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Full Length Research Paper

Misconceptions of cell division held by student teachers in biology: A drawing analysis

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The purpose of this study was to identify biology student teachers' misconceptions of cell divisions using drawings and interviews. Data were collected from 124 biology student teachers. An analysis of drawings and interviews suggested that biology student teachers have a series of significant problems and misconceptions regarding cell division and structuring of concepts in a meaningful manner. These problems were mainly associated with meiosis rather than mitosis. The students confused the stages of the cell division process and the events occurring at these stages. Some misconceptions identified from this study included that DNA replication occurs in the prophase during the cell division, interphase is the resting phase of mitosis, the chromosome number is doubled in prophase of mitosis and halved in anaphase of mitosis, the chromosome number remains the same during meiosis-I and it is halved during meiosis-II, and a chromosome has always two chromatids during cell division. These results were compared with related literature and recommendations were made for teachers and researchers for future studies to overcome students' misconceptions.

Key words: Biology education, cell division, students' drawings, misconceptions.

INTRODUCTION

A major thrust in science education research over the past three decades has been the documentation of students' misconceptions in a wide range of subject areas (Pfundt and Duit, 2004). The term "misconceptions" has been coined to describe alternative conceptions, naive theories or views of science which are not consistent with concepts currently accepted by the community of scientists. Students' misconceptions are often deeply rooted, instruction-resistant obstacles to the acquisition of scientific concepts and remain even after instruction. Misconceptions are part of a larger knowledge system that involves many interrelated concepts that students use to make sense of their experiences. Students hold misconceptions that were developed before and during their early school years. These misconceptions may be compounded by the teacher or the textbook (Bahar, 2003; Wandersee et al., 1994).

A large number of prior studies reported that primary and secondary school students have many conceptional problems concerning cell biology and genetics (Flores et al., 2003; Lewis and Wood-Robinson, 2000; Marbach-Ad and Stavy, 2000). However, any detailed research related to biology student teachers' misconceptions about cell division was not found. If higher education curriculum designers knew students' misconceptions, it might be helpful to prepare effective teaching strategies. Teachers can play an important role in teaching scientific concepts and, from a constructivist perspective, students should gain meaningful knowledge about biological concepts like cell division. Biologically literate students should be able to use and apply basic biological concepts when considering biological problems or issues. Prior studies have shown that students experience difficulties in learning concepts related to the cell division process (Kindfield, 1994). Cell division constitutes the basis for genetics, reproduction, growth, development, and molecular biology subjects in the biology curriculum. As a matter of fact, a majority of the students or teachers evaluated topics such as gene, DNA, chromosome, and cell division as difficult to learn topics (Oztas et al., 2003).

Research on students' conceptual understandings often indicates that, even after being taught, students use misconceptions different from the scientific concepts (Lewis et al., 2000; Yesilyurt and Kara, 2007). Reasons for these misconceptions include students' inability to differentiate between doubling (replication), pairing (synapsis), and separating (disjunction), as well as determining whether or not these processes occur in mitosis, meiosis, or both (Smith, 1991). Further misconceptions include a lack of understanding of basic terms confusing chromatids with chromosomes, or repli-cated chromosomes with unreplicated chromosomes, etc. (Kindfield, 1994). This is a concern for instructors because cell division processes are fundamental to the understanding of growth, development, reproduction, and genetics (Chinnici et al., 2004; Cordero and Szweczak, 1994).

Studies conducted on problem-solving related to genetics revealed that students have some misconceptions regarding the stages of meiosis (Brown, 1990; Stewart and Dale, 1989). Accurate organizing of many concepts in cell biology is dependent on the degree of understanding cell division (Smith and Kindfield, 1999). As a matter of fact, a study related to genetics mentioned that students possess misconceptions and inadequate knowledge about the behavior of chromosomes and transference of genetic material during cell division. It further suggested that such misconceptions lead to conceptual problems in genetics (Kibuka-Sebitosi, 2007).

Yilmaz et al. (1998) studied the misconceptions possessed by 9^{th} grade students relating to cell division, and the effect of the conceptual teaching regarding elimination of such conceptions. They posit that concepttual teaching is an effective method for understanding the concepts related to cell division and for elimination of misconceptions. Lewis et al. (2000) studied the students' levels of understanding in regards to mitosis, meiosis, and fertilization. Conclusions of this study have shown that students possess inadequate knowledge and numerous misconceptions related to the physical relationships between the genetic material and the chromosomes, and the relationships between the behavior of the chromosomes and continuity of the genetic information. Lewis et al. (2000) further emphasized the fact that the students mainly experience difficulties for explaining the relationships between the cell, nucleus, chromosome, and gene concepts, and the similarities and differences between mitosis and meiosis. Clark and Mathis (2000) indicated that students experience difficulties particularly for discriminating chromatids, chromosomes, and the homologous parts of the chromosomes during the cell division process. Conclusions of this study have shown that these difficulties related to the structure and behavior of the chromosome can be easily identified and removed by means of models. Atilboz (2004) studied the level of understanding and misconceptions of 9^{th} grade students related to mitosis and meiosis. Conclusions of this study have shown that students experience difficulties in understanding fundamental concepts, such as DNA, chromosome, chromatid, homologous chromosomes, haploid and diploid cells, and the relationships between such concepts, and possess some misconceptions. Saka et al. (2006) have shown that science student teachers have misconceptions, particularly regarding the concepts of gene and chromosome, in accordance with their findings obtained from written responses and drawings. Kruger et al. (2006) studied the concepts of students regarding cell division and growth. Conclusions of this study revealed that students generally focus on the increase occurring with number of the cells, as a result of cell division and disregard the growth occurring in the cells. Kruger and colleagues also indicated that such difficulties experienced during understanding such concepts might be overcome by learning activities that researchers have developed. Riemeier and Gropengießer (2008) analyzed the difficulties in learning as experienced by the 9^{th} grade students regarding cell division, and their conceptual understandings within teaching experiments. They have shown that well planned teaching activities for the cell biology might enhance the conceptual development process and might contribute to the conceptual learning by the students. It is obvious from the literature that misconceptions related to cell division processes lead to a series of problems for the biology teaching. When attending their biology classes, students bring their perceptions, prejudices, and former experiences in conflict with the scientific facts. This situation causes various problems to arise during their biology classes. Keeping knowledge or conceptual frames of the students in line with the scientific facts can only be possible with effective conceptual teaching.

There are a number of techniques used to determine conceptual understanding and misconceptions of students. Open-ended questions, two-tier diagnostic tests, interviews, and drawings may be given as examples of these techniques. Using drawings to access student's thinking has been a feature of educational research. Students can present a broad spectrum of ideas through drawings (Rennie and Jarvis, 1995). Drawings have been used broadly in science education studies of students' conceptual understanding (Ben-Zvi Assaraf and Orion, 2005). It is recognized that drawings expose students' true understanding and conceptualization of basic scientific ideas and concepts. This is in contrast to what is exposed by standard written texts, where students can repeat what they learned in class without revealing their misconceptions (Scherz and Oren, 2006). Student drawings in the area of biology can provide useful insight into common misconceptions or alternative conceptions (Bahar et al., 2008; Bowker, 2007; Kose, 2008; Prokop and Fanèovièová, 2006). As a technique for exploring ideas, drawing taps holistic understanding and prevents students from feeling constrained by attempting to match their knowledge with that of the researcher (White and Gunstone, 2000). Thus, by using simple drawings, biology educators can gather

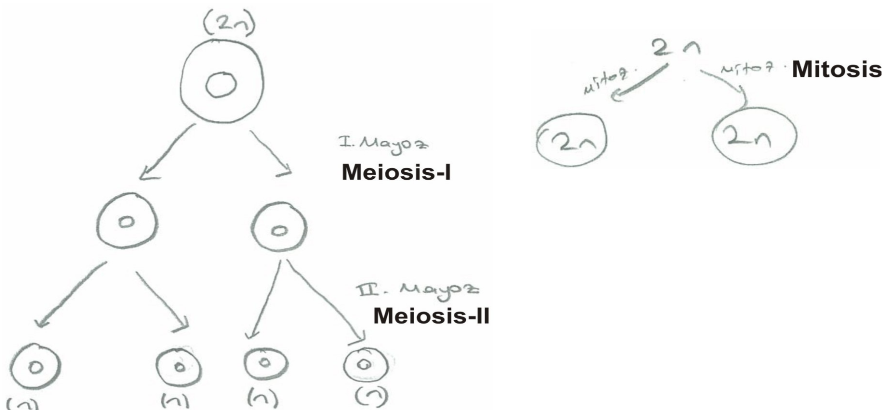

Figure 1. Example of level 2 (non-representational drawing).

large amounts of data on the mental models students have about scientific concepts.

Purpose

The purpose of this study was to identify biology student teachers' misconceptions of cell divisions using drawings and interviews. This study focuses on the misconceptions that biology student teachers possess about the cell division processes and both the content and scope of these misconceptions.

METHODOLOGY

Participants

A total of 124 student teachers, who were studying to become secondary biology teachers at the Faculty of Education in Selcuk University in Turkey, participated in this study. The average age of students was 22.3 years (range 21 - 25). The majority of students were females (76 of 124). However, this study was not focused on gender differences. In the literature no high gender differences were found in this field (Kibbos et al., 2004). Thus, the gender difference was not examined in this study. Participants previously had studied cell division in cytology, genetics, and molecular biology, as a school subject during various semesters. Research was conducted in October, 2008.

Data collection

Biology student teachers' understanding of the mitosis and meiosis was examined by two different methods not mutually exclusive: 1.) students' drawings and 2.) individual interviews. The drawing method was chosen to enable a deep, distinctive insight into the students' understanding (Rennie and Jarvis, 1995). The participating students were asked to draw mitosis and meiosis in a cell on a blank piece of A4-sized paper. The participants were informed about the drawing method before this application. Also some practices were applied about this method. In addition, individual interviews were conducted about the detailed subjects with 15 randomly chosen students who demonstrated misconceptions. The purpose was to check the validity of the interpretation of the drawings. In the interview, these students were asked to respond to questions like "What are chromosomes?," "When does DNA replication occur in a cell?," "What are the differences and similarities between mitosis and meiosis?," "What happens to the cell organelles during the cell division process?," "How do the chromosomes act during mitosis and meiosis?." Their responses are given below by comparing with the drawings.

Analysis

All the drawings were analyzed independently by the researcher and three lecturers in biology. The analyzing results were compared; the differences about a few cases were opened for discussion and then a final decision about the analyzing was made. Students' responses to the drawing activity were analyzed, using a coding framework prepared by Kose (2008) and Reiss and Tunnicliffe (2001). Using this framework, five levels of conceptual understanding were identified for this investigation-no drawing, non-representational drawings, drawings with misconceptions, partial drawings, and comprehensive representation drawings. Details of the levels were as follows:

Level 1: No Drawing: Students replied, "I don't know," or no response was given to the statement.
Level 2: Non-Representational Drawings: These drawings included identifiable elements of cell division. Also the responses, which included diagrams or formulations instead of the drawings, were evaluated in this category (See Figure 1).
Level 3: Drawings with Misconceptions: These types of drawings showed some degree of understanding on cell division concepts, but also demonstrated some misconceptions (Figures 2a and b).
Level 4: Partial Drawings: The drawings in this category demonstrated partial understanding of the concepts. They included elements of the cell division like prophase, metaphase, anaphase, telophase, etc. (Figure 3).
Level 5: Comprehensive Representation Drawings: Drawings in this category were the most competent and realistic diagrams of cell division (Figure 4). These drawings showed a sound understanding and contained seven or more elements of the validated response for this particular statement (Table 1).

RESULTS

This study was conducted to determine biology student

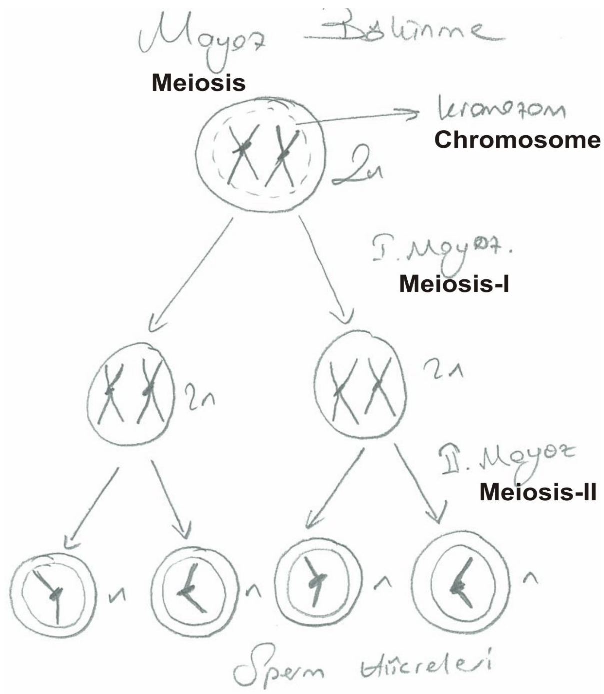

Figure 2a. Example of level 3 (drawing with misconception).

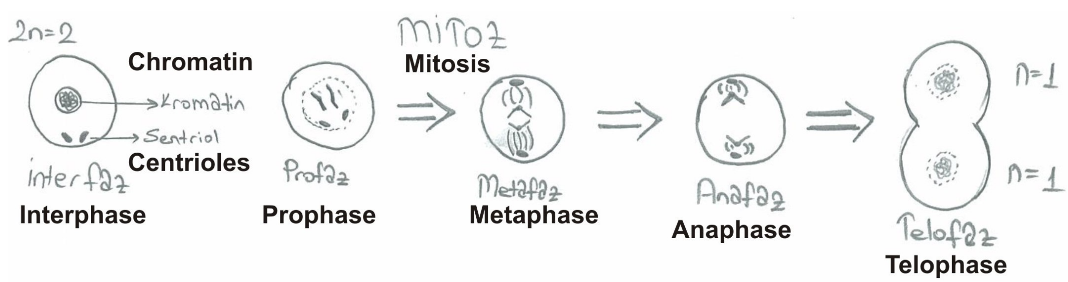

Figure 2b. Example of level 3 (drawing with misconception).

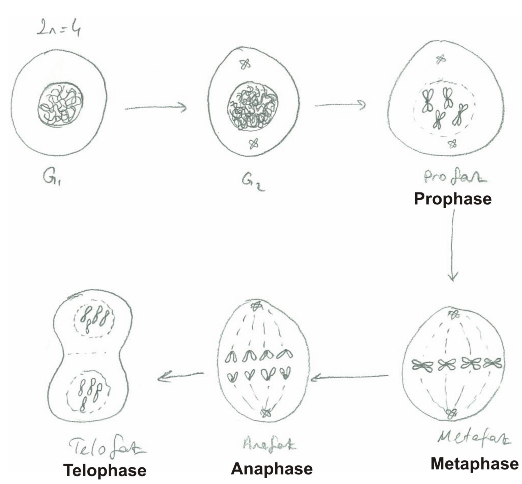

Figure 3. Examples of level 4 (partial drawing).

teachers' conceptual understandings and misconceptions of cell division using drawings and interviews. The data obtained from drawings were analyzed according to criteria mentioned above and demonstrated in Figure 5.

When Figure 5 is examined, it is seen that 46% of these students produced drawings with misconceptions (level 3) related to mitosis and 54% of them produced drawings with misconceptions related to meiosis. These findings reveal the fact that almost half of these students possess various misconceptions related to mitosis and meiosis. The proportion of partial drawings (level 4) is determined as 19 and 16% for mitosis and meiosis, respectively. In addition, it is further determined that 28% of these students produced comprehensive representation drawings (level 5) for mitosis and 13% for meiosis. Furthermore, it is seen that 5% of these students produced non-representational drawings (level 2) for

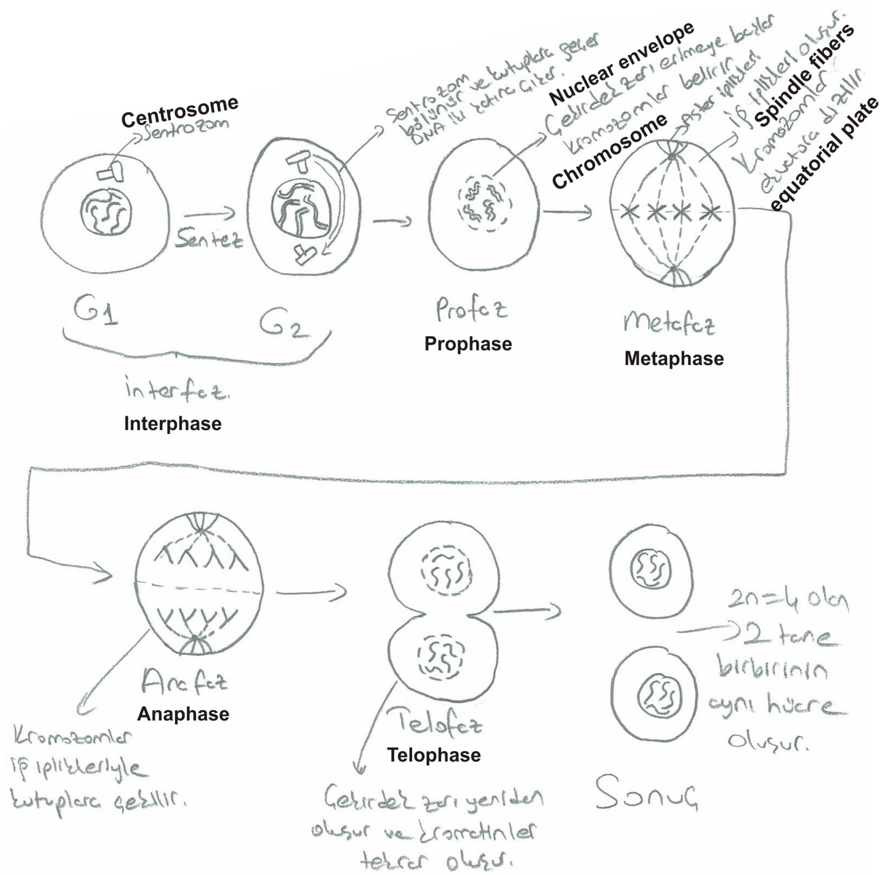

Figure 4. Examples of level 5 (comprehensive representation drawing).

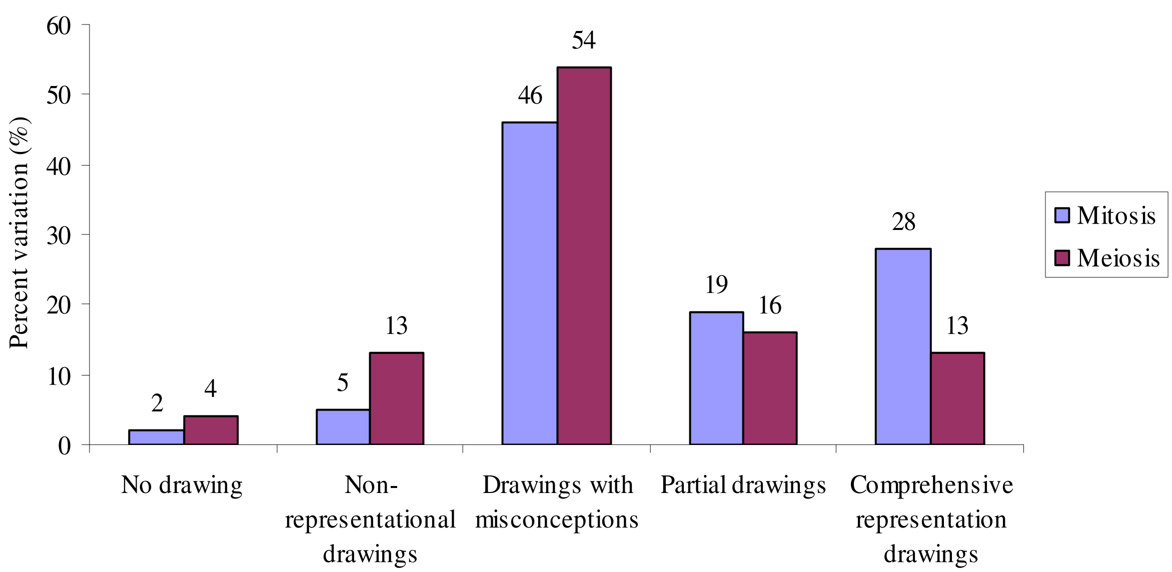

Figure 5. Biology student teachers' understandings of the cell division as shown in their drawing

mitosis and 13% for meiosis. These proportions indicate that meiosis is more complicated and a difficult topic to learn for these students, when compared to mitosis. These results show that less than half of these students

Table 1. The most frequent elements for mitosis and meiosis drawn by biology student teachers.

Elements for mitosis	n	%	Elements for meiosis	n	%
Karyokinesis (Prophase, Metaphase, etc.)	115	93	Karyokinesis (Prophase, Metaphase, etc.)	112	90
Chromosome	110	89	Homologous chromosomes	98	79
Chromatids	100	80	DNA Replication	83	67
DNA Replication	87	70	Diploid (2n) / Haploid (n)	77	62
Interphase	85	69	Chromatids	64	52
Nuclear envelope	84	68	Interphase	61	49
Spindle fibers	77	62	Chromatin	53	43
Centrosome / Centrioles	72	58	Spindle fibers	46	37
Chromatin	54	44	Equatorial plate	39	31
Nucleolus	40	32	Crossing-over	30	24
Cytokinesis	29	23	Nuclear envelope	23	19
Equatorial plate	20	16	Nucleolus	18	15
Sister chromatids	14	11	Centrosome / Centrioles	15	12
Centromere	9	7	Cytokinesis	10	8
Cell cycle	4	3	Centromere	5	4

possess comprehensive or partial knowledge related to cell division, in particular, to meiosis.

The elements recurring most frequently on the drawings as related to mitosis are presented in Table 1, which shows that more than half of these students concentrate on elements like karyokinesis, chromosome, chromatids, DNA replication, interphase, nuclear envelope, spindle fibers, and centrosome/centrioles. On the other hand, it is reported that less than half of these students show elements like chromatin, nucleolus, equatorial plate, sister chromatids, centromere, and cell cycles in their drawings. These results demonstrate these students mainly focus on the stages of the karyokinesis and the events occurring at these stages related to mitosis.

When the elements related to meiosis are taken into consideration, it is found that more than half of the students concentrate on elements like karyokinesis, homologous chromosomes, DNA replication, diploid/ haploid, and chromatids. On the other hand, it is reported that less than half of the students display elements like interphase, chromatin, spindle fibers, equatorial plate, crossing-over, nuclear envelope, nucleolus, centrosome/ centrioles, cytokinesis, and centromere in their drawings (Table 1). Analysis of the elements related to mitosis and meiosis shows that these student teachers mostly considered elements related to the karyokinesis for an animal cell and disregarded the karyokinesis for a plant cell. For example, almost none of these student teachers noted the cytokinesis or cell plate in a plant cell, except for a few students.

Twenty-four misconceptions were determined in total as a result of the analyses on biology student teachers' drawings. These misconceptions are given in Table 2. The drawing method provided detailed information on determination of the misconceptions related to cell division. For example, in their drawings, thirty-three students indicated the number of chromosomes remained the same at the end of meiosis-I and halved at the end of meiosis-II (Figure 2a). Moreover, in their drawings, ten students indicated the number of chromosomes is halved at the end of mitosis (Figure 2b). These results showed that biology student teachers possess some misconceptions about mitosis and meiosis, in particular, about the number of chromosomes.

In addition, many misconceptions were determined during interviews with 15 randomly chosen students who demonstrated misconceptions. A majority of the misconceptions obtained from the interviews were consistent with the misconceptions detected on the drawings. Misconceptions obtained from the interviews are given in Table 3. Some of the significant misconceptions obtained from the interviews were as follows. Eleven of the interviewed students mentioned the organelles, such as mitochondria and chloroplasts, dissolve and vanish during cell division, and then are reformed. It is further seen that such students also believe the alterations occurring at the nucleus in karyokinesis also occurred at the organelles, such as mitochondria and chloroplasts in a similar manner. Three of these students mentioned the centrioles are found in the nucleus of a cell. This misconception was also encountered in the drawings of 14 students (Table 1, Figure 6).

Nine of the interviewed students mentioned DNA replication occurs in the prophase, while two of these students mentioned DNA replication occurs between the prophase and the metaphase during cell division. These students did not mention the DNA molecule replicates at the S stage of the interphase prior to cell division. These misconceptions obtained from the interviews were also encountered in a majority of the drawings (Figure 7).

Table 2. Misconceptions about cell division obtained from the drawings.

	Misconceptions	n
1	Interphase is the resting phase of mitosis.	47
2	DNA replication occurs in prophase during the process of cell division.	46
3	The chromosome number is doubled in the prophase of mitosis and halved in the anaphase of mitosis.	40
4	Chromosomes and chromatids are essentially the same thing.	35
5	The chromosome number remains the same during meiosis-I and is halved during meiosis-II.	33
6	In mitosis, homologous chromosomes separate in the anaphase.	23
7	Diploid (2n) cells are formed as a result of meiosis.	23
8	A chromosome has always two chromatids during cell division.	21
9	Sister chromatids do not separate in mitosis.	20
10	Homologous chromosomes are separated at the anaphase-II of the meiosis.	20
11	At a cell whose number of diploid chromosomes is 4, there are two chromosomes—each comprises of two chromatids.	19
12	Sister chromotides are separated from each other at the anaphase-I of the meiosis.	16
13	Sister chromotides only separate with meiosis.	16
14	Centrioles are found in the nucleus of a cell.	15
15	DNA replication occurs between meiosis-I and meiosis-II.	13
16	Spindle fibers are formed by centromere.	12
17	DNA replication occurs between prophase and metaphase during the process of cell division.	11
18	The number of chromosomes is halved after mitosis.	10
19	The meiosis of a cell with 2n = 4 chromosomes produces cells with a single chromosome.	9
20	Crossing over occurs at the metaphase-I of the meiosis.	7
21	The number of chromosomes remains the same after meiosis.	6
22	The number of chromosomes is doubled after mitosis.	5
23	DNA replication occurs between anaphase and telophase during the process of cell division.	4
24	DNA replication occurs in cytokinesis during the process of cell division.	4

Table 3. Misconceptions about cell division obtained from the interviews.

	Misconceptions
1	The organelles, such as mitochondria and chloroplasts, dissolve and vanish during cell division and then are reformed.
2	Centrioles are found in the nucleus of a cell.
3	DNA replication occurs in the prophase during the process of cell division.
4	DNA replication occurs between prophase and metaphase during cell division.
5	Interphase is the resting phase of mitosis.
6	DNA replication takes place only in the meiosis process.
7	Chromosomes are formed as a result of shrinkage and thickening of spindle fibers.
8	In mitosis, homologous chromosomes separate in the anaphase.
9	The chromosome number is doubled in the prophase of mitosis and halved in the anaphase of mitosis.
10	Meiosis occurs in the reproductive (sperm or egg) cells.
11	A chromosome has always two chromatids during cell division.
12	Centrioles are replicated during the prophase stage.
13	Diploid (2n) cells are formed as a result of meiosis.
14	During cell division, each centriole of the centrosome is separated and moves towards the opposite poles.
15	Spindle fibers are formed from centromers.
16	The centrosome and centrioles is essentially the same thing.
17	The sister chromatids are homologous chromosomes.

Seven of these students mentioned the interphase is the resting phase of mitosis. These students did not mention the interphase is a phase of cell cycle. This misconception was not only encountered during the inter-

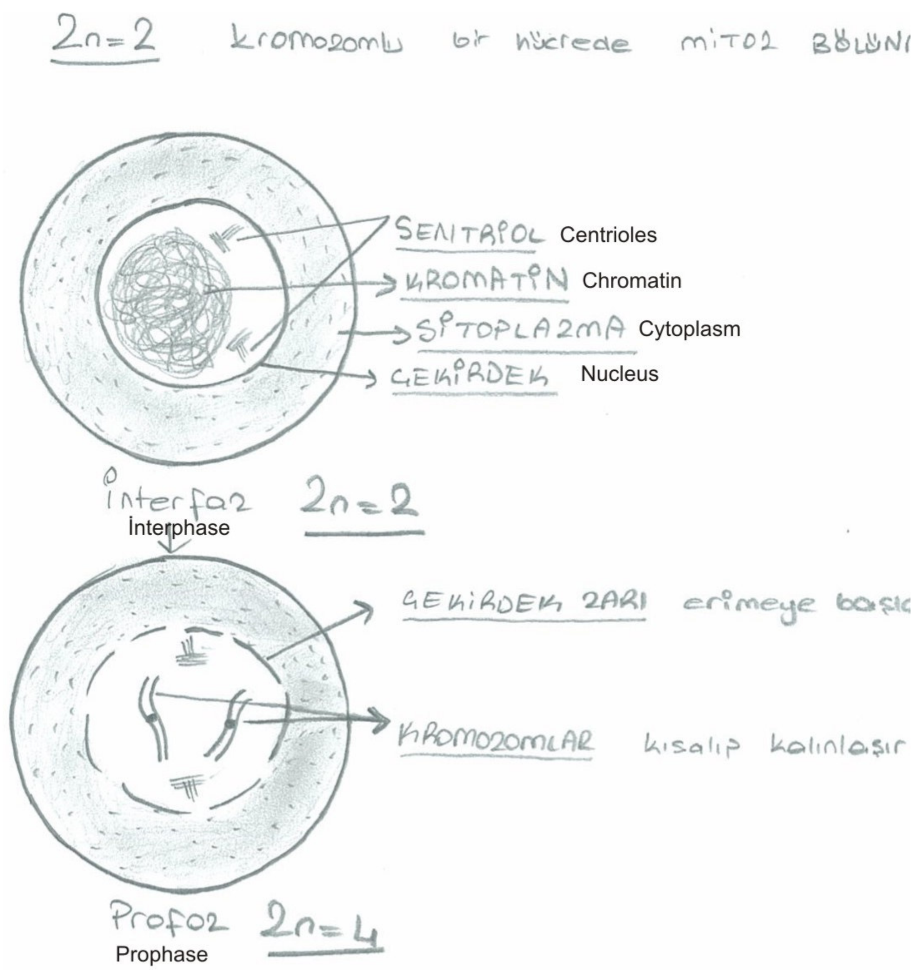

Figure 6. A drawing of misconception of "centrioles are found in the nucleus of a cell"

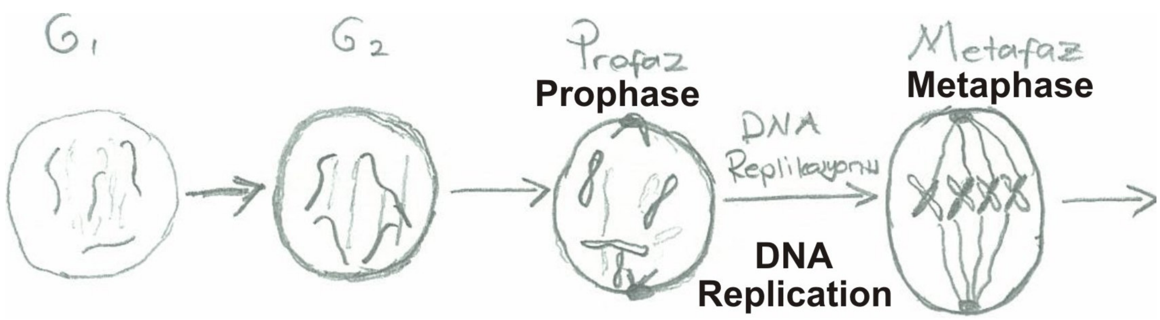

Figure 7. A drawing of misconception of "DNA replication occurs between prophase and metaphase during cell division".

views, but also from the drawings (Figure 8).

Six of the interviewed students mentioned the chromosome number is doubled in the prophase of mitosis and halved in the anaphase of mitosis. This misconception was also encountered from the drawings (Figure 9). It was observed that a majority of the misconceptions obtained from the interviews consistent with the misconceptions determined from the drawings. This fact consolidated the validity of the misconceptions obtained from the drawings. For example, five of the interviewed students indicated that typically one chromosome always has two chromatids during the cell division process. These students believed that typically one chromosome comprises of two chromatids and the chromosome is replicated

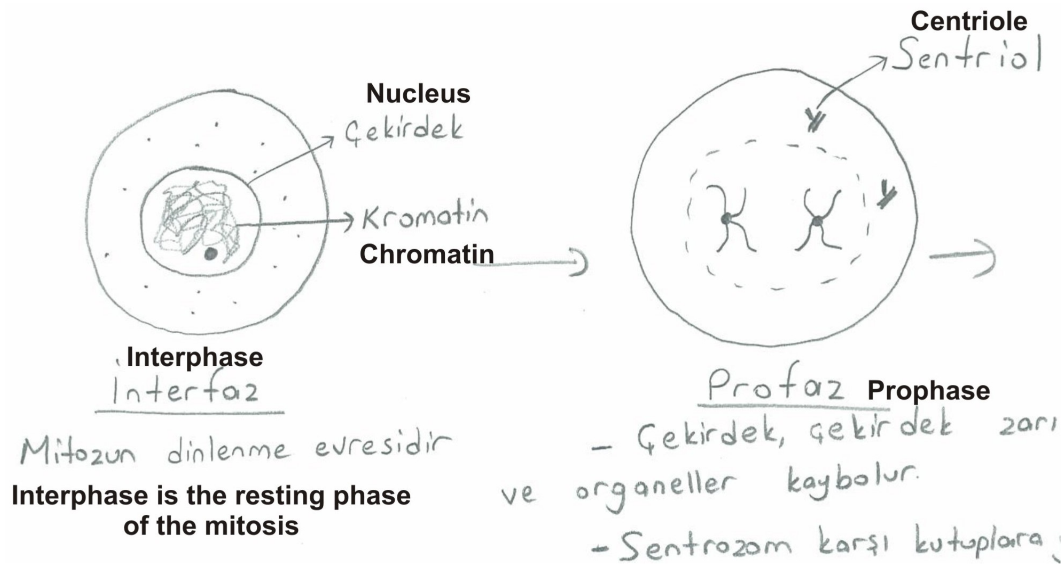

Figure 8. A drawing of misconception of "interphase is the resting phase of the mitosis".

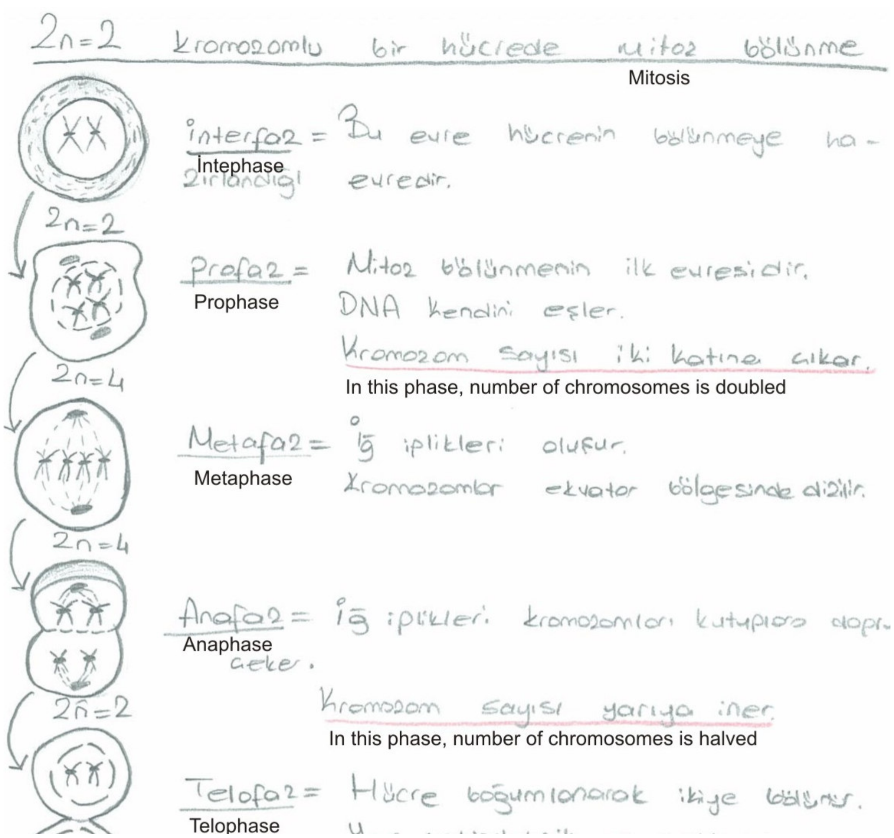

Figure 9. A drawing of misconception of "the chromosome number is doubled in the prophase of mitosis and halved in the anaphase of mitosis".

in this form. This misconception was not only encountered during the interviews, but also from 21 of the student's drawings (Figure 10). In addition, four of the interviewed students indicated the diploid cells are formed as a result of meiosis. This misconception was also encountered from 23 of the student's drawings

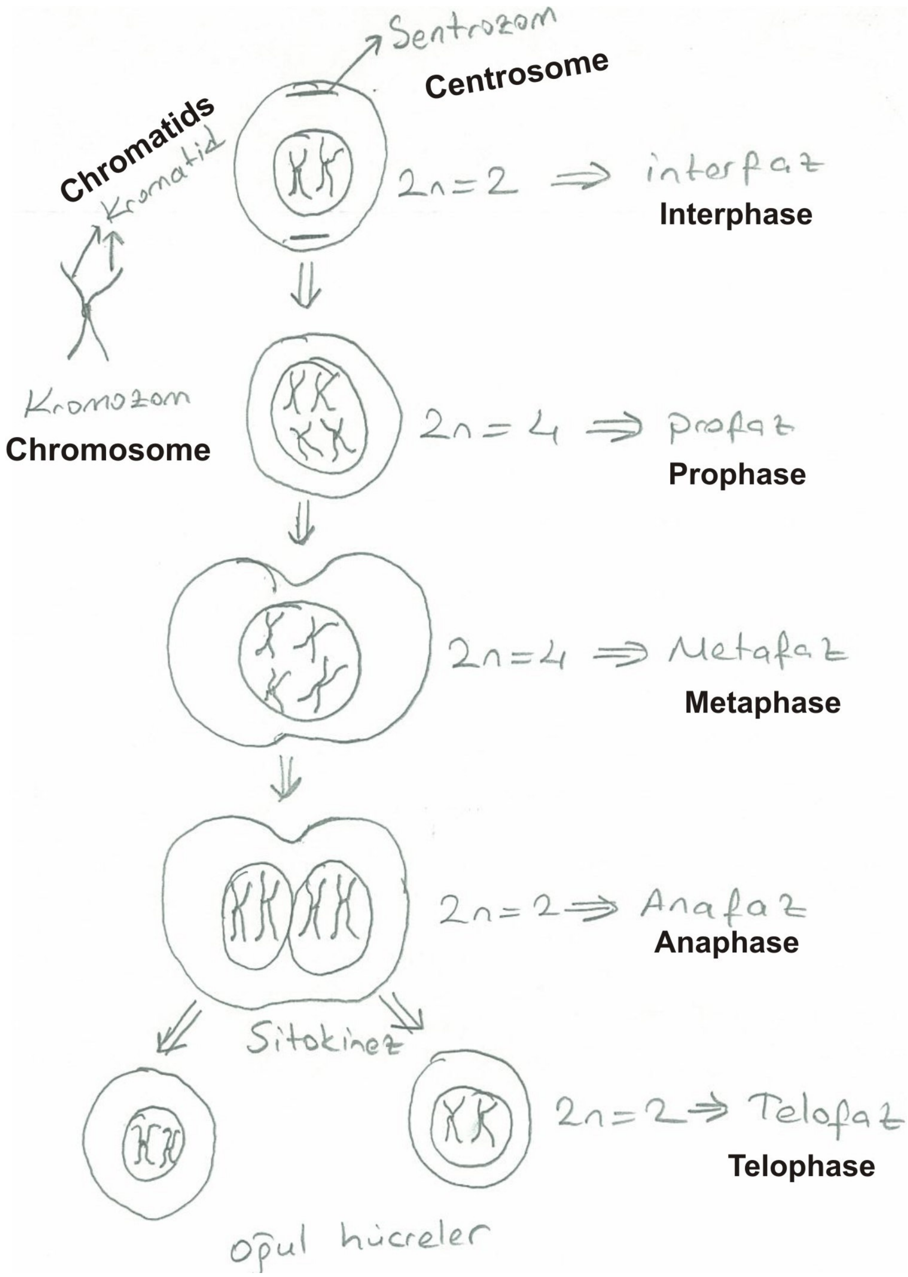

Figure 10. A drawing of misconception of "a chromosome has always two chromatids during cell division".

(Figure 11).

DISCUSSION

Utilization of student drawings and interviews together with an appropriate sample size ensured determination of numerous alternative points of view that biology student teachers possess in relation to cell division. The findings gained from the drawings and the interviews show that a majority of the students cannot establish accurate relationships between cell cycle and cell division. It was observed that the students participating in this study are not able to establish conceptual relations associated with mitosis and meiosis, and possess a complicated knowledge frame. For example, these students were observed to be in conceptual confusion, particularly between the concepts related to the cell cycle-cell division, mitosis-meiosis, haploid-diploid cells, sister chromatids-homologous chromosomes, centrosome-centrioles-centromere, and spindle fibers-chromatin-chromatid-chromosome. These findings support the studies

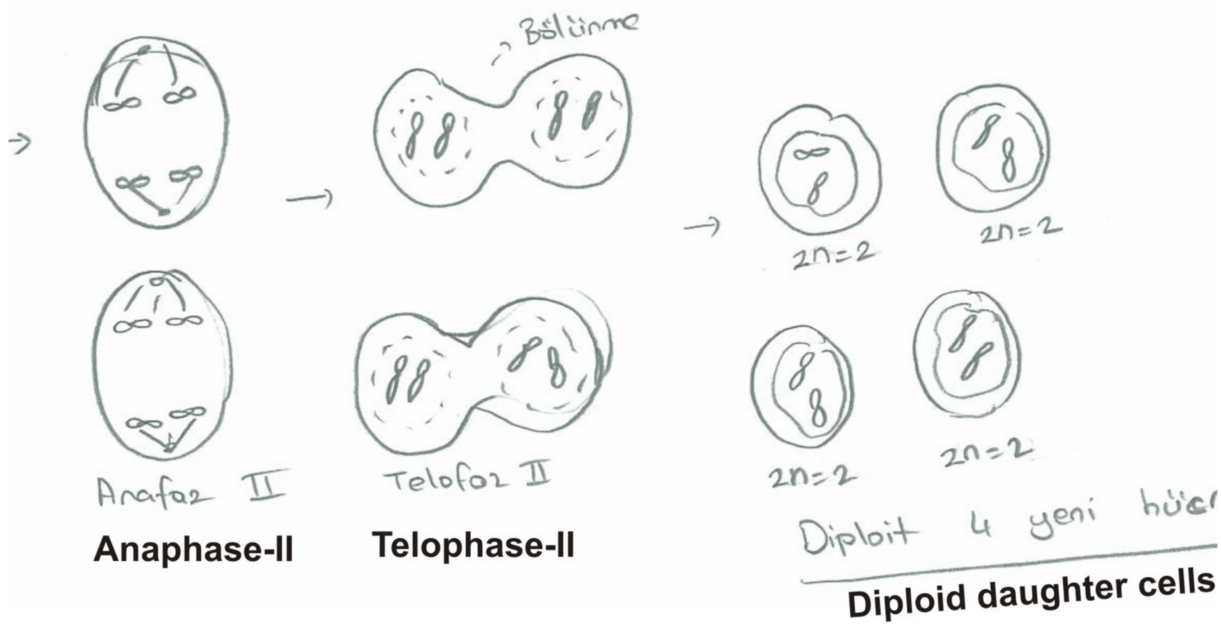

Figure 11. A drawing of misconception of “diploid cells are formed as a result of meiosis”.

conducted previously in regards to this subject matter (Kindfield, 1994; Smith, 1991).

Analysis of the drawings revealed that a conceptual understanding of these biology student teachers is relatively weak, particularly regarding the behaviors of the chromosomes, chromosome numbers, alterations occurring at the organelles, stages of the cell division, and the DNA replication during mitosis and meiosis. These findings are surprisingly since the subjects of mitosis and meiosis are incorporated into primary, secondary, and undergraduate curriculums. Some of the misconceptions indicated in this study resembled the misconceptions mentioned for previous studies conducted in Turkey and other countries on some periods of school life (Atilboz, 2004; Brown, 1990; Flores et al., 2003; Kindfield, 1991; Lewis et al., 2000; Lewis and Wood-Robinson, 2000; Marbach-Ad and Stavy, 2000; Riemeier and Gropengießer, 2008; Saka et al., 2006; Smith, 1991; Yesilyurt and Kara, 2007; Yilmaz et al., 1998). But, it was also observed that some misconceptions indicated in this study emerged for the first time. Some of these new misconceptions include: “DNA replication occurs between prophase and metaphase during the process of cell division” (Figure 7), “A chromosome has always two chromatids during cell division” (Figure 10), “Interphase is the resting phase of mitosis” (Figure 8), “The chromosome number remains the same during meiosis-I and is halved during meiosis-II” (Figure 2a), “Centrioles are found in the nucleus of a cell” (Figure 6), “The organelles, such as mitochondria and chloroplasts, dissolve and vanish during cell division and then are reformed,” “Chromosomes are formed as a result of shrinkage and thickening of spindle fibers.” The existence of these misconceptions, despite the fact students are educated with various education techniques at the university, show that such misconceptions are extremely resistant against change (Bahar, 2003; Wandersee et al., 1994). Therefore, the teachers at the primary and secondary education levels, and the lecturers at the university assume very important roles regarding employment of alternative teaching strategies to eliminate or at least minimize such misconceptions. Effective teaching methods must be used to eliminate or minimize these misconceptions that the university students possess. Otherwise, the new teachers will continue teaching these misconceptions and the cycle is not broken. Graphical or visual tools, such as conceptual maps, conceptual networks, and conceptual change strategies, such as conceptual change texts, are the methods more likely to reduce or eliminate misconceptions of students (Novak and Canas, 2004; Tekkaya, 2003).

Biology student teachers are confused about the concepts related to mitosis and meiosis. These findings overlap with the findings of the study conducted by Flores et al. (2003). The misconceptions related to mitosis and meiosis might also originate from the textbooks and explanations given in the classrooms. Cook (2008) indicates that some illustrations contained in textbooks related to meiosis lead to understanding difficulties for students. It is a well-known fact that it is not an easy task to eliminate these misconceptions by means of traditional teaching methods. An alternative way for overcoming problems related to these misconceptions might be to employ computer-aided educational materials for biology classes (Cepni et al., 2006; Yesilyurt and Kara, 2007). In addition, many studies suggest that the use of models in biology greatly enhances student understanding of cell division (Clark and Mathis, 2000; Pashley, 1994). Moreover, Chinnici et al. (2004) report that to procure students to act as “human chromosomes” through role-playing mitosis and meiosis is an effective method to enhance learning of these important processes for students.

Another source of the misconceptions might be the terminology used during teaching. For instance, the misconceptions determined under the scope of this study, such as “Spindle fibers are formed by centromere (Table 2),” “Chromosome and chromatid are essentially the same thing (Table 2),” and “Centrosome and centrioles are essentially the same thing (Table 3),” clearly indicate that students are confusing terms, such as chromatid - chromosome, centrosome - centrioles, centrosome – centromere, with each other. As a matter of fact, it is known from previous studies that the conflicting terms such as “divide, replicate, copy, share, split” used for identification of cell division processes in terms of genetic information and chromosomes are being confused by the students (Lewis and Wood-Robinson, 2000). Therefore, it is understood that it shall be necessary to pay specific attention to the terminology by the teachers and textbook authors in regard to education on cell division.

Conclusions and Recommendations

This study revealed biology student teachers have a series of significant problems regarding the concepts of cell division and structuring of such concepts in a meaningful manner. These problems are mainly associated with meiosis rather than mitosis. The students confuse the stages of the cell division process and the events occurring at these stages with each other. Misconceptions revealed in this study showed that students have conceptual difficulties in explaining the phenomena that require a good understanding of cell division concepts, such as cell cycle-cell division, mitosis-meiosis, haploid-diploid cells, sister chromatids-homologous chromosomes, centrosome-centrioles, and spindle fibers-chromatin. The students mostly focus on cell division with animal cells and disregard cell division with plant cells.

In summary, biology student teachers have many misconceptions related to cell division. Misconceptions are often resistant to elimination through conventional teaching strategies (Bahar, 2003; Wandersee et al., 1994). Therefore, new teaching strategies, such as conceptual maps, conceptual networks, semantic features analysis and conceptual change texts (Novak and Canas, 2004; Tekkaya, 2003), are chosen and students’ conceptions are taken into account when preparing lessons. Student-centered learning activities should be implemented with a conceptual development towards the scientific concept (Riemeier and Gropengießer, 2008). Lecturers must be aware of students’ misconceptions, as well as their sources, in order to improve teaching of cell division. In addition, for students to understand cell division, related subordinate concepts must be mastered. Biology curricula developers should consider students’ difficulties in understanding cell division concepts and take students’ perspectives into account. Moreover, employment of educational materials, such as computer technologies (Cepni et al., 2006; Yesilyurt and Kara, 2007) and models (Clark and Mathis, 2000; Pashley, 1994) for teaching the cell division processes should assist these students to concretize abstract concepts.

The study determined that students can reveal what they know and understand through drawings. The interpretation of the drawings and interviews gave insight into students’ understanding about cell division and demonstrated that drawings can be an effective method of probing some aspects of their learning difficulties. The literature supports this finding and suggests that students’ drawings are effective in identifying their biological misconceptions (Bahar et al., 2008; Bowker, 2007; Kose, 2008; Reiss and Tunnicliffe, 2001). In this respect, it is recommended employment of the drawing method for determination of the misconceptions and learning difficulties for further studies.

REFERENCES

Atilboz NG (2004). 9th Grade students’ understanding levels and misconceptions about mitosis and meiosis. J. Gazi Edu. Faculty 24 (3): 147-157.

Bahar M (2003). Misconceptions in biology education and conceptual change strategies. Edu. Sci.: Theory Pract. 3(1): 55-64.

Bahar M, Ozel M, Prokop P, Usak M (2008). Science student teachers’ ideas of the heart. J. Baltic Sci. Edu. 7(2): 78-85.

Ben-Zvi Assaraf O, Orion N (2005). Development of system thinking skills in the context of Earth system education. Res. Sci. Teach. 42 (5): 518-560.

Bowker R (2007). Children’s perceptions and learning about tropical rainforests: An analysis of their drawings. Environ. Edu. Res. 13(1): 75-96.

Brown CR (1990). Some misconceptions in meiosis shown by students responding to an advanced-level practical examination question in biology. J. Bio. Edu. 24(3): 182-186.

Cepni S, Tas E, Kose S (2006). The effects of computer-assisted material on students’ cognitive levels, misconceptions and attitudes towards science. Comp. Edu. 46(2): 192-205.

Chinnici JP, Yue JW, Torres KM (2004). Student as “human chromosomes” in role-playing mitosis and meiosis. The Am. Bio. Teach. 66(1): 35-39.

Clark DC, Mathis PM (2000). Modeling mitosis and meiosis, a problem-solving activity. The Am. Bio. Teach. 62(3): 204-206.

Cook M (2008). Students’ comprehension of science concepts depicted in textbook illustrations. Elect. J. Sci. Edu. 12: 1.

Cordero RE, Szweczak CA (1994). The developmental importance of cell division. The Am. Bio. Teach. 56(3): 176-179.

Flores F, Tovar M, Gallegos L (2003). Representation of the cell and its processes in high school students: An integrated view. Int. J. Sci. Edu. 25(2): 269-286.

Kibbos JK, Ndirangu M, Wekesa EW (2004). Effectiveness of a computer-mediated simulations program in school biology on pupils’ learning outcomes in cell theory. J. Sci. Edu. Technol. 13(2): 207-213.

Kibuka-Sebitosi E (2007). Understanding genetics and inheritance in rural schools. J. Bio. Edu. 41(2): 56-61.

Kindfield ACH (1991). Confusing chromosome number and structure: A common student error. J. Bio. Edu. 25(3): 193-200.
Kindfield ACH (1994). Understanding a basic biological process: Expert and novice models of meiosis. Sci. Edu. 78(3): 255-283.
Kose S (2008). Diagnosing student misconceptions: Using drawings as a research method. World Appl. Sci. J. 3(2): 283-293.
Kruger D, Fleige J, Riemeier T (2006). How to foster an understanding of growth and cell division. J. Bio. Edu. 40(3): 135-140.
Lewis J, Leach J, Wood-Robinson C (2000). Chromosomes: The missing link - young people's understanding of mitosis, meiosis and fertilization. J. Bio. Edu. 34(4): 189-199.
Lewis J, Wood-Robinson C (2000). Genes, chromosomes, cell division and inheritance - do students see any relationship? Int. J. Sci. Edu. 22(2): 177-195.
Marbach-Ad G, Stavy R (2000). Students cellular and molecular explanations of genetic phenomena. J. Bio. Edu. 34(4): 200-205.
Novak JD, Canas A (2004). Building on new constructivist ideas and Cmap tools to create a new model for education. Proceedings of the First Int. Conference on Concept Mapping, Pamplona, Spain.
Oztas H, Ozay E, Oztas F (2003). Teaching cell division to secondary school students: An investigation of difficulties experienced by Turkish teachers. J. Bio. Edu. 38(1): 13-15.
Pashley M (1994). A-level students: Their problems with gene an allele. J. Bio. Edu. 28(2): 120-126.
Pfundt H, Duit R (2004). Bibliography: Students' alternative frameworks and science education. University of Kiel Institute for Science Education: Kiel, Germany.
Prokop P, Fanèovièová J (2006). Students' ideas about human body: Do they really draw what they know? J. Baltic Sci. Edu. 2(10): 86-95.
Reiss MJ, Tunnicliffe SD (2001). Students' understandings about human organs and organ systems. Res. Sci. Edu. 31: 383-399.
Rennie LJ, Jarvis T (1995). English and Australian children's perceptions about technology. Res. Sci. Technol. Edu. 13(1): 37-52.
Riemeier T, Gropengießer H (2008). On the roots of difficulties in learning about cell division: Process-based analysis of students' conceptual development in teaching experiments. Int. J. Sci. Edu. 30(7): 923-939.
Saka A, Cerrah L, Akdeniz AR, Ayas A (2006). A cross-age study of the understanding of three genetic concepts: How do they image the gene, DNA and chromosome? J. Sci. Edu. Technol. 15(2): 192-202.
Scherz Z, Oren M (2006). How to change students' images of science and technology. Sci. Edu. 90(6): 965-985.
Smith MU (1991). Teaching cell division: Student difficulties and teaching recommendations. J. Coll. Sci. Teach. 21(1): 28-33.
Smith MU, Kindfield ACH (1999). Teaching cell division: Basics and recommendations. The Am. Bio. Teach. 61(5): 366-371.
Stewart J, Dale M (1989). High school students' understanding of chromosome/gene behavior during meiosis. Sci. Edu. 73(4): 501-521.
Tekkaya C (2003). Remediating high schools' misconceptions concerning diffusion and osmosis through concept mapping and conceptual change text. Res. Sci. Technol. Edu. 21(1): 5-16.
Wandersee JH, Mintzes JJ, Novak D (1994). Research on alternative conceptions in science. In D.L. Gabel (Ed.), Handbook of research on science teaching and learning. New York: Macmillan pp. 177-210
White R, Gunstone RF (2000). Probing understanding. London, UK, Falmer Press.
Yesilyurt S, Kara Y (2007). The effects of tutorial and edutainment software programs on students' achievements, misconceptions and attitudes towards biology on the cell division issue. J. Baltic Sci. Edu. 6(2): 5-15.
Yilmaz O, Tekkaya C, Geban O, Ozden Y (1998). Lise-1. Sinif ogrencilerinin hcre bolunmesi unitesindeki kavram yanilgilarinin tespiti ve giderilmesi, III. Ulusal Fen Bilimleri Egitimi Sempozyumu, 23-25 Eylul 1998, KTU, Trabzon (in Turkish).