JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898

LEARNING CYCLE MODEL TO FOSTER CONCEPTUAL UNDERSTANDING IN CELL DIVISION AND REPRODUCTION CONCEPTS

Abstract. *What should teachers do to ensure a student construct meaningful understanding in cell division and reproduction concepts? This research examined the effect of 5E learning cycle on 10th grade students' understanding of cell division and reproduction concepts and their alternative conceptions on these concepts. Mixed methods research design was utilized for this aim. Eight classes with 228 students from two public high schools were selected conventionally. Experimental groups received learning cycle (LC) and control groups received conventional teaching (CT) throughout the 10 weeks. A three-tier diagnostic test was administered to both groups as pre and post-tests. After the treatment, 12 students were interviewed semi-structurally. The results revealed that learning cycle is superior to conventional teaching on promoting conceptual change along with increasing understanding. The present research recommends teachers utilize learning cycle to improve students' understanding and remediate their alternative conceptions.*
Key words: *alternative conceptions, biology education, cell division, learning cycle, 5E model.*

Harika Özge Arslan
Yuzuncu Yil University, Turkey
Ömer Geban
Middle East Technical University, Turkey
Necdet Sağlam
Hacettepe University, Turkey

Harika Özge Arslan,
Ömer Geban,
Necdet Sağlam

Introduction

Cell Division and Reproduction (CDR) Concepts as a School Subject

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. Therefore, biological concepts are perceived as difficult to learn, and most of the students have difficulty with a wide range of biological concepts (Tekkaya, Ozkan, & Sungur, 2001). Specifically, genetics and the related concepts in biology curriculum have considered among the most difficult concepts in biology to learn by students (Brown, 1990; Kindfield 1991; Williams, Debarger, Montgomery, Zhou, & Tate, 2012). Williams et al. emphasized that "a strong understanding of biological inheritance necessarily requires a clear conception of cell division and of the differences and importance of mitosis and meiosis" (2012, p. 82). Consequently, lack of understanding and disconnection between meiosis, sexual reproduction and inheritance result in poor conceptual basis for genetics (Knippels, 2002). Most of the students have a great deal of difficulties in keeping in mind 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 daily life experiences to the knowledge of a/sexual reproduction (Knippels, 2002; Tekkaya et al. 2001). Domain specific terminology (Lewis, Leach, & Wood-Robinson, 2000), abstract nature of genetic concepts (Knippels, 2002; Tekkaya et al. 2001), and alternative conceptions (ACs), refers to students' incompatible ideas with scientific views for this particular research, on the cell division and reproduction (CDR) concepts (Atilboz, 2004; Brown, 1990; Kindfiled, 1991; Stewart, Hafner, & Dale, 1990) were stated among the sources of these difficulties. Smith also 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). 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, promoting effective teaching and learning of the fundamental ideas that underlie human genomics and genetic modification, such as inheritance, cell division, and sexual reproduction concepts are needed because of the important role of genetics in the society (Williams, et. al., 2012).

The findings of the studies conducted on students' conceptions of the CDR concepts revealed that students hold a mixture of many scientific and ACs in specifically about the purpose and the products of mitosis and meiosis processes (Brown, 1990; Lewis et al. 2000; Stewart et al. 1990; Williams et al. 2012). The more prevalent ACs are about the chromosome structure, chromosome number, homologous chromosomes, duplication, separation and crossing over in chromosomes, distinguishing the mitosis, and meiosis processes. Dispelling ACs requires more specific teaching strategies other than traditional methods because of the fact that ACs are stable and often resistant to change (Taber, 2001). In their research, Banet and Ayuso (2000) emphasized that traditional teaching strategies have a 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).

In Turkey, primary students (age 10) learn concrete biological concepts in science courses like the basic structure and function of several organ systems since they are in Piaget's concrete operational stage. In grade 6 (age 12), students begin to investigate the basic concepts related to cell and the connection with the cell division and growth and reproduction. They also learn the structure and functions of the chromosomes, asexual and sexual reproduction concepts without detail. In grade 8 (age 14), cell division and basic concepts of the heredity is studied, the name of the phases of divisions and the processes are not described. In grade 10 (age 16), students learn the process of cell division more closely within the context of sexual and asexual reproduction. Mitosis and meiosis are described in detail and the gametogenesis is also studied.

Learning Cycle (LC) to Promote Conceptual Change

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. Pioneer research studies generally claimed that at the beginning, students' current conceptions must be challenged then students must confront with some experiences and finally they must reconstruct their own understanding by more adequate explanations. Therefore, there should be a specific sequence in the instruction and this idea makes the learning cycle be one of the recommended teaching models that found as effective at helping students overcome ACs (Lawson, 1988; 2010). Lawson claimed in his research entitled with "A better way to teach biology" that the correct use of the LC 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 model is specially designed to facilitate the progress of conceptual change (Bybee et al. 2006). 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 teaching materials by the well-known project, Biological Sciences Curriculum Study (BSCS) (Bybee et al. 2006). Bybee et al. emphasized that each phase of 5E model has a particular function to foster both teachers' teaching and the learners' understanding of scientific concepts (2006). The significant effect of LC on conceptual achievement (Cakiroglu, 2006), and bringing about conceptual change (Bybee et al. 2006; Marek, Cowan, & Cavallo, 1994; Stepans, Dyche, & Beiswenger, 1988) compared to more teacher-centred teaching have been reported. Although many studies were conducted to compare teaching procedures, few have examined the effectiveness of the LC on eradicating the ACs related with the biology concepts. None of these limited number of studies (Marek et al. 1994; Saygin, 2009; Stepans et al. 1988) performed statistical hypothesis testing. These studies reported their results only as percentages of ACs before and after implementation.

ISSN 1648–3898

When the researches on the CDR concepts were examined, the effectiveness of LC related with these concepts are limited. Even, Danieley (1990) and Lawson (1991) prepared three-phase learning cycles to show how LC could be used to introduce the concept of mitosis; they did not investigate the effectiveness of them. In addition, there are unpublished dissertations on the effectiveness of LC on the CDR concepts; however, none of them examined the effect of LC on meaning construction of students or eliminating their ACs.

Aim of the Research

In view of the deficiency of research in cell division and reproduction concepts, perceived as one of the most difficult subjects in biology, we hypothesized that learning cycle might be an effective way to improve students' understanding and to promote conceptual change about cell division and reproduction concepts. Therefore, the results of this research have the potential to provide empirical evidence to the LC literature, especially related to the effectiveness in dispelling ACs. Specifically, this research aims to examine what are the differences in understanding and alternative conceptions between 10th graders who treated with learning cycle and those who treated with conventional teaching on cell division and reproduction concepts.

Methodology of Research

Mixed methods research design was utilized by collecting and analysing both quantitative and qualitative data in a single research. Explanatory design started with quantitative methods and then followed up with qualitative methods was used to explain the initial quantitative results (Creswell, Plano Clark, & Garrett, 2008). Therefore, triangulation of the data interpretations could be ensured. Two treatments; the learning cycle (LC) and conventional teaching (CT) have applied throughout the 10 weeks (2 class periods [=90 minutes] per week) during the spring 2011-2012 academic year. Diagnostic test was administered prior to and right after the intervention. Then, semi-constructed interviews were conducted.

Participants

Two hundred and twenty eight 10th graders from two public high schools were selected conveniently for the quantitative part of the research. The schools are in the same district and they were in the same percentile (5th percentile) based on the high school entrance examination results. One teacher from each school volunteered to participate. The groups have already formed by the school administrations before the research; however the teaching methods were randomly assigned to four intact classes of each teacher. So, each teacher who has over 10 years' experience in biology teaching, had two experimental and two control groups. After the treatment, 12 students also participated in the interviews. These students were selected purposefully to ensure medium level biology achievement and a high tendency to participate in the interview. The age range of the students was between 16-18 years (Table 1).

Table 1. Distributions of students in schools, groups, and gender.

	School-1				School-2				Total
	CG-1	CG-2	EG-1	EG-2	CG-1	CG-2	EG-1	EG-2	
Male	13(1)	12	12(1)	15	14	13(1)	16	15	110
Female	14(1)	17(1)	15(1)	12(1)	15(1)	16(1)	15(2)	14(1)	118
Total	27	29	27	27	29	29	31	29	228

Note. *CG-1 and CG-2 were treated with CT; EG-1 and EG-2 were treated with LC. Numbers in the parentheses show the numbers of the students participated to the interviews.*

Treatments

Lesson plans (Table 2) for both teaching methods were developed based on the national learning objectives (MONE, 2011). Reviews of a professor majoring in biology education and two participant biology teachers were used to establish treatment fidelity.

Learning Cycle (LC): Four lesson plans were prepared on four subtitles of the CDR unit based on the 5E learning cycle steps. The structure of the lesson plans was given in Table 2. In the first lesson plan, videos related to a famous singer who died of lung cancer, and an actress received treatment for cancer were displayed to stimulate students' curiosity in engagement phase. After the videos, teacher asked questions to reveal prior knowledge and ideas about cancer; they discussed how cancer might develop. The students guessed that the development of cancer is based on a fault in cell procedures. In the exploration phase, three activities were performed. In the first activity, groups of 4-5 students read a reading named as "One to Many: Cell Cycle" and how the body grows were discussed. Then, the teacher performed an experiment (Lets' Observe Cell Cycle), prepared microscope slides for each group to show mitosis in onion root tip cells and asked them to draw three cells with different appearance and to find how many daughter cells are produced after division. At the end, the teacher showed prepared microscope slides of mitosis to ensure that students see the desired display of the stages. The teacher provided support for the students who have limited microscopy skills. In the second activity, groups of 4- 5 students make a model of what they see under the microscope in the first experiment. The teacher did not interfere in student models, let them finish the model either correct or incorrect. Groups took notes of their questions and difficulties during the activity. In the explanation phase, the groups explained their models; teacher encouraged them to speak and directed leading questions to make them realize their mistakes. The students also asked the questions they have noted and the 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. Some of the groups used figures on their textbooks while constructing mitosis model and confused much. Because cell figures illustrated the phases of mitosis in the students' textbook were depicted as having replicated chromosomes in each phase. When all of the questions were discussed, the teacher divided board into three parts, wrote, interphase, mitosis, and cytokinesis in each cell respectively. Then teacher 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 wrote the name of the each phase. During this explanation phase teacher paid attention to ACs that were emerged from students' answers. When any AC was detected, the teacher asked that AC as a question to the class, whether it is correct or wrong according to their exploration. The teacher helped them find the correct explanations with reasons instead of providing knowledge. If they could not find it, the teacher referred the activities that students done and wanted them to think and discuss, guided them to find the scientific explanations by their own. The teacher had never explained directly the scientifically correct explanation to dispel ACs 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 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, the groups discussed the questions at the end of the activity sheet and then the whole class discussed them. Then the 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?" and "how cell cycle works in plants that do not have centrosome?". The class discussed these kinds of questions and they used their knowledge in different situations. In the evaluation step the teacher showed real cell pictures which are in different phases of cell cycle, asked students to determine the phase, justify their reasons and clarify the process of these phases. In addition, teacher made students summarize what they have learned by questions.

ISSN 1648–3898

Table 2. The structure of the lesson plans for EGs and CGs.

Subtitles	Experimental Groups	Control Groups	Duration
Mitosis (Lesson Plan I)	- Watching Videos on Cancer (E1) - Let's Observe Cell Cycle (E2) - Modelling Mitosis with Play dough (E2-E3) - Tumor Formation Experiment (E2-E3) - Discussion (Mitosis in Plant cells) (E4) - Conceptual Questions (E5)	- Remind prior knowledge - Reading: Cell Cycle - Present definitions directly - Explain the phases of mitosis - Show prepared posters - Explain mitosis in plant cells - Watching Videos on Cancer - Teacher asks conceptual questions	7 Class Hours
Asexual Reproduc-tion (Lesson Plan II)	- Reading: "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)	- Reading:" Summer Holiday" - Present definitions directly - Give examples of organisms - Watching Video on Grafting - Teacher explains the video - Teacher asks conceptual questions	3 Class Hours
Meiosis (Lesson Plan III)	-Reading: "A Story of A Baby" (E1) - Let's Observe Meiosis (E2) - Surprise with Sockosomes* (E2- E3) - Video on Mitosis and Meiosis (E4) - Bajema Strategy** (E5)	- Reading: "A Story of A Baby" - Present definitions directly - Explain the phases of meiosis - Show prepared posters - Video on Mitosis and Meiosis - Teacher asks conceptual questions	6 Class Hours
Sexual Reproduction (Lesson Plan IV)	- Frayer Model***(E1) - Explore an Egg (E2) - Video on Fertilization (E2) - How do Living Creatures Reproduce? (Activity) (E2) - Stem Cells Activity (E3) - Reading: "Life Cycle of Bees" (E4) - Comparison of Reproduction Types (E5)	- Present definitions directly - Give examples of organisms - Reading: "Life Cycle of Bees" - Video on Fertilization - Teacher explains the video - Teacher asks conceptual questions	4 Class Hours

Note. *E1= Engage, E2= Explore, E3= Explain, E4=Elaborate, E5=Evaluate. *Idoko, 2007** Mertens & Walker, 1992 *** Frayer, Fredrick, & Klausmeer, 1969.*

Conventional Teaching (CT): Similar with the EGs, four lesson plans were prepared on four subtitles of the CDR unit in accordance with conventional teaching for CGs. The structure of the lesson plans was given in Table 2. In CGs, the teachers mainly used lecturing and questioning during the lessons. They followed textbook and asked students to read the related parts before classes. Most of the time students were passive and asked for time to take notes on their notebooks. CGs did not make any activities performed in the EGs. John Henry Effect; the possible effect of receiving no treatment in students' performance either in the negative or positive manner was avoided by reading same readings and watching the same videos with the EGs in CGs. CGs discussed the readings or videos with their friends and teachers, but did not perform any experiments. The first lesson started with reminding students' existing knowledge such as; cell structure, the nucleus, the chromosome structure and DNA replication briefly since they have already instructed on these concepts in 8th and 9th grades. The teacher asked related questions with these concepts to take their attentions. In addition, CG students read the reading "One to Many: Cell Cycle" (same with EGs) and teacher encouraged them to explain what they thought about the meaning of cell cycle. Then, the teacher presented the definitions of chromatid, homolog chromosome, sister chromosome, haploid and diploid concepts to provide basis for clear understanding of cell division and let students to write each definition on their notebooks. The meaning of cell cycle was explained and each phase of mitosis was given in detail via board and chalk. The teacher showed prepared posters to make students visualize what is happening in the nucleus during mitosis. The teacher get students to take note all of the mitosis process and so, a large part of the time allocated for the mitosis passed with the students take notes on their notebooks since most of the students tended to write every words of teacher. The differences between the mitosis process of animal cells and plant cells were explained by the teacher. The CG students watched videos on cancer (same with EGs) and discussed the relationship between cancer and cell division. Then the teacher explained the control mechanisms of cell cycle and directed conceptual questions to sum up mitosis. During the CG lessons, the teacher provided further explanations of the concepts when students asked questions.

Procedure

Before teaching period, biology teachers were trained in the learning cycle model and how they should follow lesson plans and use teaching materials. In addition, before each class session, researchers reminded teachers the important points of lesson plans, provided handouts and materials which were not included in schools' laboratories. To verify treatments, one of the researchers and a research assistant carried out systematic classroom observations as a non-participant observer and rated classroom observation checklists for both EG and CG. The comparison of the checklists resulted in the lessons were consistent with the researchers planned.

Data Collection

Cell Division and Reproduction Diagnostic Test (CDRDiT): To determine students' understanding and reveal possible ACs on CDR concepts, the authors developed Cell Division and Reproduction Diagnostic Test (CDRDiT) from an already formed two-tier cell division diagnostic test (Ozdemir, 2008). The original test, consisted of 16 two-tier multiple-choice questions related to cell division concepts, was developed after students' interviews and pilot administrations. The first-tier of each item was a multiple-choice content question having usually two to three choices and 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 different from the listed ones. The distracters of the second tiers of the items consisted of ACs. Two questions were eliminated and 6 new questions on a/sexual reproduction concepts were generated based on the objectives of the national curriculum (MONE, 2011). Studies on ACs about the reproduction concepts were reviewed and listed to construct new questions. The list of ACs detected by CDRDiT was presented in Table 5.

A confidence-tier asking whether the students were confident or not about their responses was added to each question to compensate the weakness of two-tier diagnostic tests. Since the likelihood of guessing on multiple choice tests might overestimate students' knowledge and AC levels, therefore they could not differentiate ACs from lack of knowledge (Arslan, Cigdemoglu, & Moseley, 2012; Pesman & Eryilmaz, 2010). The CDRDiT included 20 three-tier multiple-choice questions reviewed by a professor majoring in biology education and three biology teachers, after revisions it was piloted with 85 11^{th} graders.

The Cronbach alpha reliability coefficient of the CDRDiT based on pilot study was .78. The mean item difficulty (p) calculated as .47 showed that it was a quite difficult test. The discrimination indices of items were higher than .30 therefore, all of the items were retained. When the alpha coefficient calculated with data obtained from the post-CDRDiT, it was .52, .69, and.79 for only the first-tiers, both two-tiers and all three-tiers of the test were considered respectively. Therefore, it can be concluded that the three-tier tests are more reliable than either regular multiple-choice tests or two-tier diagnostic tests (Pesman & Eryilmaz, 2010).

Interviews: After the intervention, semi-structured interviews were conducted with 12 students (see Table 1). In addition to the twenty conceptual questions (see Table 7), the researchers also directed probing questions to delve into the students' answers. Interviews lasted about 25-30 minutes and were audio-taped.

Data Analysis

The scoring procedure of the CDRDiT was quite complex than regular multiple-choice tests since different answer combinations are possible. Understanding score (Post CDRDiT) is the sum of correct responses to both first and second tiers along with being certain (correct/correct/ certain). Alternative conception score (Post AC) is the sum of being certain even the incorrect responses to the first and/or second tiers (correct/incorrect/certain, incorrect/correct/certain, and incorrect/incorrect/certain). Descriptive and inferential statistics (multivariate analysis of covariance [MANCOVA]) used to interpret the raw data. The variables were checked for any violation of the assumptions underlying the MANCOVA. Post-CDRDiT (understanding) and Post-AC (alternative conceptions)

ISSN 1648–3898

were dependent variables, teaching method was independent variable and Pre-AC scores were the covariate.

The qualitative data were transcribed verbatim and categorized under themes according to the rubric developed to evaluate the responses. Letters were used as nicknames for the interviewees (from A to F for the CG and from G to L for EG). If a student said s/he did not know the answer, it was categorized as "no response" (N). When a student's explanation includes a specific AC and s/he insisted on the response or repeated it more than once, it was categorized under "alternative conceptions" (ACs). Students sometimes just gave wrong answer and did not insist on their response in spite of the probing questions and these responses were categorized as "incorrect response" (I) since they are neither "no response" nor "AC". If a student answered a question partially even after the probing questions, it was categorized under "partially correct response" (P). When the response was comprehensive and included the whole answer of the question, it was categorized as "correct response" (C).

Results of Research

Before interpreting the descriptive and inferential statistics, the possible differences in post-CDRDiT, pre and post- AC scores of the students across schools and teachers were investigated and statistically significant difference was not found.

Descriptives: Table 4 shows the mean scores and the standard deviations of CG and EG on pre and post tests. The mean scores on pre-test were very close to each other, it can be said that these students have similar level of prior knowledge on CDR concepts, their conceptual understanding levels were also similar and very low and they held some ACs on these concepts before implementation. Therefore; it can be assumed that the groups were equivalent in this regard. The mean post-CDRDiT scores of the EG were higher than the score of CG. In harmony with these results, ACs scores of the EG were lower than CG.

Table 4. CG and EG students' scores on pre and post-CDRDiT.

Tests	Group	N	Pre-CDRDiT Mean	Pre-CDRDiT SD	Post-CDRDiT Mean	Post-CDRDiT SD
Understanding	CG	114	1.43	1.60	6.73	3.35
	EG	114	1.75	1.82	10.38	4.52
	Total	228	1.59	1.71	8.56	4.37
Alternative Conceptions	CG	114	7.21*	2.79	6.47*	2.07
	EG	114	7.48*	3.00	4.84*	2.42
	Total	228	7.35*	2.90	5.65*	2.39

Note. *CG: Control Group, EG: Experimental Group, *The higher the score the more ACs that the students' hold. Max score is 20 for CDRDiT, SD: Standard Deviation.*

The percentages of the ACs that the students held before and after the treatment were given in Table 5. After the treatment, nearly all of the percentages of ACs that EG students had decreased, but, in the CG group even some of them decreased, 12 of the ACs increased. When CG students' ACs examined (Table 5), 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-37 that is 'Homologous 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 ACs of EG are in the range of 0-1% percentages after implementation which shows that these ACs remediated with the help of LC.

Table 5. List of ACs in the CDRDiT and their percentages before and after treatment.

Topic	Alternative Conceptions	CG (%) Pre	CG (%) Post	EG (%) Pre	EG (%) Post
Mitosis	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, amount of chromosomal DNA does not change.	12	18	5	1
	5. The number of chromosome is fixed and remains unchanged 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 preparation 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 separate from each other during mitosis.	18	6	30	3
	11. Sister chromatids separate from each other only during mitosis.	11	4	11	1
	12. All of the organelles dissolve and disappear during mitosis.	19	17	14	13
	13. Spindle fibers are only formed by centrosomes.	24	28	28	14
	14. There are centrosomes in plant cells.	11	1	13	3
Asexual Rep.	15. Only single-celled organisms can reproduce by mitosis.	10	8	7	2
	16. All single-celled organisms and multicellular organisms that have regeneration ability can reproduce by mitosis.	18	4	17	5

Even the prevalence of 39 ACs decreased, some of the EG students still held ACs after the treatment. Especially AC-33 which is stated 'Sexual reproduction must involve mating' shows the highest percentage among the ACs. There is not any objectives stressed on the role of mating in the national curriculum therefore, the lack of emphasize on mating in lesson plans might be the primary reason of this situation in both groups.

(Table 5 continued).

Topic	Alternative Conceptions	CG (%) Pre	CG (%) Post	EG (%) Pre	EG (%) Post
Meiosis	17. The number of chromosome remains unchanged after meiosis.	9	1	2	0
	18. Both homologous chromosomes and sister chromatids separate and the number of chromosomes halves in two times.	20	4	24	5
	19. Homologous chromosomes separated in meiosis I and they are sent to daughter cells without a change.	2	14	6	9
	20. The number of chromosome remains unchanged in meiosis-I and halves in meiosis II.	16	11	26	9
	21. Daughter cells have diploid chromosome number.	4	2	4	1
	22. Sister chromatids separate from each other only during meiosis.	16	2	20	0
	23. DNA needs to be replicated after meiosis I.	23	11	18	9
	24. All diploid cells can undergo cell division by mitosis and meiosis.	11	11	15	5
	25. Only haploid cells can undergo mitosis.	16	6	15	9

ISSN 1648–3898

Topic	Alternative Conceptions	CG (%) Pre	CG (%) Post	EG (%) Pre	EG (%) Post
Sexual Reproduction	26. Changes in the number of chromosomes provide genetic diversity.	8	1	4	0
	27. Plants reproduce by only asexual reproduction.	17	3	15	4
	28. Plants reproduce by pollination which is a kind of asexual reproduction.	6	2	4	0
	29. Non-flowering plants reproduce by asexual but flowering plants reproduce by sexual reproduction.	17	34	20	10
	30. Fertilization occurs during parthenogenesis.	25	26	36	21
	31. Reproduction is not possible without fertilization.	11	7	9	15
	32. Diploid gametes can develop without fertilization.	4	4	9	3
	33. Sexual reproduction must involve mating.	35	56	48	47
Chromosomes and Organelles	34. Centrioles are located in the nucleus of the cell but move to cytoplasm after the nucleus wall dissolves.	12	15	11	14
	35. Gamete mother cells are haploid.	5	7	10	4
	36. Gametes are diploid.	16	8	20	3
	37. Homologous chromosomes placed only in the daughter cells after meiosis.	20	30	15	8
	38. Homologous chromosomes are produced by DNA replication.	34	27	29	9
	39. Homologous chromosomes are formed only in meiosis.	15	2	15	1
	40. Homologous chromosomes and sister chromatids are essentially the same thing.	15	13	14	6
	41. Homologous chromosomes are tied each other from their centromeres.	6	3	5	3
Regeneration	42. Highly organized animals have more regeneration ability compared to primitive ones.	2	4	5	3
	43. Animals with large bodies have much regeneration ability.	21	8	23	9
	44. Genetic diversity can be provided by regeneration.	4	7	4	4

Inferential Statistics: Prior to treatment, independent sample t-test was performed to determine if a statistically significant mean differences exist between EGs and CGs with respects to pre-CDRDiT and Pre-AC scores. No significant mean difference across CG (M= 1.43, SD= 1.60) and EG (M= 1.75, SD= 1.82) [t (226) = -1.390, p > 0.05] in Pre-CDRDiT scores was found. In addition, no difference between groups (M= 7.21, SD= 2.79 for CG and M= 7.48, SD= 3.00 for EG) based on their pre-AC scores [t (226) = -.684, p > 0.05] was detected.

The results on the main effects of teaching methods showed that there are statistically significant mean differences between CG and EG on the combined dependent variables of post-CDRDiT and post-AC scores after adjusting for pre-AC scores of the students [F (2, 223) = 26.419, Wilks'λ = .808, p =.000, partial ' ^{2}=.19]. The ANCOVAs (Table 6) showed the particular effect of independent variables on each dependent variable.

Table 6. Results of follow-up ANCOVAs.

Independent Variable	Dependent Variable	df	F	Sig. (p)	Eta Squared	Observed Power
Teaching Method	Post-CDRDiT	1	45.519	.000*	.169	1.000
	Post-AC	1	29.465	.000*	.116	1.000

Note. **Test is significant at the .025 level (Bonferroni adjustment was used to control type 1 error).*

Since both tests were significant, it can be concluded that there is significant mean difference between CGs and EGs' conceptual understanding and ACs on CDR concepts because of different teaching methods. When the estimated marginal post-CDRDiT means of the groups (M=6.712 for CG and M=10.361 for EG), and Post-AC means (M=6.481 for CG and M=4.878 for EGI) were compared, the differences were in favor of EG. The EG scored higher on average on the Post-CDRDiT scores and they had statistically significantly fewer ACs than the CG.

Qualitative Results

The analysis of the interview questions indicated that the EG students demonstrated higher understanding and held less ACs on the CDR concepts when compared to CG students after the treatment. The percentages of the students' answers were summarized in Table 7.

When the responses to the questions about cell division were examined, in CG maximum 3 students (50%) gave the correct answer, however, in EG minimum 3 students (50%) answered correctly. For instance, when researcher directed question "what happens to the parent cell after cell division?" all students in EG (100%) and three students (50%) in CG answered correctly.

Moreover, two of the rest of the students held a specific AC that "Parent cell remains after cell division". Both of the students insisted on their answers. The excerpt below belongs to Student C from the CG shows AC of the student and the possible 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 cell remains and there will be three cells.

Table 7. The number of the students based on their responses to interview questions.

		CG					EG				
Topic	Interview Questions	N	AC	I	P	C	N	AC	I	P	C
Cell Division	Does every cell divide?	0	0	2	1	3	0	0	2	0	4
	Why do cells divide?	1	1	0	2	2	1	0	0	2	3
	What happens to a parent cell?	1	2	0	0	3	0	0	0	0	6
	What are the meaning of n and 2n?	1	3	0	0	2	0	1	0	1	4
Mitosis	What is the aim of mitosis?	0	0	0	2	4	0	0	0	1	5
	When does DNA replication occur?	1	2	1	0	2	1	0	0	0	5
	Which cells undergoes mitosis?	2	1	0	2	1	0	0	0	0	6
	Do parent cell and daughter cells differ?	0	0	1	2	3	0	0	0	2	4
	Do daughter cells differ?	0	1	0	2	3	0	0	0	2	4
Meiosis	What is the aim of meiosis?	1	0	1	2	2	0	0	0	1	5
	Which cells undergoes meiosis?	1	2	0	1	2	0	1	0	0	5
	What is the reason of decrease in chromosome number?	0	0	2	0	4	0	0	0	0	6
	Is it advantageous to delete one pair of each homolog chromosomes?	3	0	1	0	2	0	0	1	1	4
Comparison of mitosis and meiosis	What are the similarities between mitosis and meiosis?	0	0	1	2	3	0	0	0	3	3
	What are the differences between mitosis and meiosis?	0	0	0	5	1	0	0	0	1	5
	What is the reason of the need for two different types of cell division?	2	0	1	2	1	0	0	0	1	5

ISSN 1648–3898

		CG					EG				
Asexual reproduction	What are the types of asexual reproduction?	1	0	0	2	3	0	0	0	1	5
	Which organisms reproduce asexually?	0	1	0	0	5	0	0	0	0	6
Sexual reproduction	Which organisms reproduce sexually?	0	1	0	0	5	0	0	0	0	6
	Is it possible to reproduce by both sexually and asexually?	1	1	1	2	1	0	1	0	0	5
	What are the similarities between asexual and sexual reproduction?	1	0	2	3	0	0	0	0	5	1
	What are the differences between asexual and sexual reproduction?	1	0	0	4	1	0	0	0	4	2

Note. *N= No response, AC= Alternative conception, I= Incorrect response, P= Partially correct response, C= Correct response. Numbers represents the numbers of the students whose answer was categorized under that theme. The percentages are; 1 (16.7%), 2 (33.3%), 3 (50%), 4(66.7%), 5 (83.3%), 6 (100%).*

Similar excerpt below belongs to student F from the CG indicates how similar ideas that these students held:

Researcher : What do you think what happens to the parent cell after 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 exists, isn't it?
Researcher : .....
Student F : I know that, there will be two new cells from the mother cell.
Researcher : So, you mean that at the end there will be three cells, right?
Student F : Yes, of course.

When the meaning of the abbreviations "n" and "2n" were asked to the students, 4 students (66%) of EG and 2 students (33%) of CG answered correctly. One of the EG students' (student G) answer which is "n is used for haploid organisms and 2n is used for diploid organisms" categorized as partially correct. 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 the 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.

There were two ACs aroused from students' responses to the fore-mentioned question. These ACs 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 CG students (50%) and one EG student (16.7%) held AC about n/2n concept. One of those CG 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 used for the diploid cells and n is used for the 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, of course, 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 ACs. The decision of the student D did not change that s/he held ACs on these concepts indeed, since both of the answers were totally wrong. It was clear that s/he does not have the idea of being hapliod or diploid cell depends on having homologuos chromosomes.

It is obvious from the above expressions, these students confused the terms mitosis with asexual reproduction and meiosis with sexual reproduction. The ACs detected via interviews were listed in Table 8. The number of ACs held by CG students is more than EG students. Seven different ACs than those that are revealed by CDRDiT were identified via interviews and most of them held by CGs.

Table 8. The numbers of students and the percentages of the ACs revealed from interviews.

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

Note. *The AC numbers given in the parentheses shows the same ones in the CDRDiT items (Table 5). The percentages are; 1 (16.7%), 2 (33.3%).*

Discussion

In this research, a significant effect of learning cycle on conceptual change, thus conceptual understanding than conventional teaching is found. In particular, compared with the CG, the EG scored significantly higher on diagnostic conceptual items and displayed fewer alternative conceptions when answering both diagnostic items and interview questions. The findings provide further empirical support for the studies reported significant results about the effectiveness of learning cycle over traditional teaching on students' understandings levels in several biology concepts (Cakiroglu, 2006; Marek et al., 1994; Saygın, 2009). During the implementation in EGs, the students constructed their understanding of the CDR concepts by involving in activities, sharing their ideas, asking questions and discussing with both their teachers and friends. Rather than presenting concepts through teacher-centred lectures, daily life contexts were put forward within the discussion to engage the students, after students explore concepts; they were prompted to explain and discuss their understanding. These efforts in experimental groups might foster conceptual understanding of the students on the CDR concepts.

Corresponding to the improvements of students' understanding of the CDR concepts, there is a decrease in their ACs in both groups. Although, groups have similar mean alternative conceptions scores before the treatment, the decrease in their scores was more than in EGs than the one in CGs. The follow-up ANCOVA results supported that the decrease is statistically significant. Data obtained from the interviews provided evidence for the CGs

ISSN 1648–3898

held more ACs than EG. Therefore, it might be concluded that 5E model created a learning environment in which students are allowed to confront their ACs and develop understandings on these concepts and eliminate ACs. The results of this particular research provided strong evidence to both Lawson's and Bybee, et al.'s claims that LC facilitates the progress of conceptual change (Bybee et al. 2006, Lawson, 1988). EGs found the opportunity to discuss and test their alternative ideas, thus they became "disequilibrated" and they conceptualized the scientific explanations by acceptable reasoning patterns at the end of the process. In addition, teachers diagnosed the typical conceptual error patterns in the explanation phase, identified the underlying alternative conceptions, and asked questions that focus these ACs until the students realized the misunderstanding and the scientific explanation. On the other hand, in CGs direct explanations of the scientific facts and lack of student-centred activities failed to improve conceptual understanding and left many ACs unchanged. However, both groups still held some ACs even after the implementation; this result might be an evidence to support the claim that the ACs are very robust and resistant to change (e.g. Taber, 2001). The result of the present research is consistent with the studies investigated the effectiveness of LC on ACs over more conventional methods, since they were reported that LC is more effective in bringing about conceptual change (Marek et al. 1994; Saygin, 2009; Stepans et al. 1988).

The interviews clarified that most of the CG students and some of the EG students could not support their answers when "why" question was directed. Therefore, it can be concluded CG students just tend to memorize the cell division processes happening at the microscopic level without conceptual understanding. After the implementation, the common AC, "Parent cell remains after cell division" was identified in two of the CG students' answers. 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. Such a finding may be attributed to the fact that the AC 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 as Smith (1991) stated. The results of the research supported the idea that the representation/diagrams play an important role on conceptual understanding on cell processes. Since, in CG the teacher usually used these kinds of representations of mitosis and meiosis to explain these processes.

Conclusions

Dispelling ACs is challenging issue and it requires more specific teaching strategies other than didactic methods. The present research hypothesized that the sequence of teaching in learning cycle model helps teachers correct their students' alternative ideas. This research is unique in a sense that both mixed method research design and hypothesis testing were utilized to investigate the effectiveness of learning cycle in conceptual understanding different from the relevant studies presented previously. Therefore, the results become more reliable since they are supported by both statistical analysis and qualitative data. The findings of this particular research provided a strong support that the learning cycle model could be a best choice for teachers to facilitate the progress of conceptual change and thus meaningful knowledge construction. The learning cycle utilized in this research, provides opportunities for students to actively engage in investigations, test their hypothesis, collect and analyse the data, and interpret the results. Thus the inquiry based nature of the learning cycle plays a crucial role on the effectiveness of this model on students' knowledge construction. Identification of alternative conceptions is an important initial step to design effective learning cycles, and it is hoped that the three-tier diagnostic test (CDRDiT) developed in this research can be used by teachers for defining their students' alternative conceptions on cell division and reproduction concepts easily.

The abstract nature of the CDR concepts requires that these concepts should be introduced to the formal operational stage students (age 12 and up). In Turkey, 6 graders (age 12) begin to study basic concepts of CDR however; a meaningful understanding of these concepts might be difficult for the students who are in the transition period from the concrete operational to the formal operational stage. In this research, alternative conceptions were detected in both groups before the instruction. Even there are different sources of alternative conceptions, ineffective learning strategies or poor learning in previous grades might result in these alternative conceptions, since students do not encounter with the CDR concepts in their daily life due to the abstract nature of these concepts. Therefore, developing learning cycles corresponding to the learning objectives of 6^{th} and 8^{th} grades of the science curriculum in Turkey will help to prevent alternative conceptions on the CDR concepts.

The generalizability of the findings is limited to the population of this research and ten week treatment period; new research designs with different population and with longer treatment period seems to be required to increase the generalizability of the effectiveness of LC. In addition, to reveal the effect of LC on the long term retention of the related concepts, further studies might investigate conceptualization with delayed post-tests. Furthermore, the current research recommends researchers to develop LC for several biological concepts to investigate the effectiveness of LC in improving students' understanding and eliminating their ACs.

References

Atilboz, N. G. (2004). 9th Grade students' understanding levels and misconceptions about mitosis and meiosis. *Journal of Gazi Education Faculty, 24* (3), 147-157.

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education*, *34* (11), 1667-1686.

Banet, E., & Ayuso, E. (2000). Teaching genetics at secondary school: A strategy for teaching about the location of inheritance information. *Science Education, 84*, 313-351.

Brown, C. R. (1990). Some misconceptions in meiosis shown by students responding to an advanced level practical examination question in biology. *Journal of Biological Education, 24* (3), 182-186.

Bybee, R., Taylor, J., Gardner, A., Scotter, P. V., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness.* Colorado Springs, CO: BSCS.

Cakiroglu, J. (2006). The effect of learning cycle approach on students' achievement in science. *Eurasian Journal of Educational Research, 22*, 61-73.

Creswell, J. W., Plano Clark, V. L., & Garrett, A. L. (2008). Methodological issues in conducting mixed methods research designs. In: M. Bergman (Eds.), *Advances in Mixed Methods Research*, (pp. 66-83). Sage, London.

Danieley, H. (1990). Exploring mitosis through the learning cycle. *The American Biology Teacher*, *52* (5), 295-296.

Dikmenli, M. (2010). Misconceptions of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essay, 5* (2), 235-247.

Frayer, D., Frederick, W. C, & Klausmeier, H. J. (1969) *A schema for testing the level of cognitive mastery*. Madison, WI: Wisconsin Center for Education Research.

Idoko, C. E. (2007). Guide for effective teaching\learning of genetics for secondary school students (Handson mindson activity instructional strategy). *Multidisciplinary Journal of Research Development, 9* (1), 22-30.

Kindfield, A. C. H. (1991). Confusing chromosome number and structure: A common student error. *Journal of Biological Education, 25* (3), 193-200.

Knippels, M. C. P. J. (2002). *Coping with the abstract and complex nature of genetics in biology education. The Yo-Yo Learning and Teaching Strategy*. Utrecht: CD-ß Press.

Lawson, A. E. (1988). A better way to teach biology. *The American Biology Teacher, 50* (5), 266-278.

Lawson, A. E. (1991). Exploring growth (& mitosis) through a learning cycle. *The American Biology Teacher*, *53* (2), 107-110.

Lawson, A. E. (2010). *Teaching inquiry science in middle and secondary schools*. Sage Publications, Inc.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000). Chromosomes: the missing link – Young people's understanding of mitosis, meiosis, and fertilization. *Journal of Biological Education, 34* (4), 189-199.

Marek, E. A., Cowan, C. C., & Cavallo, A. M. (1994). Students' misconceptions about diffusion: How can they be eliminated? *The American Biology Teacher*, *56* (2), 74-77.

Mertens, T. R., & Walker, J. 0. (1992). A paper-and-pencil strategy for teaching mitosis and meiosis, Diagnosing learning problems and predicting examination performance. *The American Biology Teacher, 54*, 470-475.

Ministry of National Education [MONE], (2011). Ortaöğretim 10. Sınıf biyoloji dersi öğretim programı. Retrieved from http://ttkb.meb.gov.tr/www/ogretim-programlari/icerik/72.

Ozdemir, A. (2008). *Üniversite öğrencilerinin hücre bölünmeleri ile ilgili kavram yanılgılarının iki aşamalı çoktan seçmeli bir test ile belirlenmesi [Identification of university students' misconceptions about the cell divisions using a two-tier multiple choice test]* (Unpublished master's thesis). Selcuk University, Konya, Turkey.

Pesman, H., & Eryilmaz, A. (2010). Development of a three-tier test to assess misconceptions about simple electric circuits. *The Journal of Educational Research, 103*, 208–222.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211–227.

Saygın, O. (2009). *Examining the effects of using learning cycle to high school students' understanding of nucleic acids and protein synthesis subjects, their motivation and learning strategies* (Unpublished doctoral dissertation). Gazi University, Ankara, Turkey.

Smith, M. U. (1991). Teaching cell division: Student difficulties and teaching recommendations. *Journal of College Science Teaching,* (21), 28-33.

ISSN 1648–3898

Stepans, J., Dyche, S., & Beiswenger, R. (1988). The effect of two instructional models in bringing about a conceptual change in the understanding of science concepts by prospective elementary teachers. *Science Education*, *72* (2), 185-195.
Stewart, J., Hafner, B., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher, 52* (4), 228-232.
Taber, K. S. (2001). Shifting sands: A case study of conceptual development as competition between alternative conceptions. *International Journal of Science Education, 23* (7), 731-753.
Tekkaya, C., Özkan, Ö., & Sungur, S. (2001). Biology concepts perceived as difficult by Turkish high school students. *Hacettepe University Journal of Education*, *21,* 145-150.
Williams, M., DeBarger, A.H., Montgomery, B.L., Zhou, X., & Tate, E. (2012). Exploring middle school students' conceptions of the relationship between genetic inheritance and cell division. *Science Education, 96* (1), 78–103.

Received: *July 16, 2015* Accepted: *October 22, 2015*

Harika Özge Arslan	PhD, Research Assistant, Yuzuncu Yil University, Department of Secondary Science & Mathematics Education, Van, Turkey. E-mail: harikaozge@gmail.com
Ömer Geban	PhD, Professor, Middle East Technical University, Department of Secondary Science & Mathematics Education, Ankara, Turkey. E-mail: geban@metu.edu.tr Website: http://fedu.metu.edu.tr/tr/node/141
Necdet Sağlam	PhD, Professor, Hacettepe University, Nanotechnology and Nanomedicine Department, Ankara, Turkey. E-mail: saglam@hacettepe.edu.tr Website: http://www.nanott.hacettepe.edu.tr/belgeler/NS_CV_20130925.pdf