bölünmesi sırasında mayoz I sonucu oluşan hücrelerde DNA eşlenmesi gerçekleşmez.

a) Doğru **b)** Yanlış

11.2. Çünkü

- **a)** Mayoz I de kromozom sayısı değişmez, mayoz II de yarıya iner ve DNA eşlenmesi yalnızca mayoz II den önce görülür.
- **b)** Kromozom sayısı hem mayoz I de hem de mayoz II de yarıya iner ve haploid hücrelerin oluşabilmesi için DNA iki defa eşlenir.
- **c) Kromozom sayısı mayoz I de yarıya iner, mayoz II de değişmez ve DNA eşlenmesi yalnızca mayoz I den önce görülür.**
- **d)** Mayoz I den sonra oluşan hücrelerin bölünebilmesi için DNA'nın eşlenmesi gerekir.
- **e)** ____.

11.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

12.1. Aşağıdaki hücrelerden hangisi ya da hangilerinde hem mitoz hem de mayoz bölünme görülebilir.

a) Polen ana hücresi **b)** Karaciğer hücresi **c)** Her ikisi

12.2. Çünkü

a) Polen ana hücresi de karaciğer hücresi de diploidtir ve bütün diploid hücreler hem mayoz hem de mitoz bölünme geçirebilirler.
b) **Mitoz bölünme her iki hücrede de görülebilir ancak mayoz bölünme yalnızca polen ana hücrelerinde görülebilir.**
c) Mitoz bölünme her iki hücrede de görülebilir fakat mayoz bölünme yalnızca haploid hücrelerde görülebilir ve polen ana hücresi haploidtir.
d) Mitoz bölünme her iki hücrede de görülebilir fakat mayoz bölünme yalnızca diploid hücrelerde görülebilir ve karaciğer hücresi diploidtir.
e) ____.

12.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

13.1. Eşeyli üreyen bir canlıda mayoz bölünme ve döllenme olayları bireylerde kalıtsal çeşitliliği sağlar.

a) Doğru **b)** Yanlış

13.2. Çünkü

a) Kalıtsal çeşitliliği sağlayan tek olay krossing-overdır ve mayoz bölünme sırasında görülür.

b) Döllenme sırasında farklı anne ve babadan gelen genler birleşir ve kalıtsal çeşitlilik sağlar.

c) **Mayozda krossing-over ve genlerin rasgele dağılımı, döllenmede ise farklı gametlerin birleşmesi kalıtsal çeşitliliği sağlar.**

d) Kromozom sayısındaki değişmeler kalıtsal çeşitliliğe neden olur ve kromozom sayısı yalnızca mayozda değişir.

e) Kromozom sayısındaki değişmeler kalıtsal çeşitliliğe neden olur ve kromozom sayısı yalnızca döllenmede değişir.

f) ____.

13.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

14.1. Bitkilerde hem eşeyli hem eşeysiz üreme gözlemlenebilir.

a) Doğru **b)** Yanlış

14.2. Çünkü

a) Eşeyli üreme için iki canlı gerektiğinden bitkiler sadece eşeysiz ürerler.
b) Bitkiler sadece vejetatif üreme ile eşeysiz olarak üremektedirler.
c) Bitkilerde tozlaşma adı verilen eşeysiz üreme görülür.
d) **Bazı çiçeksiz bitkiler spor ile eşeysiz, gamet ile de eşeyli olarak ürerler.**
e) Çiçeksiz bitkilerde eşeysiz, çiçekli bitkilerde eşeyli üreme olur.
f) ____.

14.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

15.1. **I.** Partenogenez **II.** Zigot Oluşumu

I ve II ile verilen olaylardan her ikisinde de döllenme gözlenir.

a) Doğru b) Yanlış

15.2. Çünkü

a) Herikisi de diploid kromozomlu bir canlının yeni bir birey oluşturmasıdır ve döllenme gerçekleşir.
b) Canlılarda oluşturulan gametler haploidtir ve döllenme gerçekleşmeden yeni bir canlı meydana gelemez.
c) Partenogenezde haploid gametler döllenme ile biraraya gelir ancak diploid zigot döllenme olmaksızın gelişir.
d) **Partenogenez ile döllenme olmaksızın haploid bir canlı, zigot oluşumunda ise döllenme ile diploid bir canlı meydana gelir.**
e) Partenogenezde canlı kendi kendini döller, zigot oluşumunda ise iki farkı eşeyli bireylerden gelen gametler döllenir.
f) ________________.

15.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

16.1. **I-** İnsan yumurtalık hücresi **II-** İnsan yumurta hücresi

Yukarıdaki hücrelerin her ikisinde de homolog kromozomlar bulunur.

a) Doğru b) Yanlış

16.2. Çünkü

a) Her iki hücrede haploidtir ve haploid hücreler homolog kromozomlar bulundurmazlar.

b) Her iki hücrede diploidtir ve yalnızca diploid hücreler homolog kromozomlar bulundururlar.

c) **Mayoz bölünme sonucu oluşan hücrelerde homolog kromozom bulunmaz.**

d) Homolog kromozomlar yalnızca mayoz sonucu oluşan hücrelerde görülür.

e) Somatik hücreler homolog kromozomları bulundurmazlar.

f) ____.

16.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.

b) Emin değilim.

17.1. I. Homolog Kromozomlar **II.** Kardeş Kromatidler

Yukarıda verilenlerin her ikisi de aynı gene ait aleller taşırlar.

a) Doğru **b)** Yanlış

17.2. Çünkü

a) Homolog kromozomlar ana hücrede kromozom eşlenmesiyle üretilir ve aynı gene ait aleller taşırlar.

b) Hem homolog kromozomlar hem de kardeş kromatidler ana hücrede kromozom eşlenmesiyle üretilir ve aynı gene ait allelleri taşırlar.

c) Homolog kromozomlar sadece mayoz bölünmede meydana gelirler ve aynı gene ait alelleri taşımazlar.

d) **Homolog kromozomlar aynı gene ait farklı allelleri taşıyabilirler ancak kardeş kromatidler birbirinin kopyası olduklarından aynı gene ait farklı alelleri taşıyamazlar.**

e) Kardeş kromatidlerin herbiri bir atadan gelir ve aynı gene ait allelleri taşırlar, homolog kromozomlar ise birbirinin kopyasıdır ve bu nedenle aynı gene ait alelleri taşırlar.

f) ____.

17.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

18.1. Eşeyli üreme yalnızca bir türe ait iki farklı eşey bireyin çiftleşme davranışı göstermesiyle gerçekleşir.

a) Doğru **b) Yanlış**

18.2. Çünkü

a) Eşeyli üremenin temelinde bir erkek birey ile dişi bireyin çiftleşmesi vardır.
b) Eşeyli üremede iki bireyin çiftleşmesi nedeniyle oluşan yeni birey daha güçlü olur.
c) Eşeyli üremede sperm ve yumurtanın bir araya gelmesi için çiftleşme olmak zorundadır.
d) **Bitkilerde çiftleşme davranışı olmaksızın eşeyli üreme gerçekleşebilmektedir.**
e) ___________________.

18.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim.
b) Emin değilim.

19.1. I. Kertenkelede kopan kuyruk **II.** Denizyıldızında kopan kol

Verilenlerden her ikisinde de kopan vücut kısmı, kendini tamamlayarak yeni bir birey oluşturabilir.

a) Doğru **b) Yanlış**

19.2. Çünkü

a) Kertenkele daha gelişmiş bir canlı olduğundan dolayı rejenerasyon yeteneği de denizyıldızından fazladır.

b) **Rejenerasyon gelişmişlik düzeyi ile ters orantılı olduğundan sadece denizyıldızında yeni birey oluşur.**

c) Kertenkele büyük vücutlu olduğundan rejenerasyon yeteneği azdır, yeni birey oluşmaz.

d) Rejenerasyon ile çeşitliliğin artması her iki canlınında bu yolla yeni birey meydana getirmesine neden olur.

e) ___________________.

19.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

20.1.

Yandaki şekilde 4 adet homolog kromozom bulunmaktadır.

a) Doğru **b) Yanlış**

20.2. Çünkü

a) Diploid ana hücrenin kromozomları eşlenerek 4 adet homolog kromozomu oluşturmuştur.

b) **Diploid ana hücrenin kromozomları eşlenerek ikişer adet kromatid içeren 2 adet homolog kromozom oluşturmuştur.**

c) Kardeş kromatidler ile homolog kromozomlar temelde aynıdırlar ve şekilde 4 tane homolog kromozom vardır.

d) Homolog kromozomlar birbirlerine sentromerlerinden bağlanmış olarak bulunurlar ve şekilde 4 adet homolog kromozom vardır.

e) ___________________.

20.3. Yukarıdaki iki soruya verdiğim cevaptan,

a) Eminim. **b)** Emin değilim.

APPENDIX E

SCIENCE PROCESS SKILL TEST
(BİLİMSEL İŞLEM BECERİ TESTİ)

AÇIKLAMA: Bu test içinde, problemdeki değişkenleri tanımlayabilme, hipotez kurma ve tanımlama, işlemsel açıklamalar getirebilme, problemin çözümü için gerekli incelemelerin tasarlanması, grafik çizme ve verileri yorumlayabilme kabiliyetlerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği işaretleyiniz.

1. Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettiklerini düşünmektedir. Güçlerini etkileyen faktörleri araştırmaya karar verir. Antrenör, oyuncuların gücünü etkileyip etkilemediğini ölçmek için aşağıdaki değişkenlerden hangisini incelemelidir?

a. Her oyuncunun almış olduğu günlük vitamin miktarını.
b. Günlük ağırlık kaldırma çalışmalarının miktarını.
c. Günlük antreman süresini.
d. Yukarıdakilerin hepsini.

2. Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini artıdığı yolundadır. Aynı tip beş arabaya aynı miktarda benzin fakat farklı miktarlarda katkı maddesi konur. Arabalar benzinleri bitinceye kadar aynı yol üzerinde giderler. Daha sonra her arabanın aldığı mesafe kaydedilir. Bu çalışmada arabaların verimliliği nasıl ölçülür?

a. Arabaların benzinleri bitinceye kadar geçen süre ile.
b. Her arabnın gittiği mesafe ile.
c. Kullanılan benzin miktarı ile.
d. Kullanılan katkı maddesinin miktarı ile.

3. Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değişkenleri araştımaktadırlar. Aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?

a. Arabanın ağırlığı.
b. Motorun hacmi.
c. Arabanın rengi
d. a ve b.

4. Ali Bey, evini ısıtmak için komşularından daha çok para ödemesinin sebeblerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez değildir?

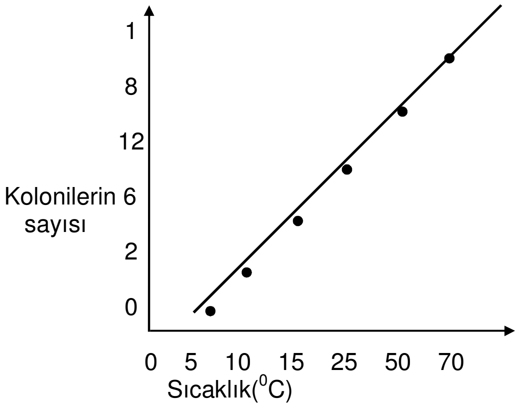
a. Evin çevresindeki ağaç sayısı ne kadar az ise ısınma gideri o kadar fazladır.
b. Evde ne kadar çok pencere ve kapı varsa, ısınma gideri de o kadar fazla olur.
c. Büyük evlerin ısınma giderleri fazladır.
d. Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

5. Fen sınıfından bir öğrenci sıcaklığın bakterilerin gelişmesi üzerindeki etkilerini araştırmaktadır. Yaptığı deney sonucunda, öğrenci aşağıdaki verileri elde etmiştir:

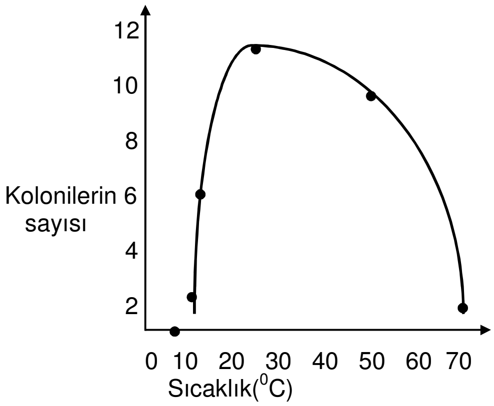
Deney odasının sıcaklığı (^{0}C)	Bakteri kolonilerinin sayısı
5	0
10	2
15	6
25	12
50	8
70	1

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

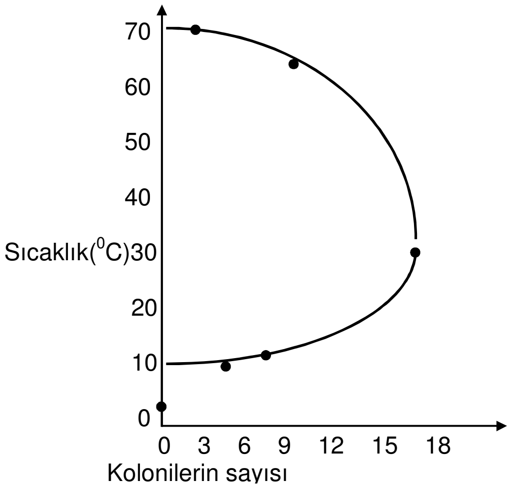
a.



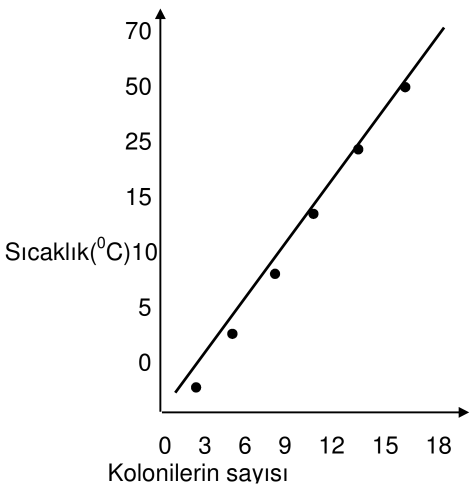
b.



c.



d.



6. Bir polis şefi, arabaların hızının azaltılması ile uğraşmaktadır. Arabaların hızını etkileyebilecek bazı faktörler olduğunu düşünmektedir. Sürücülerin ne kadar hızlı araba kullandıklarını aşağıdaki hipotezlerin hangisiyle sınayabilir?

a. Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.
b. Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.
c. Yollarde ne kadar çok polis ekibi olursa, kaza sayısı o kadar az olur.
d. Arabalar eskidikçe kaza yapma olasılıkları artar.

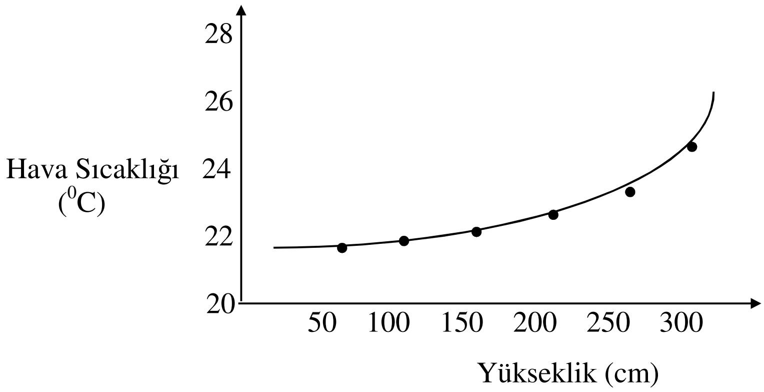
7. Bir fen sınıfında, tekerlek yüzeyi genişliğinin tekerleğin daha kolay yuvarlanması üzerine etkisi araştırılmaktadır. Bir oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğik düzlem) aşağı bırakılır ve daha sonra düz bir zemin üzerinde gitmesi sağlanır. Deney, aynı arabaya daha dar yüzeyli tekerlekler takılarak tekrarlanır. Hangi tip tekerleğin daha kolay yuvarlandığı nasıl ölçülür?

a. Her deneyde arabanın gittiği toplam mesafe ölçülür.
b. Rampanın (eğik düzlem) eğim açısı ölçülür.
c. Her iki deneyde kullanılan tekerlek tiplerinin yüzey genişlikleri ölçülür.
d. Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

8. Bir çiftçi daha çok mısır üretebilmenin yollarını aramaktadır. Mısırların miktarını etkileyen faktörleri araştırmayı tasarlar. Bu amaçla aşağıdaki hipotezlerden hangisini sınayabilir?

a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.
b. Ne kadar çok mısır elde edilirse, k**a**r o kadar fazla olur.
c. Yağmur ne kadar çok yağarsa , gübrenin etkisi o kadar çok olur.
d. Mısır üretimi arttıkça, üretim maliyeti de artar.

9. Bir odanın tabandan itibaren değişik yüzeylerdeki sıcaklıklarla ilgli bir çalışma yapılmış ve elde edilen veriler aşağıdaki grafikte gösterilmiştir. Değişkenler arasındaki ilişki nedir?

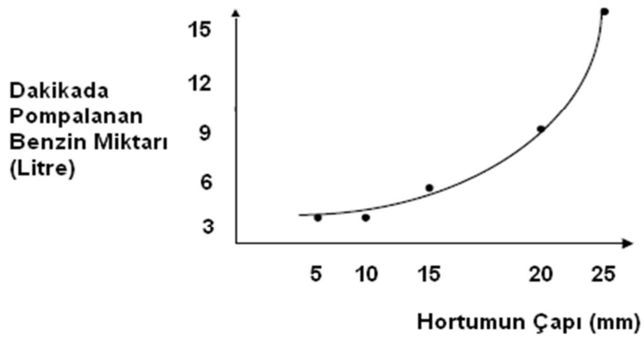


a. Yükseklik arttıkça sıcaklık azalır.
b. Yükseklik arttıkça sıcaklık artar.
c. Sıcaklık arttıkça yükseklik azalır.
d. Yükseklik ile sıcaklık artışı arasında bir ilşki yoktur.

10. Ahmet, basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçracağını düşünmektedir. Bu hipotezi araştırmak için, birkaç basketbol topu alır ve içlerine farklı miktarda hava pompalar. Ahmet hipotezini nasıl sınamalıdır?

a. Topları aynı yükseklikten fakat değişik hızlarla yere vurur.
b. İçlerinde farklı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.
c. İçlerinde aynı miktarlarda hava olan topları, zeminle farklı açılardan yere vurur.
d. İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

11. Bir tankerden benzin almak için farklı genişlikte 5 hortum kullanılmaktadır. Her hortum için aynı pompa kullanılır. Yapılan çalışma sonunda elde edilen bulgular aşağıdaki grafikte gösterilmiştir.



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

a. Hortumun çapı genişledikçe dakikada pompalanan benzin miktarı da artar.
b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.
c. Hortumun çapı küçüldükçe dakikada pompalanan benzin miktarı da artar.
d. Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

Önce aşağıdaki açıklamayı okuyunuz ve daha sonra 12, 13, 14 ve 15 inci soruları açıklama kısmından sonra verilen paragrafı okuyarak cevaplayınız.

Açıklama: Bir araştırmada, bağımlı değişken birtakım faktörlere bağımlı olarak gelişim gösteren değişkendir. Bağımsız değişkenler ise bağımlı değişkene etki eden faktörlerdir. Örneğin, araştırmanın amacına göre kimya başarısı bağımlı bir değişken olarak alınabilir ve ona etki edebilecek faktör veya faktörler de bağımsız değişkenler olurlar.

Ayşe, güneşin karaları ve denizleri aynı derecede ısıtıp ısıtmadığını merak etmektedir. Bir araştırma yapmaya karar verir ve aynı büyüklükte iki kova alır. Bumlardan birini toprakla, diğerini de su ile doldurur ve aynı miktarda güneş ısısı alacak şekilde bir yere koyar. 8.00 - 18.00 saatleri arasında, her saat başı sıcaklıklarını ölçer.

12. Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?

a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.

b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.

c. Güneş farklı maddelari farklı derecelerde ısıtır.

d. Günün farklı saatlerinde güneşin ısısı da farklı olur.

13. Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Herbir kovanın güneş altında kalma süresi.

14. Araştırmada bağımlı değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Herbir kovanın güneş altında kalma süresi.

15. Araştırmada bağımsız değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Herbir kovanın güneş altında kalma süresi.

16. Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinasıyla her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili hipotezler kurmaya başlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?

a. Hava sıcakken çim biçmek zordur.
b. Bahçeye atılan gübrenin miktarı önemlidir.
c. Daha çok sulanan bahçedeki çimenler daha uzun olur.
d. Bahçe ne kadar engebeliyse çimenleri kesmekte o kadar zor olur.

17, 18, 19 ve 20 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.
Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın herbirine 50 şer mililitre su koyar. Bardaklardan birisine 0 ^{0}C de, diğerine de sırayla 50 ^{0}C, 75 ^{0}C ve 95 ^{0}C sıcaklıkta su koyar. Daha sonra herbir bardağa çözünebileceği kadar şeker koyar ve karıştırır.

17. Bu araştırmada sınanan hipotez hangisidir?
a. Şeker ne kadar çok suda karıştırılırsa o kadar çok çözünür.
b. Ne kadar çok şeker çözünürse, su o kadar tatlı olur.
c. Sıcaklık ne kadar yüksek olursa, çözünen şekerin miktarı o kadar fazla olur.
d. Kullanılan suyun miktarı arttıkça sıcaklığı da artar.

18. Bu araştırmada kontrol edilebilen değişken hangisidir?
a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

19. Araştımanın bağımlı değişkeni hangisidir?
a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

20. Araştırmadaki bağımsız değişken hangisidir?
a. Her bardakta çözünen şeker miktarı.
b. Her bardağa konulan su miktarı.
c. Bardakların sayısı.
d. Suyun sıcaklığı.

21. Bir bahçıvan domates üretimini artırmak istemektedir. Değişik birkaç alana domates tohumu eker. Hipotezi, tohumlar ne kadar çok sulanırsa, o kadar çabuk filizleneceğidir. Bu hipotezi nasıl sınar?

a. Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.
b. Her sulamadan bir gün sonra domates bitkisinin boyunu ölçer.
c. Farklı alanlardaki bitkilere verilen su miktarını ölçer.
d. Her alana ektiği tohum sayısına bakar.

22. Bir bahçıvan tarlasındaki kabaklarda yaprak bitleri görür. Bu bitleri yok etmek gereklidir. Kardeşi "Kling" adlı tozun en iyi böcek ilacı olduğunu söyler. Tarım uzmanları ise "Acar" adlı spreyin daha etkili olduğunu söylemektedir. Bahçıvan altı tane kabak bitkisi seçer. Üç tanesini tozla, üç tanesini de spreyle ilaçlar. Bir hafta sonra her bitkinin üzerinde kalan canlı bitleri sayar. Bu çalışmada böcek ilaçlarının etkinliği nasıl ölçülür?

a. Kullanılan toz ya da spreyin miktarı ölçülür.
b. Toz ya da spreyle ilaçlandıktan sonra bitkilerin durumları tespit edilir.
c. Her fidede oluşan kabağın ağırlığı ölçülür.
d. Bitkilerin üzerinde kalan bitler sayılır.

23. Ebru, bir alevin belli bir zaman süresi içinde meydana getireceği ısı enerjisi miktarını ölçmek ister. Bir kabın içine bir litre soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini nasıl ölçer?

a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kayeder.
b. 10 dakika sonra suyun hacminde meydana gelen değişmeyi ölçer.
c. 10 dakika sonra alevin sıcaklığını ölçer.
d. Bir litre suyun kaynaması için geçen zamanı ölçer.

24. Ahmet, buz parçacıklarının erime süresini etkileyen faktörleri merak etmektedir. Buz parçalarının büyüklüğü, odanın sıcaklığı ve buz parçalarının şekli gibi faktörlerin erime süresini etkileyebileceğini düşünür. Daha sonra şu hipotezi sınamaya karar verir: Buz parçalarının şekli erime süresini etkiler. Ahmet bu hipotezi sınamak için aşağıdaki deney tasarımlarının hangisini uygulamalıdır?

a. Herbiri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
b. Herbiri aynı şekilde fakat farklı ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
c. Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
d. Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

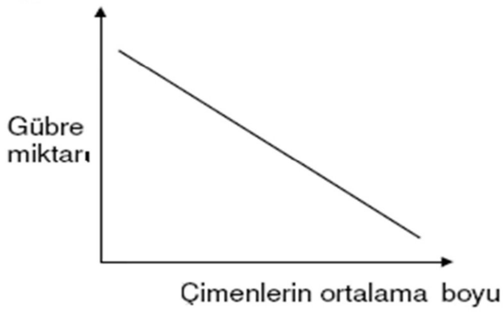
25. Bir araştırmacı yeni bir gübreyi denemektedir. Çalışmalarını aynı büyüklükte beş tarlada yapar. Her tarlaya yeni gübresinden değişik miktarlarda karıştırır. Bir ay sonra, her tarlada yetişen çimenin ortalama boyunu ölçer. Ölçüm sonuçları aşağıdaki tabloda verilmiştir.

Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

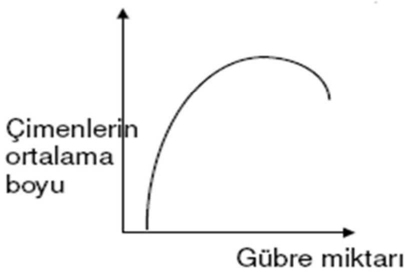
Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

a.

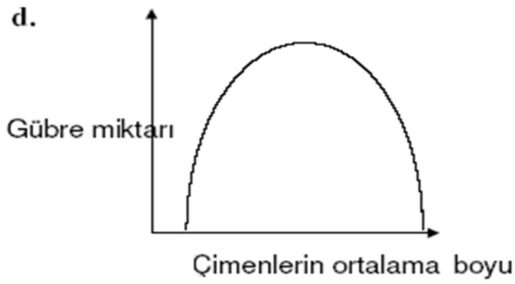
b.



c.



d.



26. Bir biyolog şu hipotezi test etmek ister: Farelere ne kadar çok vitamin verilirse o kadar hızlı büyürler. Biyolog farelerin büyüme hızını nasıl ölçebilir?

a. Farelerin hızını ölçer.

b. Farelerin, günlük uyumadan durabildikleri süreyi ölçer.

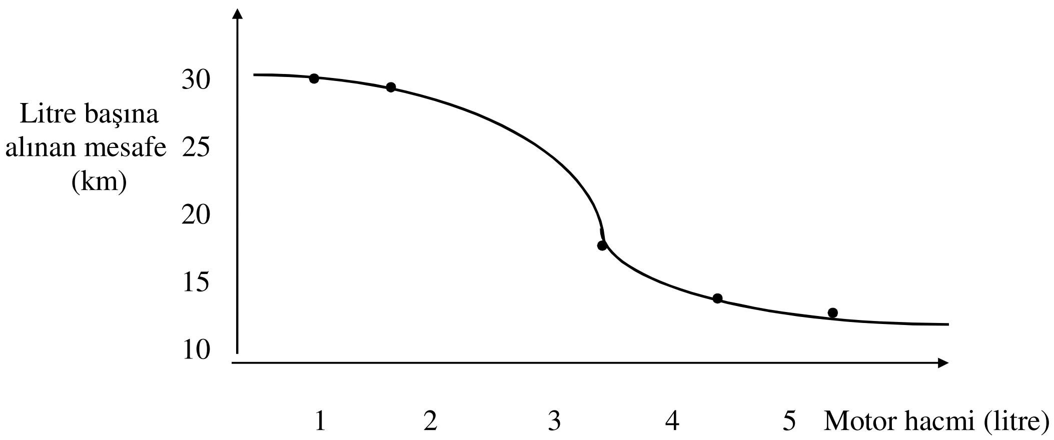
c. Hergün fareleri tartar.

d. Hergün farelerin yiyeceği vitaminleri tartar.

27. Öğrenciler, şekerin suda çözünme süresini etkileyebilecek değişkenleri düşünmektedirler. Suyun sıcaklığını, şekerin ve suyun miktarlarını değişken olarak saptarlar. Öğrenciler, şekerin suda çözünme süresini aşağıdaki hipotezlerden hangisiyle sınayabilir?

a. Daha fazla şekeri çözmek için daha fazla su gereklidir.
b. Su soğudukça, şekeri çözebilmek için daha fazla karıştırmak gerekir.
c. Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.
d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştıma grubu, değişik hacimli motorları olan arabaların randımanlarını ölçer. Elde edilen sonuçların grafiği aşağıdaki gibidir.



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

a. Motor ne kadar büyükse, bir litre benzinle gidilen mesafe de o kadar uzun olur.
b. Bir litre benzinle gidilen mesafe ne kadar az olursa, arabanın motoru o kadar küçük demektir.
c. Motor küçüldükçe, arabanın bir litre benzinle gidilen mesafe artar.
d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

29, 30, 31 ve 32 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Toprağa karıştırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki toprağa 15 kg., ikinciye 10 kg., üçüncüye ise 5 kg. çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır. Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan elde edilen domates tartılmış ve kaydedilmiştir.

29. Bu araştırmada sınanan hipotez hangisidir?

a. Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.
b. Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.
c. Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.
d. Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

30. Bu araştırmada kontrol edilen değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki toprak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

31. Araştırmadaki bağımlı değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki toprak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

32. Araştırmadaki bağımsız değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki torak miktarı.

d. Çürümüş yapak karıştırılan saksı sayısı.

33. Bir öğrenci mınatısların kaldırma yeteneklerini araştırmaktadır. Çeşitli boylarda ve şekillerde birkaç mıknatıs alır ve her mıknatısın çektiği demir tozlarını tartar. Bu çalışmada mıknatısın kaldırma yeteneği nasıl tanımlanır?

a. Kullanılan mıknatısın büyüklüğü ile.

b. Demir tozlarını çeken mıknatısın ağırlığı ile.

c. Kullanılan mıknatısın şekli ile.

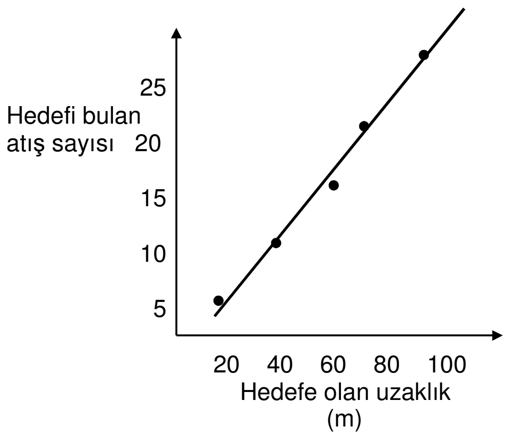
d. Çekilen demir tozlarının ağırlığı ile.

34. Bir hedefe çeşitli mesafelerden 25 er atış yapılır. Her mesafeden yapılan 25 atıştan hedefe isabet edenler aşağıdaki tabloda gösterilmiştir.

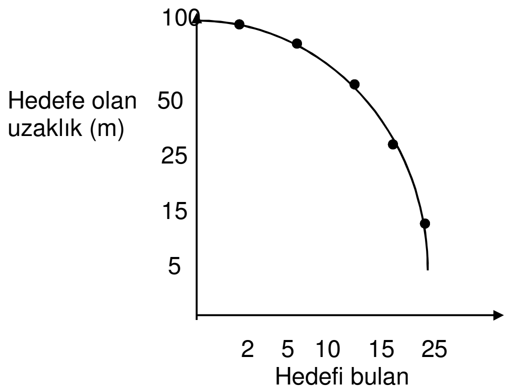
Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

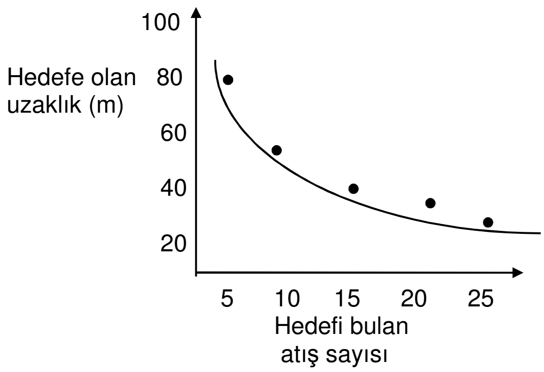
a.



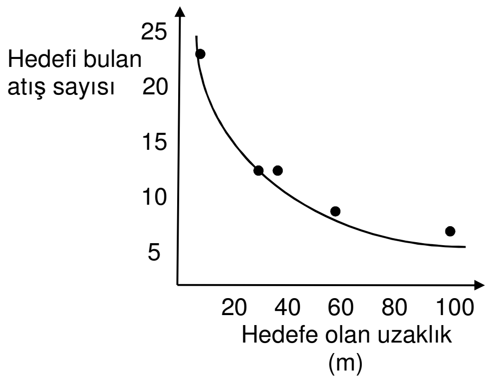
b.



c.



d.



35. Sibel, akvaryumdaki balıkların bazen çok haraketli bazen ise durgun olduklarını gözler. Balıkların hareketliliğini etkileyen faktörleri merak eder. Balıkların hareketliliğini etkileyen faktörleri hangi hipotezle sınayabilir?

a. Balıklara ne kadar çok yem verilirse, o kadar çok yeme ihtiyaçları vardır.
b. Balıklar ne kadar hareketli olursa o kadar çok yeme ihtiyaçları vardır.
c. Su da ne kadar çok oksijen varsa, balıklar o kadar iri olur.
d. Akvaryum ne kadar çok ışık alırsa, balıklar o kadar hareketli olur.

36. Murat Bey'in evinde birçok elektrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker. Kullanılan elektrik miktarını etkileyen faktörleri araştırmaya karar verir. Aşağıdaki değişkenlerden hangisi kullanılan elektrik enerjisi miktarını etkileyebilir?

a. TV nin açık kaldığı süre.
b. Elektrik sayacının yeri.
c. Çamaşır makinesinin kullanma sıklığı.
d. a ve c.

APPENDIX F

INTERVIEW QUESTIONS

Hücre bölünmeleri genel:

1. Her hücre bölünebilir mi? İnsanlarda bütün hücrelerde bölünme olabilir mi? Neden?
2. Hücrenin bölünmesinin nedeni olabilir? Açıklayabilir misin?
3. Hücrenin bölünmesi sonrasında ana hücreye ne olmuştur?
4. 2N ne anlama gelmektedir? Homolog kromozom kavramını biliyor musun?

Mitoz Hücre Bölünmesi:

5. Sence mitoz bölünmenin amacı nedir?
6. DNA eşlenmesi hangi safhada gerçekleşir?
7. Mitoz bölünmenin nerede gerçekleştiğini biliyor musun?
8. Başlangıçtaki hücre ile bölünme sonrası oluşan yeni hücreleri karşılaştırabilir misin? Farklar neler? Benzerlikler neler?
9. Oluşan iki yeni hücreyi birbiri ile karşılaştırabilir misin?

Mayoz Hücre Bölünmesi:

10. Mayoz bölünmenin amacı nedir?
11. Mayoz bölünmenin nerede gerçekleştiğini biliyor musun?
12. Mayoz bölünmede neden kromozom sayısı azalıyor? Sence neden sadece bir kromozom takımı yok edilmiyor da bölünme ile uğraşılıyor?

Mitoz ve mayoz karşılaştırması:

13. Mitoz ile mayoz hücre bölünmelerini karşılaştırabilir misin? Benzer özellikleri nelerdir?
14. Farklı özellikleri nelerdir?
15. Neden canlılar iki farklı üreme çeşidine ihtiyaç duymuş olabilirler?

Eşeysiz Üreme:

16. Eşeysiz üreme çeşitlerini biliyor musun?
17. Eşeysiz üreme hangi canlılarda gerçekleşir?

Eşeyli Üreme:

18. Eşeyli üreme hangi canlılarda gerçekleşir? Örnek verebilir misin?
19. Bir canlıda hem eşeyli hem de eşeysiz üreme bir arada görülebilir mi? Böyle bir canlıya örnek verebilir misin?
20. Eşeyli üreme ile eşeysiz üremeyi karşılaştırabilir misin?

Metot

1. Biyoloji dersini, bu dönem geçen dönemki ile aynı formatta mı işlediniz? Fark var mıydı? Fark varsa bu farklardan bahseder misiniz?
2. Hangi sınıf aktiviteleri sizin hücre bölünmesi ve üreme konularını anlamanıza daha çok yardımcı oldu? Açıklar mısınız?
3. Bu dönem yaptıklarınız hoşunuza gitti mi?
4. Biyoloji dersinin bu dönemdeki gibi mi yoksa geçen dönemdeki gibi mi olmasını istersiniz? Neden?
5. Derslerin bu dönemdeki gibi işlenmesi, okulda öğrendiğiniz biyoloji bilgilerini günlük hayatla ilişkilendirmenizde herhangi bir etki sağladı mı? Örnek vererek açıklayabilir misin?
6. Derslerin işlenişi sırasında herhangi bir problem ile karşılaştınız mı? Neler?

APPENDIX G

OBSERVATION CHECKLISTS

GELENEKSEL YÖNTEM

Okul- Sınıf :………………………………………
Gözlemci :…………………….……….…………..
Konu :……………………………….…………...
Süre :……………………………….…………...

Yargılar	EVET	KISMEN	HAYIR
Öğretmen konuyu anlattı.			
Öğretmen konuyla ilgili sorular sordu.			
Öğretmen öğrencilere konu ile ilgili sorular sordu.			
Öğretmen merkezli bir yaklaşım sergilendi.			
Ders geleneksel yöntem kullanılarak anlatıldı.			

ÖĞRENME DÖNGÜSÜ

Okul- Sınıf :…………………………… Gözlemci:……………………….……

Konu :………………………….... Süre :………………………….

		Yargılar	**EVET**	**KISMEN**	**HAYIR**
	Isındırma	Öğretmen yapılacak etkinlikle ilgili sorular sordu mu?			
		Öğretmen öğrencilerin ilgilerini çekebildi mi?			
		Öğretmen öğrencilerin konuyla ilgili sahip oldukları fikir ve düşünceleri ortaya çıkarabildi mi?			
		Öğretmen öğrencilerin konuyla ilgili hipotezler kurmalarını sağladı mı?			
		Öğretmen sorduğu soruların cevaplarını verdi mi?			
	Araştırma	Öğretmen dersi doğrudan anlatmak yerine öğrencilerin beraberce araştırma yapmalarını sağladı mı?			
		Gerektiğinde öğrencilerin araştırmalarına yeniden yön vermek amacıyla öğretmen öğrencilere irdeleyici sorular sordu mu?			
		Öğretmen öğrencilerin araştırmaları için onlara yeterince zaman tanıdı mı?			
		Öğretmen öğrenciler için bir rehber ve danışman gibi davrandı mı?			
		Öğretmen araştırma sorularını cevapladı mı?			
	Açıklama	Öğrenciler gözlem ve bulgularını kendi ifadeleriyle açıkladılar mı?			
		Öğretmen öğrencilerden açıklamaları için kanıt talep etti mi?			
		Öğretmen bilimsel açıklamaları öğrencilerin gözlem ve bulgularını kullanarak mı yaptı?			
		Öğretmen kanıt sunulmayan açıklamaları kabul etti mi?			
		Öğretmen cevapları öğrencilerden almayı ihmal etti mi?			

	Yargılar	EVET	KISMEN	HAYIR
Genişletme	Öğretmen öğrencilere yeni bilgilerini kullanmalarına olanak sağlayan başka bir uygulama sağladı mı?			
	Öğretmen öğrencileri bilimsel açıklamaları yeni durumlarda kullanmaları için teşvik etti mi?			
	Yeni uygulama sırasındaki soruları cevaplayan bilgileri öğretmen mi verdi?			
Değerlendirme	Açık uçlu sorular sordu mu?			
	Öğretmen öğrencilerin yeni bilgileri doğru anlayıp anlamadıklarını ölçtü mü?			
	Öğrencilerin fikir ve düşüncelerini değiştirdiklerine dair kanıtlar aradı mı?			
	Ders öğrenci merkezli miydi?			
	Sizce dersin işlenişi öğrenme döngüsü yöntemini yansıttı mı?			

*Eğik yazılmış olan ifadeler öğretmenden yapmaması beklenen davranışları göstermektedir.

APPENDIX H

SAMPLE LESSON PLAN-I FOR LEARNING CYCLE GROUP

Konu: Mitoz Bölünme

Kazanımlar:

Mitoz ile ilgili olarak öğrenciler;

- Mitozun evrelerini şema üzerinde açıklar.
- Tek hücreli ve çok hücreli canlılar için mitozun önemini açıklar.
- Mitozun kontrol edilmesi ve bunun önemini açıklar.
- Bitki ve hayvan hücrelerinde mitozu karşılaştırır.

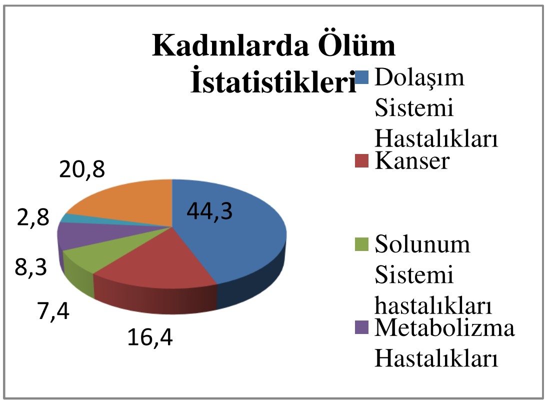
1. MERAK UYANDIRMA (ENGAGEMENT)

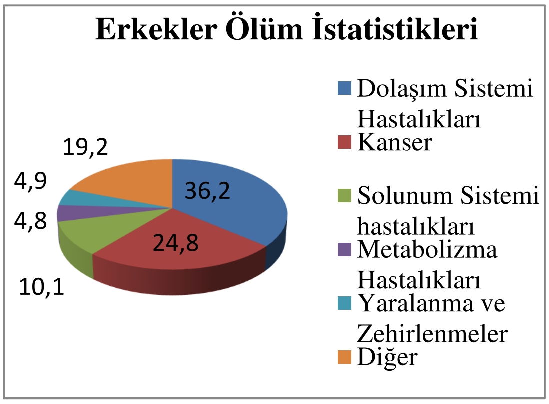
Selamlaşmanın ardından öğretmen, 2005 yılında akciğer kanseri nedeniyle 33 yaşında vefat eden şarkıcı Kazım Koyuncu için hazırlanmış belgeseli (3:35) ve meme kanseri tedavisi görmüş oyuncu Oya Başar ile yapılmış röportajı (4:50) öğrencilere izlettirir.

Video bitince öğretmen aşağıdaki soruları öğrencilere yönlendirir.

- Yakınızda kanser hastalığı ile mücadele eden insanlar var mı?
- Kanserin nasıl bir hastalık olduğunu biliyor musunuz?
- Sizce kanser hastalığı neden olmaktadır?

Sağlık Bakanlığı sağlık istatistikleri yıllığında elde edilmiş olan Türkiye'de kadın ve erkeklere ait ölüm nedenlerinden ilk beşini gösteren aşağıdaki grafikleri projektör ile duvara yansıtır (Saglık Bakanlıgı, 2011)





Daha sonra öğretmen, "Türkiye Büyük Millet Meclisi (TBMM) Araştırma Komisyonu Mart 2011 raporuna göre, Türkiye'de hayatını kaybeden her 100 kişiden 14'ünün ölüm sebebi kanser. Rapordaki bilgilere göre, kanserle yaşayan kişi sayısı yaklaşık olarak 400 bin ve her yıl 150 binin üzerinde kanser vakası ortaya çıkıyor. Kanserin 2030 yılında ülkemizin önemli bir sağlık sorunu olacağı kaydedilmiş." şeklindeki bilgiyi paylaşır ve öğrencilerin konuyu hücre bazında düşünmelerini sağlamak amacıyla aşağıdaki soruları yönlendirir. Öğretmen, öğrencilerin cevaplarını dinler, bu soruların cevaplarının bu konudan sonra daha iyi anlaşılacağı belirtilir.

- Bu kadar yaygın bir hastalık olan kanserin nasıl geliştiğini biliyor musunuz?
- Daha önce hiç "tümör" kelimesini duydunuz mu?
- Tümörler nasıl oluşur fikriniz var mı?
- Kanser hücre Bölünmesinden temel alır. Peki, nedir bu hücre bölünmesi?

2. KEŞFETME (EXPLORATION)

Hücre döngüsünün anlaşılabilmesi için üç adet etkinlik yapılır. Birinci etkinlik için öğrenciler okulun biyoloji-kimya laboratuvarına götürülür. Öğretmen öğrencileri istekleri doğrultusunda 4-5 kişilik gruplara ayırdıktan sonra soğan kök hücrelerinde hücre döngüsünün gözlemlenmesi deneyinin yapılışını açıklayan Etkinlik-1'i öğrencilere dağıtır. Öğrencilerden etkinlik kağıdının ilk kısmını okumalarını ister. Gerekli malzemeleri gruplara dağıtır.

ETKİNLİK 1

BİR HÜCREDEN ÇOK HÜCREYE KURALI: Hücre Döngüsü

Fillerin vücutlarının büyüklüğü farelere göre ne kadar da büyüktür. Aslında fillerin aynı dokulardaki hücreleri farelerden biraz küçüktür ama asla daha büyük değildir-sadece onlardan daha çok sayıda hücresi vardır. Hem filler hem de fareler aslında zigot - döllenmiş tek bir hücre- ile hayata başlarlar. Zigotun bölünebilme ve büyüyerek yeni bir canlının tüm vücudunu oluşturabilme özelliği vardır. Bir canlının oluşumu için gerekli tüm hücreleri meydana getirebilmesi, zigotun yeni hücre için gerekli maddeleri sentezlemesi ve ikiye bölünmesi ile mümkündür. Bu çok iyi şekilde organize edilmiş olaya hücre döngüsü adı verilir.

(Bir insan vücudunda yaklaşık 10^{13} hücre bulunmaktadır. Sizce bir filde yaklaşık kaç hücre bulunur?)

Hücre Bölünmesi Gözlemlenebilir mi?

Bu amaçla kullanılacak araç-gereçler:

- Köklendirilmiş kuru soğan
- Makas,
- Asetokarmen boyası,
- Saat Camı,
- Pens,
- İspirto Ocağı, Kibrit
- Jilet

- Lam,
- Lamel,
- Mikroskop,
- Kurutma Kağıdı
- İmmersiyon yağı

Aşağıda sıralanmış adımları takip ederek deneyi gerçekleştiriniz.

Adım 1. Kuru soğanın taze köklerinden birkaç tanesinin uçlarını makasla yaklaşık 4-5 mm uzunluğunda keserek saat camının üzerine alalım.

Adım 2. Köklerin üzerleri örtecek kadar asetokarmen boyası dökelim.

Adım 3. Saat camını pens yardımıyla yakmış olduğumuz ispirto ocağının ateşine tutalım. (Dikkat: Boya kaynamamalıdır, bu sebeple ateşe yaklaştırıp uzaklaştırmak gerekebilir.)

Adım 4. Isıtılan köklerden bir tanesini bir lam üzerine alarak jilet yardımıyla kesebileceğiniz en ince (2-3 mm) şekilde keselim. (Dikkat: Jilet çok kesici olduğundan dikkatli davranınız.)

Adım 5. Kesitin üzerine bir damla asetokarmen boyası damlatalım ve üzerine lameli kapatalım.

Adım 6. Lamelin üzerine bir parça kurutma kağıdı yerleştirdikten sonra, başparmağınız yardımıyla hareket ettirmemeye özen göstererek ezelim. (Dikkat: Lamel çok kolay kırılabilir, sert davranmayınız.)

Adım 7. Hazırladığınız preparatı mikroskoba yerleştirelim, öncelikle küçük objektif ile görüntü bulduktan sonra hiç kaydırma yapmadan sıra ile büyük objektifler ile inceleyelim. Görüntü bulamazsanız öğretmeninizden yardım isteyiniz. (Dikkat: X 100 büyütmeli objektif ile net görüntü immersiyon yağı damlatılarak elde edilir.)

Adım 8.Görebildiğiniz birbirinden farklı hücreleri dikkatlice inceleyiniz.

Adım 9. En az 3 tane farklı görünüşlü hücre çiziniz.

- En fazla nasıl görünüşlü hücre gördünüz? Bunun anlamı ne olabilir?

- Bölünme sonunda sizce kaç hücre oluştu?

Etkinlik 1'i tamamlayan öğrenciler, öğretmenin 5 ayrı mikroskoba karışık olarak yerleştirmiş olduğu mitoz evreleri gösteren hazır preparatları incelerler (Bu aşamada öğretmen Cordero ve Szweczak'ın (1994) çalışmalarında verilmiş olan gerçek hücre bölünmesi resimlerini projektör ile duvara yansıtarak öğrencilere görecekleri görüntü hakkında fikir verir.) Öğrenciler her bir preparatta gördükleri görüntüler ile ilgili gözlemlerini not ederler ve preparatları mitoz evrelerine uygun olarak mantıksal olarak sıralamaya çalışırlar. Gruplar önerilerini sınıf ile paylaşır. Öğretmen yanlış öneriler sunulsa bile müdahale etmez.

Öğretmen mitoz bölünme evrelerini açıklayabilmek amacıyla Etkinlik 2'yi öğrencilere yaptırır. İkinci etkinlik sınıf ortamında gerçekleştirilir. Öğretmen yine sınıfı 4-5 kişilik gruplara ayırır ve Etkinlik 2 isimli çalışma kağıtlarını öğrencilere dağıtır. Öğrencilerden verilen çalışma kağıdını okumaları ve anlatılan etkinliği yapmaları istenir. Gerekli malzemeler öğretmen tarafından gruplara dağıtılır.

ETKİNLİK 2

Theodor Boveri

Theodor Heinrich Boveri (12 Ekim 1862 – 15 Ekim 1915) genetik, hücre biyolojisi ve kanser ile ilgili çalışmalar yapmış Alman biyologdur.

Boveri'nin denizkestaneleri ile yapmış olduğu bir dizi deney, zigottan bir canlı oluşması için canlının bütün kromozomlarının olması gerektiğini göstermiştir. Bu buluş Boveri–Sutton kromozom teorisinin önemli bir parçasını oluşturmuştur. Kromozomların genetik materyali taşıdığını tanımlayan bu teori genetik biliminin temel teorilerindendir. Bu teori, bölünen her hücrede görülebilen ve nesilden nesile aktarılan kromozomların, genetik kalıtımın temelini oluşturduklarını söylemektedir.

Boveri, kromozomların devamlılığı ve özgünlüğü olmak üzere iki temel prensipten bahsetmiş ve Mendel'in kalıtım kuralları doğrultusunda, kalıtım ve kromozom davranışlarını bir araya getirmiştir. Boverinin bir diğer önemli buluşu, 1888 yılında "hücre bölünmesinin özel organı" olarak isimlendirdiği sentromerdir.

1902 yılında, Boveri, kanser tümörlerinin, hücrenin kontrolsüz bölünmesine neden olan kromozomları karışmış tek bir hücre ile başladığı şeklinde akıl yürütmüştür. Hücre döngüsünde kontrol noktaları olduğunu, kromozomlarda tümör baskılayıcı genler ve onkogenler (kansere neden olan genler) bulunduğunu ayrıca radyasyon, fiziksel veya kimyasal travmalar ya da mikroskobik bazı canlıların kontrolsüz hücre bölünmesine neden olabileceğini öne sürmüştür. Daha sonra Boveri' nin haklı olduğu birçok araştırmacı tarafından kanıtlanmıştır. Theodor Boveri kendisinden sonra iki kuşak daha Amerikan hücre bilimcileri etkilemiştir.

Günümüzde bir lise öğrencisinin belkide Boveriden daha fazla hücre bilgisi olduğunu biliyor muydunuz?

Hücre Bölünmesi sırasında kromozomların rolü nedir?

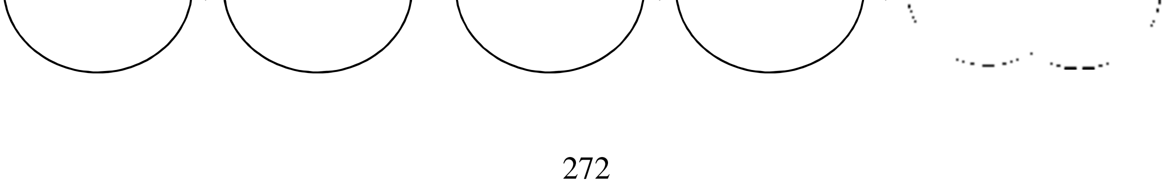
Bu amaçla kullanılacak araç-gereçler:

- Renkli oyun hamurları (en az 3 renk)
- İplik
- A3 boyutlarında karton
- Makas
- Kalem

Aşağıda sıralanmış adımları takip ederek etkinliği gerçekleştiriniz.

Adım 1. 2N=4 kromozom sayısına sahip bir canlının bir hücresinin mitoz bölünmesi sırasında kromozom hareketlerini şekillendireceğiz.

Adım 2. Bu amaçla, karton üzerine aşağıdaki gibi 5 adet içi boş hücre çiziniz.
(Dikkat: Her biri aynı hücrenin bölünme sırasındaki farklı görüntüsünü temsil edecektir.)



Adım 3. İki farklı renk oyun hamuru kullanarak bir çift uzun ve bir çift kısa olmak üzere 4 adet kromozom hazırlayınız ve birinci şeklin içine yerleştiriniz. (Dikkat: homolog kromozom çiftlerini düşününüz.)
Adım 4. Hazırlamış olduğunuz kromozomların yanlarına birer tane daha aynı renk ve uzunlukta yeni kromozomlar yaparak onları eşleyiniz. (Dikkat: sentromer için farklı bir renk kullanınız.)
Adım 4. Kromozomları, kardeş kromatidleri ve homolog kromozomları işaretleyerek yanlarına belirtiniz. Hücrenin kromozomal DNA miktarı ve kromozom sayısında değişiklik oldu mu?
Adım 5. Etkinlik 1 sırasında çizmiş olduğunuz hücreler yardımıyla 2, 3, 4 ve 5 numaralı hücrelerin içine kromozomları yerleştiriniz. (Dikkat: bu adımda bir hücreden iki hücre oluşabilmesi için sizce neler olmalıdır? Aklınıza gelen soruları not ediniz.)
Adım 6. Her bir şeklin yanına hücrenin sahip olduğu kromozom sayısını yazınız.

3.AÇIKLAMA (EXPLANATION)

Öğretmen, her bir öğrenci grubundan bir temsilciyi tahtaya davet eder ve hazırlamış oldukları mitoz modelini anlatmalarını ister. Sorular sorarak öğrencilerin yanlış kısımları fark etmelerini sağlar. Daha sonra sınıfça tartışma ortamı yaratır. Öğrencilerin modellerini doğru şekilde düzeltmeleri için hem açıklamalar yapar hem de onların etkinlik sırasında not ettikleri sorularını cevaplar. Bu sırada fazla terim vermemeye dikkat eder. Hücre döngüsünün interfaz, mitoz ve sitokinez olmak üzere üç safhada incelendiğinin, mitoz isminin sadece çekirdek bölünmesini ifade ettiğinin altını çizer. Daha sonra tahtayı 3 parçaya ayırır, sırasıyla interfaz, mitoz ve sitokinez yazdıktan sonra mitoz için ayırdığı kısmı 4 parçaya ayırarak evrelerin isimlerini yazar, her bir evrede olan olayları maddeler halinde yazar. Bu aşamada öğretmenin bölünmenin aslında birbirinden tamamen ayrılmış evrelerden oluşmadığını, süreklilik arz ettiğini söylemesi önemlidir. Mitoz bölünmenin incelemeyi ve anlamayı kolaylaştırmak için evreler halinde incelendiğinin altının çizilmesi gerekir. Bunun dışında öğretmen aşağıda listesi verilmiş kavram yanılgılarını dikkate almalıdır.

1. Mitoz bölünmede farklı evrelerdeki kromozomal DNA miktarı da farklıdır.

2. DNA eşlenmesi profaz evresinde gerçekleşir.

3. Bir hücredeki kromozomal DNA miktarı anafazda yarıya iner.

4. Kromozomal DNA miktarı hiçbir safhada değişmez.

5. Mitoz bölünmenin bütün safhalarında kromozom sayısı sabittir ve ana hücrenin kromozom sayısı ile aynıdır.

6. Kromozom sayısı mitoz bölünmenin anafaz safhasında yarıya iner.

7. Kromozom sayısı interfazda iki katına çıkar ve bu sayı bütün safhalarda korunur.

8. Profaz mitoz bölünmenin dinlenme ve hazırlık evresidir ve kromozom sayısı henüz iki katına çıkmamıştır.

9. Bir hücredeki kromozom sayısı mitoz bölünmenin bütün safhalarında aynıdır.

10. Homolog kromozomlar mitozda ayrılırlar.

11. Kardeş kromatidler sadece mitoz bölünmede ayrılırlar.

12. Mitoz bölünme sırasında bütün organeller eriyerek kaybolur.

13. Mitoz bölünme sırasında devam eden enzim ihtiyacı ya da iğ ipliklerinin oluşumu için yalnızca golgi varlığını bölünme boyunca sürdürür.

14. Devam eden enzim gereksinimi için golgiye, bölünme sırasında gerekli olan enerjiyi karşılamak için de mitokondriye ihtiyaç vardır.

15. Bölünme için gerekli bütün maddeler ve enerji interfaz evresinde hazırlanır ve bölünme sırasında herhangi bir organele ihtiyaç duyulmaz.

16. İğ ipliklerini yalnızca sentrozom tarafından olusturur.

17. Bitkilerde sentrozom vardir.

18. İğ ipliklerini sentromer olusturur.

19. Sentrioller çekirdekte bulunur.

20. Sentrioller, çekirdekte bulunurlar ancak bölünme sırasında çekirdek zarının erimesiyle sitoplazmaya geçerler

21. Gamet ana hücreleri haploidtir.

22. Gamet hücreleri diploidtir.

23. Somatik hücreler homolog kromozomları bulundurmazlar.

24. Homolog kromozomlar ana hücrede kromozom eşlenmesiyle üretilir.

25. Kardeş kromatidler ile homolog kromozomlar temelde aynıdırlar.

26. Homolog kromozomlar birbirlerine sentromerlerinden bağlanmış olarak bulunurlar.

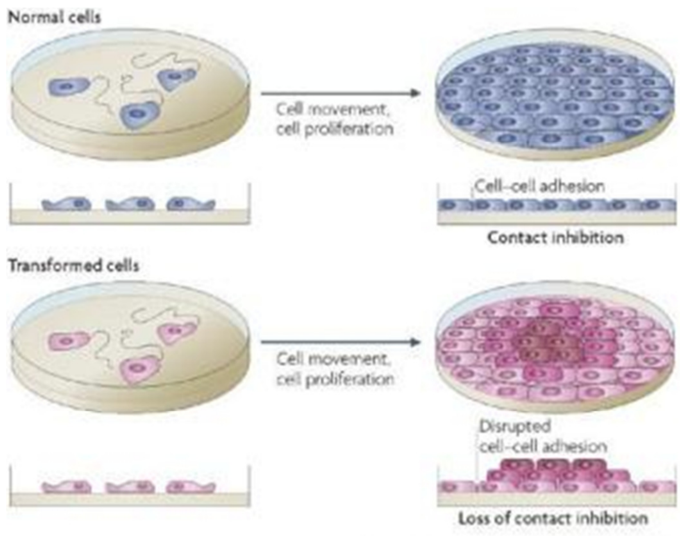
Öğretmen grupların Etkinlik 1 sonunda yapmıs oldukları sıralamanın doğru olup olmadığını kontrol etmelerini ister. Daha sonra hücre bölünmesinin kontrol mekanizmalarını ve kontrolsüz hücre bölünmesini açıklamak amacıyla Etkinlik 3' ü öğrencilere yaptırır. 4-5 kişilik öğrenci gruplarına basit etkinliği kısaca anlatır ve yapmalarını ister. Etkinlik sonunda tartışma soruları sınıfça cevaplandırılır.

ETKİNLİK 3

Tümörler nasıl oluşur?

Bu amaçla kullanılacak araç-gereçler:

- 2 adet petri kabı
- Düğmeler (iki farklı renkte)
- Etiket



Aşağıda sıralanmış adımları takip ederek etkinliği gerçekleştiriniz.

Adım 1. Petri kaplarını "normal doku" ve "tümör dokusu" olarak etiketleyiniz.

Adım 2. Normal doku adı ile etiketlediğiniz petri kabının ortasına istediğiniz renkte bir adet düğme yerleştiriniz. Bu düğmenin mitoz bölünme geçirdiğini düşününüz ve aynı renkte yeni düğmeler ekleyiniz. Düğme eklemeyi petri kabında 1 sıra düğme olana kadar devam ediniz. Petri kabının dolana kadar kaç defa hücre bölünmesi (mitoz) gerektiğini bulunuz.

Adım 3.Tümör dokusu adı ile etiketlediğiniz petri kabının ortasına da diğer renkte 1 adet düğme yerleştiriniz. Bu düğmenin mitoz bölünme geçirdiğini düşününüz ve aynı renkte yeni düğmeler ekleyiniz. Düğme eklemeyi petri kabında 1 sıra düğme olana kadar devam ediniz. Daha sonra orta noktadan (birinci düğmeyi koyduğunuz yerden) başlayarak yeni düğme eklemeye devam ediniz, üst üstte düğmeler ekleyiniz.

Tartışma soruları

-Düğmeler neyi temsil etmektedir?

-Sizce, tümörlü dokudaki hücreler normal hücrelerden farklı mıdır?

-İyi huylu tümör, kötü huylu tümör kelimelerini duydunuz mu? Neden böyle bir isimlendirme yapılmış olabilir?

-Vücudumuzda her gün kanser hücreleri oluşur ama kanser olmayız, Neden?

Tartışma sonunda öğretmen hücre döngüsünün interfaz safasının G1, S, G2 evrelerinden oluştuğunu, bu evrelerde gerçekleşen olayları ve hücre döngüsünün kontrol mekanizmalarını ayrıntılı olarak anlatır.

4. GENİŞLETME (ELABORATION)

Öğretmen aşağıdaki soruları yönlendirerek öğrencilerin öğrendikleri bilgileri kullanmalarını sağlar.

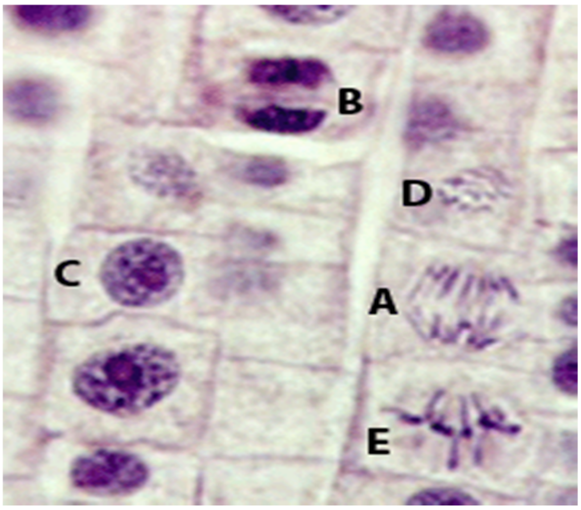
- Günlük hayatımızda vücudumuzda gözlemleyebileceğimiz mitoz bölünmeye örnek olabilecek değişiklikler neler olabilir?
  (Saçların uzaması, tırnakların uzaması, cildin yenilenmesi, kanımızın yenilenmesi, yaraların iyileşmesi vb. şeklinde cevaplar beklenmektedir.)
- Sizce neden kemoterapi (kanser hastalarının kullandıkları kimsayal ilaç) alan hastaların saçları dökülmektedir?
- Mitoz bölünme için bir hücrenin hangi yapılara ihtiyacı vardır?
  (Kalıtım materyaline (DNA) ve sentrozoma ihtiyaç vardır.)
- Sentrozomu olmayan hücreler var mıdır? Bu hücreler bölünebilirler mi?

(Bitki hücrelerinde sentrozom yoktur cevabı beklenir. Bu cevabı alan öğretmen bitkilerde sentrozom olmadığı için profazda iğ ipliklerinin sitoplazmadaki proteinler tarafından oluşturulduğu bilgisini verir.)

- Bitkilerde hayvanlardan farklı olarak başka hangi yapılar var? Bunlardan hücre bölünmesinde farklılığa neden olabilecek olan var mı?
  (Hücre duvarı ve plastitler vardır, hücre duvarı farklılık yaratabilir cevabı beklenir. Bu cevabı alan öğretmen bitkilerde ara lamel oluşumu ile duvarın bölündüğünü anlatır.)
- Bölünemeyen hücre olabilir mi? İnsan vücudundan bölünme özelliğini kaybetmiş hücrelere örnek verebilir misiniz?
  (Sinir hücresi, çizgili kas hücreleri, olgun alyuvar hücresi, gözdeki retina hücresi ve üreme hücrelerinde mitoz bölünme gözlenmez cevapları beklenir ancak alınamazsa nedenleri ile öğretmen tarafından açıklanır.)

5. DEĞERLENDİRME (EVALUATION)

Öğretmen aşağıdaki resmi projektör ile tahtaya yansıtır ve öğrencilerden harfler ile işaretlenmiş hücrelerin hücre döngüsünün hangi evresinde olduklarını söylemelerini ister.



Öğretmen aşağıdaki soruları öğrencilere yönlendirir.

- Interfaz evresinde gerçekleşen olaylar nelerdir?
- Profaz evresinde gerçekleşen olaylar nelerdir?
- Mitoz sonucunda oluşan hücreler ile ana hücreyi özellikleri bakımından karşılaştırınız.
- Bitki ve hayvan hücrelerinde mitozu karşılaştırınız.
- Hücre döngüsünün kontrolü nasıl sağlanır?

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CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Arslan, Harika Özge

Nationality: Turkish (TC)

Date and Place of Birth: 24 August 1980, Ankara

Marital Status: Married

e-mail: harikaozge@hotmail.com

EDUCATION

Degree	Institution	Year of Graduation
Ph.D.	METU, Biology Education	2014
MS	METU, Biology Education	2005
BS	Hacettepe University, Biology Dept.	2003
Lycee	Batıkent High School, Ankara	1998

WORK EXPERIENCE

Year	Place and Enrollment
2007 - Present	Middle East Technical University, Research Assistant SSME, Ankara.
2010 - 2011	University of Texas at San Antonio, Visiting Scholar, USA.
2005 - 2006	Çınar Diyaliz, Biolog, Ankara.
2003 - 2004	Final Dergisi Dersaneleri, Biology Teacher, Ankara.

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

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