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Teaching Processes and Methods Suggested by Science Teachers for Overcoming Alternative Conceptions about Genetics

Abstract

The purpose of this study was to describe processes and methods suggested by science teachers for changing alternative conceptions about genetics. The study focused on a group of 17 (8 male and 9 female) science teachers who were graduate level students or completed a graduate program. Hence, the group was the case of this study. Qualitative data of the study was collected by detailed lesson plans prepared by the participants for overcoming two alternative conceptions about genetics (chromosome is an organelle and DNA is found as a whole set in the body) and follow-up interviews. The data was analyzed by descriptive analysis. The findings showed that the case group of this study represented fragmented processes to overcome the alternative conceptions. At the same time, they did not provide methods or processes in line with conceptual change models. These findings mean that science and technology teachers who have completed a graduate program or are currently graduate students of science education are not able to plan coherent teaching on alternative conceptions or are not aware of conceptual change processes and methods.

Keywords: *alternative conceptions, genetics, conceptual change processes, science and technology teachers*

Introduction

Technological improvements in the genetics field are frequently seen in nearly all aspects of life. For instance, the Human Genome Project and following technolo-

gies have opened a new era in diagnostics and treatment of many diseases. At the same time, genetics has become a new socio-scientific topic to discuss in the media and on different platforms. These developments have increased the importance of learning about the concepts of genetics. In line with developments in the genetics field, the number of concepts to be learned has also increased (Lanie et al., 2004). Learning of these concepts has become another problem in life. Substantive teaching of the concepts of genetics is conducted in science classes despite the fact that individuals can learn about them via TV, radio, the Internet, books and newspapers (Lanie et al., 2004). Multiple sources of learning of the concepts of genetics might produce alternative conceptions (Kibuka-Sebitosi, 2007) and overcoming such alternative conceptions is the job of science and technology teachers. Alternative conceptions as a term are more neutral than misconceptions (Franke, Scharfenberg & Bogner, 2013), hence it is used in this study to explain the conceptions of individuals. In its basic definition, an alternative conception is a pre-instructional conception that is not consistent with scientifically accepted concepts (Dega, Kriek & Mogese, 2013).

As another resource of alternative conceptions, science teachers are of importance due to their dual role in making and overcoming alternative conceptions about the concepts of genetics. Studies show that science teachers might contribute to alternative conceptions of students about genetics (Treagust & Duit, 2009). But they can also use conceptual change teaching effectively to overcome alternative conceptions. Hence, determining science teachers' suggestions concerning the teaching process and methods for overcoming alternative conceptions of students might shed light on the missing parts of the teaching of alternative conceptions about genetics. The majority of the studies on conceptual change indicate that conceptual change processes and methods are effective in overcoming alternative conceptions (Hewson, 1992) and they also assume that science teachers use the processes and methods as intended (Treagust & Duit, 2009). However, there is a need to determine the processes and methods suggested by science teachers to see the use of conceptual change by science teachers in their classrooms. Vosniadou, Ioannides, Dimitrakopoulou and Papdemetriou (2001) defined conceptual change as a revision of the existing conceptual system through addition of elements and the accepted scientific explanations into the system.

The conceptual change process has an important place in learning and teaching genetics since students represent various alternative conceptions about different concepts of genetics (Banet ve Ayuso, 2000; Lanie et al., 2004; Lewis & Kattmann, 2004; Knippels, Waarlo & Boersma, 2005; Kibuka-Sebitosi, 2007; Williams, Debarger, Montgomery, Zhou & Tate, 2011; Akkaya & Köksal, 2013). The alterna-

tive conceptions of the students are frequently about the "chromosomes, genes, homozygote, heterozygote, meiosis, mitosis, regeneration, modification and adaptation" concepts (Banet & Ayuso, 2000; Lanie et al., 2004; Lewis & Kattmann, 2004; Knippels, Waarlo & Boersma, 2005; Kibuka-Sebitosi, 2007; Williams, Debarger, Montgomery, Zhou & Tate, 2011; Akkaya & Köksal, 2013). For instance, students believe that chromosomes are organelles, meiosis provides reproduction of all living things, DNA is found as a whole molecule (Akkaya & Köksal, 2013), genes have a special location in the body and abilities and behaviors are inherited characteristics (Lanie et al., 2004). In fact, the majority of these alternative conceptions are determined by descriptive studies. However, there is a need to determine suggested solutions for alternative conceptions. Hence, solutions for teaching genetics should be proposed by researchers. The solutions require planning and conducting the conceptual change process after determining alternative conceptions (Posner, Strike, Hewson & Gertzog, 1982).

The conceptual change process is suggested by researchers to change alternative conceptions (Posner, Strike, Hewson & Gertzog, 1982; Lee, Jonassen & Teo, 2011). The conceptual change theory was recommended by Posner, Strike, Hewson and Gertzog (1982). They summarized the conceptual change process with two components: conceptual ecology and conditions of change. Conceptual ecology is a pool of all concepts and their relationship with a concept. However, conditions describe the process of conceptual change, feeling cognitive conflict concerning the existing conceptual structure about a concept, intelligibility, plausibility and fruitfulness of a new conception. Planning the conceptual change process effectively gives advantages in reaching the objectives regarding alternative conceptions in a short time. In the literature, conceptual change processes are planned by using various methods, techniques and approaches. Baker and Lowson (2001) and Treagust and Duit (2009) used analogies while Çalik, Kolomuç and Karagölge (2010) and Özmen (2010) suggested using questions, animations and discussion. Moreover, Lewis and Katmann (2004) suggested cognitive process based planning; Franke and Bogner (2011) suggested active teaching approaches to plan conceptual change processes while Pimthong *et al.* (2011) focused on fragmented teaching based learning process. More current studies suggested a method or model oriented planning process; Lee, Jonassen and Teo (2011) suggested a problem solving model, Çelikten, İpekçioğlu, Ertepınar and Geban (2012) used a cooperative learning model while Al khawaldeh (2013) used conceptual change text to provide a conceptual change process. Science teachers have two options to plan the conceptual change process, i.e., the use of the ways suggested by literature or the use of their own ways. Posner, Strike, Hewson and Gertzog (1982) pointed out that teachers play two roles in the

conceptual change process: they should develop activities to provide a cognitive conflict and they should provide guidance on how to reach scientific conceptions. In other words, science teachers play an important role in designing instruction in line with the conceptual change process and managing the process.

In the above-mentioned literature, there is not enough research on the suggested ways for science teachers to change alternative conceptions. At the same time, science teachers who are graduate students or graduated from Master's or doctorate degrees are not represented in the literature about the topic, so they are involved in this study to get a more detailed picture of the ways suggested for changing alternative conceptions. The participants in this study are also of importance due to the fact that they have knowledge about alternative conceptions, hence, they can provide more coherent data concerning the problem of this study. If evidence for problematic situations in changing alternative conceptions is determined, more effective ways of changing them can be suggested for science teacher education. Therefore, the purpose of this study was to determine teaching processes suggested by science teachers to change alternative conceptions about genetics.

Method

The study was designed as qualitative research, a case study. The design of the study is a holistic case design (Yin, 1984). The participants in the study were 17 science teachers who were graduate students or had graduated from Master's or doctorate level programs of science education. The participants were members of a special group in terms of their education level, so they were treated as a case to study the problem of this study in detail. For selecting the participants, purposive sampling was used. Data collection process was done by asking the participants to write a plan for teaching about two alternative conceptions. Then three of the participants were interviewed to describe their plan in detail. Both plan documents and interview transcripts were used as data in this study. Information about the participants is summarized in Table 1.

Table 1. Descriptive information about the participants

Participants	Gender	Workplace	Teaching Experience (Years)
Participant I	Male	Urban	12
Participant II	Female	Rural	1
Participant III	Male	Rural	2
Participant IV	Female	Urban	5

Participants	Gender	Workplace	Teaching Experience (Years)
Participant V	Male	Urban	1
Participant VI	Female	Rural	5
Participant VII	Male	Rural	7
Participant VIII	Female	Rural	6
Participant IX	Female	Rural	3
Participant X	Male	Urban	5
Participant XI	Female	Rural	1
Participant XII	Male	Urban	6
Participant XIII	Male	Rural	4
Participant XIV	Female	Rural	5
Participant XV	Female	Rural	2
Participant XVI	Female	Rural	4
Participant XVII	Male	Urban	8

Data Analysis

For data analysis, a conceptual change process suggested by literature is illustrated in Figure 1. In the Figure the process was divided into four themes: Preparation for concept teaching, Concept introduction, Conceptual change activity, and Evaluation of conceptualization (Al Khawaldeh, 2013; Çalık, Kolomuç & Karargölge, 2010; Geban, Celikten, İpekcioglu & Ertepınar, 2012; Scot, Asoko & Driver, 1991). In these four themes, suggested activities were described and this frame was used as an analysis tool. At the following stage, two alternative conceptions, "chromosomes are organelles," and "DNA is found as a whole molecule in the body," were introduced to the participants. These two alternative conceptions are the most frequently encountered conceptions among middle school students (Akkaya & Köksal, 2013). Then, the participants were asked to make a plan to replace these alternative conceptions with scientific conceptions. The plans were analyzed by two experts in terms of the themes represented in Figure 2. Descriptive analysis was used to test digressions and coherency between the suggested teaching and conceptual change process. Based on the analysis made by two experts, Figure 3 was drawn. In spite of the detailed analysis of two experts, trustworthiness was also established by additional interviews with three participants. Their answers to interview questions were analyzed by two experts again to check whether digressions from conceptual change process occurred or not. Then their interview

answers and plans were compared to check trustworthiness. Based on the analysis of interview answers, Figure 1 was drawn.

Figure 1. Diagrammatic representation of conceptual change process suggested by three participants to change alternative conceptions (interview data)

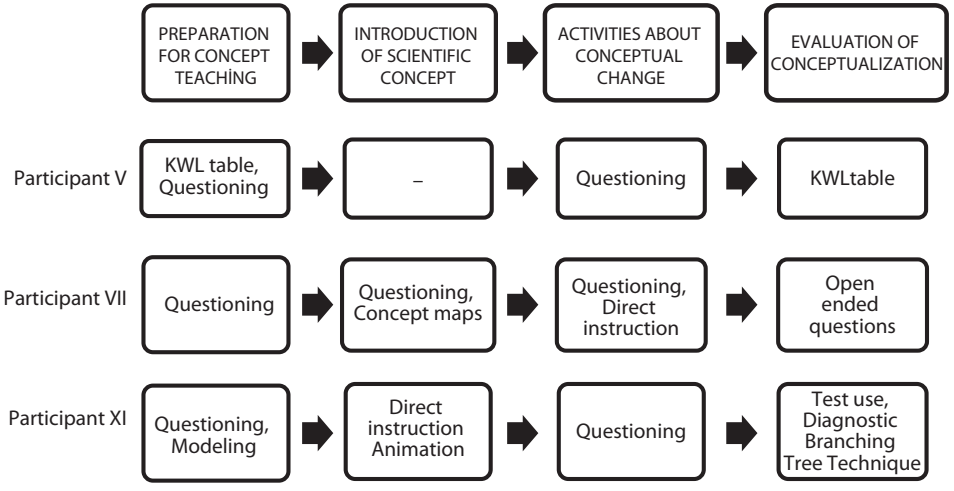
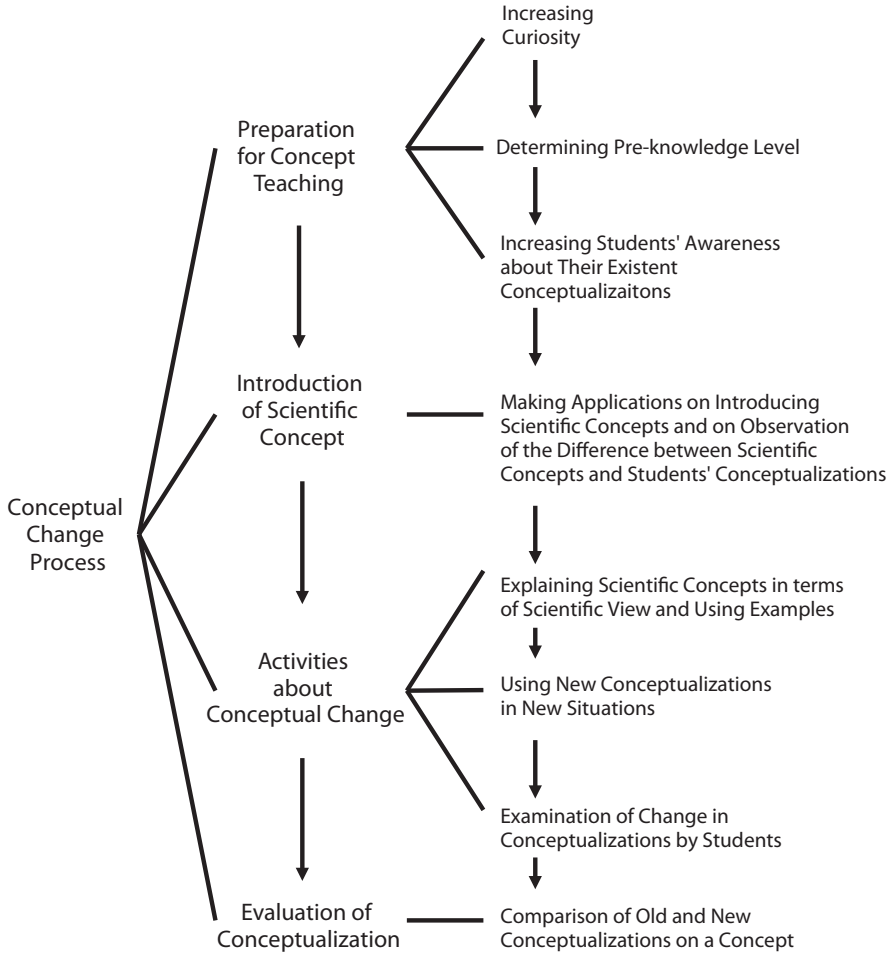


Figure 1 presents interview data coming from randomly selected three participants for establishing trustworthiness. The suggested ways in the interview are compared with their ways in plans. In this way, trustworthiness of the data in this study was ensured. Looking at the data for participant V, it is seen that KWL table use and questioning are suggested in both the plan and interview. At the same time, participant V does not suggest anything for the "introduction of scientific concept" stage in the plan and interview. For the other two stages, participant V also suggests the same ways as questioning and KWL table. The picture for participant VIII is similar since the participants suggest questioning for the preparation stage, questioning for the introduction stage, questioning and direct instruction for the activities stage and the use of open-ended questions for the evaluation stage in both the plan and interview. For participant XI, both interview and plan data show similarities, as the participant suggests questioning and modeling for the preparation stage, questioning for the activities stage and the Diagnostic branching tree technique and tests for the evaluation stage in both the plan and interview. The findings on the data collected by the interview and examining plans show a similar pattern. Hence, the findings support trustworthiness of the data in this study.

Findings

The results of data analysis show that the science teachers in this study did not understand the process of conceptual change and they could not provide a systematic and coherent plan to change alternative conceptions about genetics. The findings of the study are presented in figures to show digressions and coherency between the suggested ways of the teachers and conceptual change process.

Figure 2. Diagrammatic representation of conceptual change process suggested by the literature to change alternative conceptions



In Figure 2, the process of conceptual change suggested in the literature is presented by showing four components of the process (Al Khawaldeh, 2013; Çalık, Kolomuç & Karargölge, 2010; Geban, Celikten, İpekcioglu & Ertepınar, 2012; Scot, Asoko & Driver, 1991). The use of four components increases functionality of the figure in analysis; moreover, the flow in the figure shows the dynamic structure of the process. Based on the components, the suggested ways of the science teachers were analyzed in a systematic and coherent way. The suggested ways of all the participants were compared with the process outlined in Figure 2 and they were presented in Figure 3.

Figure 3. Teaching process Suggested by science teachers to change alternative conceptions on genetics

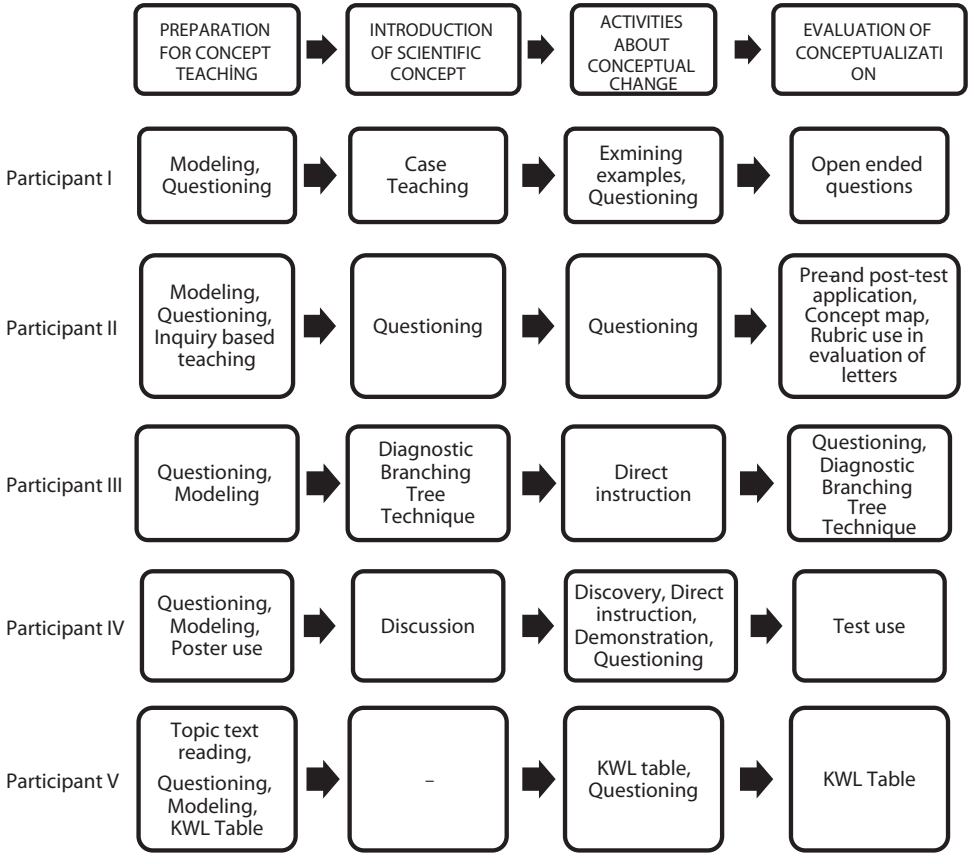


Figure 3. continued

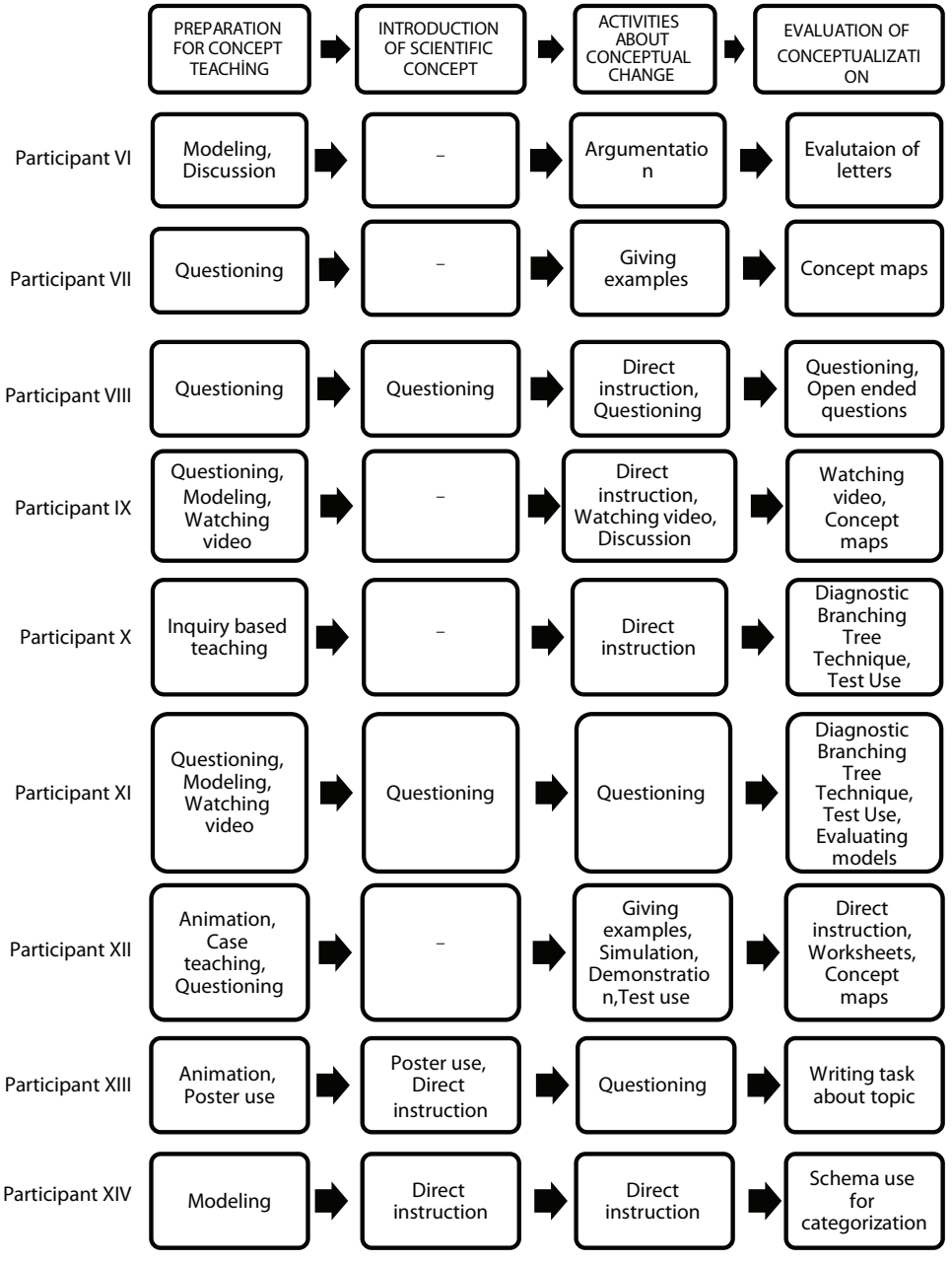
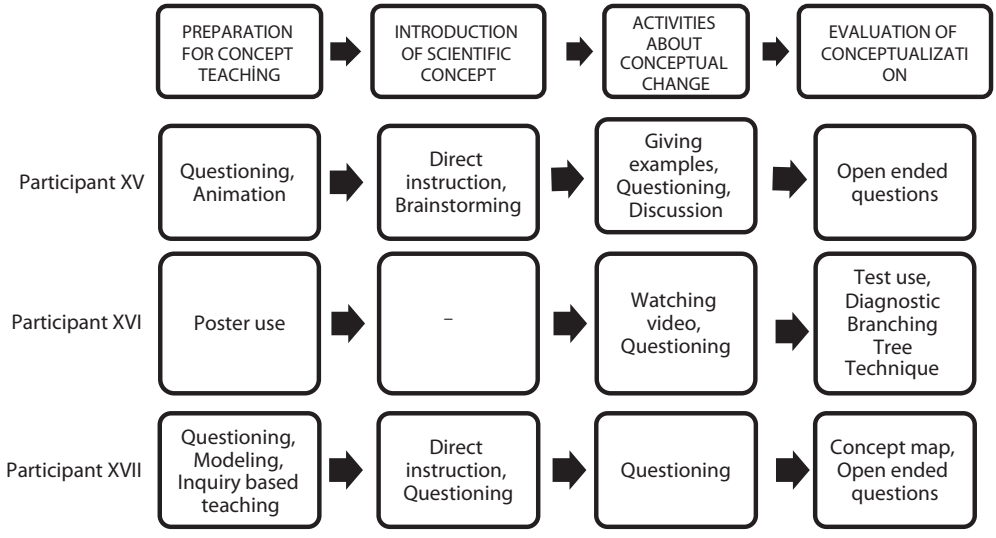
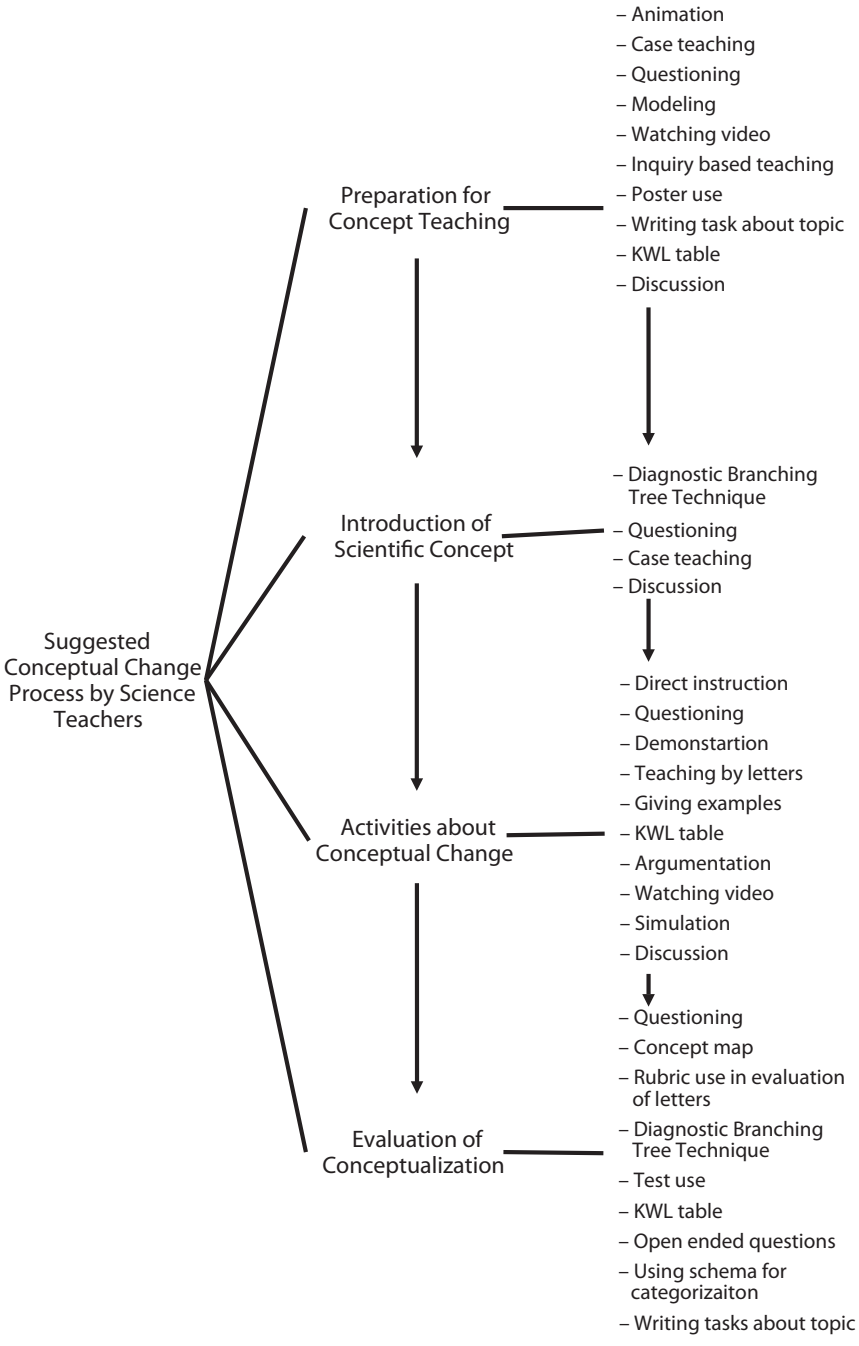


Figure 3. continued



The data based on the participants' plans were categorized into the themes determined previously. The findings showed that the participants suggested different ways from the flow of conceptual change process summarized in Figure 1. The stage called "introduction of scientific concept" is a preliminary stage in the conceptual change process, but some of the participants (V, VI, VII, IX, X, XII, XVI) did not suggest any way to use it and they directly jumped into conceptual change activities. Moreover, the majority of the participants suggested ineffective ways (methods and techniques) for conceptual change. For instance, direct instruction is among the most preferred methods in activities on conceptual change, but direct instruction does not have any component targeting the change of alternative conceptions. At the same time, the use of direct instruction is not an appropriate way to provide constructivist experience. In addition to direct instruction, the participants suggested the use of questioning; questioning might provide an effective way for experiencing discontentment, however, it is not appropriate for the constructivist nature of the conceptual change process since questioning is teacher-based and does not involve individual active learning experience. In general, the participants in the study did not give up their ordinary teaching ways for presenting the conceptual change process on alternative conceptions. The summary of the ways suggested by the participants is presented as a flowchart in Figure 4.

Figure 4. Flowchart of the ways suggested by science teachers to change alternative conceptions



The findings show that the participants do not prefer similar ways of instruction. At the same time, none of the participants mentioned conceptual change texts, reputational text or analogy, which are effective ways in changing alternative conceptions. Moreover, they suggested same ways at different stages, e.g., participant IX suggested watching video at three different stages. Similarly, participant VIII suggested questioning at all stages. Ordinary teaching activities, such as direct instruction, questioning and use of tests are suggested by the science teachers to change alternative conceptions. For the evaluation stage, test use, KWL table, open-ended questions and the diagnostic branching tree technique are suggested by the science teachers.

Discussion and Suggestions

The findings of this study support the idea that science teachers do not have a sufficient level of understanding about the conceptual change process in spite of their higher level education (graduate level) in science education. Changing alternative conceptions of scientific concepts requires applying the conceptual change process in teaching about the concepts. Science concepts, such as genetics concepts, are hard to understand and alternative conceptions about genetics occur when students learn them in inappropriate ways, such as direct instruction or questioning (Banet & Ayuso, 2000; Lanie *et al.,* 2004; Lewis & Kattmann, 2004; Knippels, Waarlo & Boersma, 2005; Kibuka-Sebitosi, 2007; Williams, Debarger, Montgomery, Zhou & Tate, 2011; Akkaya & Köksal, 2013). Knippels (2005) stated that genetics concepts are complicated and abstract, hence, alternative conceptions might easily be developed by students. However, there are ways to change students' alternative conceptions of genetics concepts. The conceptual change process is one of the ways to be used. Posner, Strike, Hewson and Gertzog (1982) point out that conceptual change has some conditions, i.e., showing alternative conceptions to students, using conceptual change techniques, and developing sufficient evaluation techniques to determine change in alternative conceptions.

In spite of the clear definition of conceptual change process, studies show that teachers do not have enough application experience or structured knowledge about conceptual change (Duit & Tregaust, 2009). This situation is also seen in this study. Duit and Tregaust, (2009) relate this situation to the difference in definitions of teaching methods in resources. However, the problem is associated with a lack of theoretical knowledge of the conceptual change process. In a study conducted by Elmas, Demirdöğen and Geban (2011), some pre-service chemis-

try teachers (22.7% out of all the participants) also suggested teacher-centered approaches to teach science. Other pre-service chemistry teachers advocated using student-centered and mixed approaches. Although the findings of the study did not provide direct data for the conceptual change process, it provided a broader picture for teaching preferences of science teachers. An important point in this study is that pre-service teachers vary in their approaches to teaching science in spite of their common education in teacher education programs. In following years in graduate programs, it is expected that they improve their preferences, but the findings of this study show similarity of preferences of science teachers and pre-service science teachers in terms of teaching ways. In a similar study, Yilmaz, Turkmen, Pedersen, and Huyuguzel Cavas (2007) studied pre-service teachers' (n=213) teaching preferences. Their findings showed that 41% of their participants preferred the teacher-centered approach to teach science. Talsma (2007) also measured teaching preferences of preservice teachers; his findings showed that 63% of 60 participants had teacher-centered preferences. Teacher-centered preferences are not in line with the conceptual change approach which is of constructivist nature. Therefore, ordinary ways are preferred by pre-service science teachers in the literature. By focusing the subject-specific conceptual change process, the findings of this study also supported these findings that even if science teachers take advanced courses in science teaching, they still prefer to use ordinary teaching ways in a non-systematic way.

The suggestion of ordinary ways by teachers who are taking advanced courses in science teaching indicates insufficiency of the courses provided in graduate level courses. In fact, changing teaching ways of science teachers is also a conceptual change problem for teacher educators. Both practical and theoretical change in teaching ways require applying the conceptual change process in advanced level courses, hence, there is a need to conduct implementation studies.

As another point in this study, the participants have knowledge of a wide range of teaching methods and techniques. Some of them might be used in the conceptual change process, if planning activities based on these methods and techniques are added to the advanced level courses, more systematic and coherent way of teaching of alternative conceptions might be provided.

This study is based on suggestions and explanations of 17 science teachers so the study is limited to the data collected from a limited number of participants. At the same time, the data were analyzed by two experts and the findings were written by consensus, hence, two experts are another limitation to this study.

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