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TEACHING FOR HOT CONCEPTUAL CHANGE: TOWARDS A NEW MODEL, BEYOND THE COLD AND WARM ONES

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Abstract:
At the beginning of the 1980's, one of the most striking explanations of conceptual change was made by Posner, Strike, Hewson & Gertzog (1982) with a Conceptual Change Theory based on a Scientific Revolution Theory of Kuhn (1970). In Conceptual Change Theory, learning was explained with the Piaget (1970)'s concepts such as assimilation and accommodation. Especially at the beginning of 1990, the Conceptual Change Theory was called as a cold conceptual change, for solely taking the cognitive factors of individuals, and for not taking the affective factors like motivation into consideration (Pintrich, Max & Boyle, 1993). In their studies Tyson, Venville, Harrison & Treagust (1997) (1997) and Alsop & Watts suggested a multidimensional structure of conceptual change including affective characteristics. Dole & Sinatra (1998) have emphasized information processing in conceptual change and have also described the impact of motivation on conceptual change in their Cognitive Reconstruction of Knowledge Model. The Authors explain how the affective and cognitive characteristics interact with each other, and they come up with the warming trend in the conceptual change. Gregoire (2003) has emphasized the automatic evaluation of message and emotions such as fear and anxiety. In order to show how these constructs effect conceptual change, the author has proposed Cognitive Affective Model of Conceptual Change called Hot Conceptual Change. According to the Zhou (2010), although hot factors, such as motivation, are added up to the conceptual change models cumulatively in time, they have little evidence at the point of science teaching. Author proposed a model called "*Argumentation Approach in Teaching Science*" in order to raise temperature in science teaching by using argumentation approach. In this study, we tried to raise temperature more than Zhou (2010) did and started hot trend in science teaching. In this paper, conceptual change literature has been summarized and our teaching model

based on a hot conceptual change and supported by motivational and metacognitive strategies has been introduced. Furthermore, application of our hot model to the Photoelectric Effect Teaching was presented.

Keywords: conceptual change; hot conceptual change; teaching for hot conceptual change; photoelectric effect

Introduction

As a result of interactions with physical world, students come to science classes with some ideas and conceptions (Tytler, 2002). In the literature, there are a lot of definitions for this existing ideas or conceptions. For example: "*alternative conceptions*" (Driver & Easly, 1978), "*misconceptions*" (Helm, 1980) or "*children's science*" (Gilbert, Watts & Osborne, 1982). In their study, Pines & West (1986) defined "*personal knowledge*" as a "*spontaneous knowledge*" and they expressed that this occurred as a result of personal interaction with environment, parents, books or cultural features. Posner, Strike, Hewson & Gertzog (1982) suggested the term existing conceptions. The term "*preconceptions*" is used in many studies (Clement, 1982; Clement, Brown & Zeitsman, 1989). In this study, we will prefer the term "*preconceptions*".

Student's preconceptions is often different from conceptions which scientists have been constructed so far and resists to change that put the hard barrier in front of science teaching (Tytler, 2002). It is a common view in the literature that preconceptions persist after the uses of traditional methods in instruction. (Gilbert, Osborne & Fensham, 1982; Tytler, 2002). How student's preconception change towards to scientific conceptions and which strategies enable this change have been one of the most striking point of all time in the literature.

Conceptual Change Theory

From the beginning of 1980s to the present, conceptual change has been playing a great role on studies based on science teaching and learning (Treagust & Duit, 2008). In 1982, Posner, Strike, and Hewson & Gertzog tried to explain conceptual change by the most striking theory of literature named Conceptual Change Theory (CCT). CCT is based on the Kuhn (1970)'s Theory of Scientific Revolution. According to this theory, scientists could sometimes fail at explaining new realities with their present perspectives. This is called "*crisis*". In such conditions, scientists move away from making science and begin to seek new paradigms by trending to philosophy. If the new reality can be explained by a new paradigm, scientists start using the new paradigm and abandon the old one.

Posner et al. (1982) established CCT by adopting crisis and transition continuum from existing / old paradigm to conceptual change.

CCT is based on Piaget (1970) in the point of explaining learning. Students' tendency of using preconceptions when they encounter the new phenomena to explain the new concepts is defined as assimilation. However, in some cases, preconceptions do not allow students to explain new phenomena successfully. They realize that their preconceptions are incapable of solving the problems and this condition makes them feel dissatisfied. Students feel the need for changing or reorganizing their existing conceptions. This stage is called "*accommodation*" in CCT. Posner et al. (1982) stated that if the existing conception was found unsuccessful, it would more likely to be rejected. If the new concept has a potential to solve the problem, it will be more likely to be accepted. According to authors, for the conceptual change, a student must have a conceptual ecology related to his / her existing concept and there must be anomalies that make him / her feel dissatisfied. Also, new concept must be comprehensible, plausible, and fruitful. The term comprehensible indicates the new concept's potential to solve problem and plausible means student's being in accordance with knowledge that he / she has constructed up to now. Fruitfulness indicates the feature of new concept that implies applicability, transferability. It means the new concept's potential to encourage students to conduct new researches (Hewson, 1981; Posner et al., 1982; Hewson & Hewson, 1983; Hewson & Thorley, 1989). CCM explains conceptual change with dissatisfaction and new concepts' features like comprehensibility, plausibility and fruitfulness. If the new concepts aren't perceived as intelligible, plausible and fruitful, preconceptions of students will persist and conceptual change doesn't occur.

Conceptual Change Approaches after Recommendation of CCT

It could be seen in the literature that a great number of studies (shown in Table 1) based on conceptual change were conducted in the post CCT period. Carey (1985) explained conceptual change by emphasizing the restructuring of the knowledge rather than its change and asserted that this restructuring period wasn't in the assimilation phase but in the accommodation phase. The author suggested that there are two different kinds of conceptual changes: weak and strong restructuring. In weak restructuring, new relations between preconceptions and the new ones are established or some modifications are constructed on preconceptions in order to explain the problem. However, strong restructuring can occur through radical restructuring by moving one conceptual system to another. Vosniadou & Brewer (1987) explain conceptual change with weak restructuring and radical restructuring. While weak restructuring indicates creating a new conception by linking existing with new conception, radical restructuring indicates theory change like the change in Posner et al. (1982)'s CCT. Vosniadou (1999) defined conceptual change as "*restructuring*". The Author emphasizes the enrichment of students' conceptions by their experiences. Thagard (1992) explains conceptual change process in two stages: weak / strong restructuring that is similar to Carey (1985)'s definition. According to the author, weak restructuring means regulating preconceptions without changing them. The strong restructuring may result in two different circumstances. The Author stated that transitions may occur among relative conceptions and this seems like a bird navigating between the branches of a tree. Also reform transition may occur between quite different conceptions and this can be regarded as a bird switching trees.

Chi, Slotta & de Leeuw (1994) alleged that ontological perspectives of conceptions in student mind have an effect on conceptual change. According to the authors, conceptual change occurs if students' concepts move from one category to another. Students have ontological categories that concern with assets and objects in the universe. These categories are called "*Matter*", "*Processes*" and "*Mental States*". "*Matter*" means personal classification of assets and objects like being alive – dead, heavy – light, solid – liquid. Phenomena and links take place in process category. The authors suggested that preconceptions indicate the category of matter, while scientific conceptions indicate the category of processes. If these two concepts are ontologically compatible, the conceptual change occurs easily. However, if both are ontologically incompatible, conceptual change is a difficult process. Chi et al. (1992) explained the conceptual change process as similar to Thagard (1992). They stated that in the assimilation phase, ontological category of concept stayed the same, but in the accommodation phase it changed. As stated in this paragraph, beside implication of change, researchers emphasized reconstruction of knowledge in order to explain conceptual change. Studies based on CCT were continued from the beginning of 1980s to 1990s. Hewson & Hewson (1984) put forth two possible outcomes when students encounter two concepts that have potential to conflict with each other. If students have no background about two concepts, both concepts may become logical thus conflict does not occur. If a student compares two concepts and realizes their confliction, he / she accepts the new concept and rejects the old one. According to Hewson & Thorley (1989), intelligibility, plausibility and fruitfulness formed the status of new concepts. When the status of the new concept was found more plausible and intelligible, status of old concepts was abandoned and replaced by new concepts' status. In the end, conceptual change process was defined as a "*status change*" (Hewson & Hewson, 1992).

Table 1: Conceptual Change Approaches in Post CCT Period

Kuhnien / Piagetian Conceptual Change			Knowledge Restructuring		
Theorists	**CC Approach**	**Most Striking Futures of Approach**	**Theorists**	**CC Approach**	**Most Striking Futures of Approach**
Posner et al.	CCT Rational Learning Approach	Conceptual ecology Cognitive conflict Dissatisfaction, Comprehensible, Plausible, Fruitful	Carey	Rational Learning Approach	Weak/ Strong re-structuring, Change from novice to expert
Hewson & Thorley	CCT Rational Learning Approach	Conceptual change is about raising or lowering the status of the conception	Thagard	Rational Learning Approach	Conceptual revolution Problem-based concept learning, tree swapping, tree switching
Hewson & Hewson	Status Change instead of CC	CC is change of status of concept	Chi et al.	Ontological perspective of CC	CC is a change of ontological category of concepts.
Strike & Posner	CCT Rational Learning Approach	In order to explain conceptual ecology motivation, goals and social context should be regarded.	Vosniadou	Restructuring	Enrichment of concepts, Revision, Conceptual change is a gradual process.

Strike & Posner (1992) accepted the effect of cognitive element on conceptual change, but they believed that some add-ons had to be done to conceptual change. The Authors expressed that, in order to explain the term conceptual ecology, motivation, goals and social context should be taken into account. Posner et al. (1982) asserted that CCT was a product of an effort of answering two basic questions. The first question is, in what conditions a concept is replaced with a scientific one, and the second question is what the features of conceptual ecology that manages process of selecting the new concept are. Especially second question was much more criticized by Strike & Posner (1992).

That's why CCT is cold

In the studies conducted between 1982 and 1993, it has often been proved that classes using conceptual change based teaching are more successful than the ones using traditional teaching system to the extent of creating conceptual change. (Dreyfus, Jungwirth & Eliovitch, 1990; Tsai, 2001; Vosniadou, 1999). However, especially after 1993, researchers made cold and classical descriptions to CCT and began to discuss its limitations (Table 2). CCT started to be criticized for not taking the individual's affective characteristics like motivation into consideration, but the cognitive elements solely. Since then, it has come to be called Cold Conceptual Change (Pintrich, Max & Boyle, 1993; Lee & Anderson, 1993; Vosniadou & Ioannides, 1998; Limón, 2001; Duit & Treagust, 2003). Pintrich et al. (1993) stated that motivational factors and the process of conceptual change are related. The focus of their criticism to the theory of conceptual change was its not taking motivational factors into consideration. After the Pintrich et al. (1993), the criticism of the CCT became the new trend in the literature. Some of these criticisms to the CCT have been summarized in Table 2.

Table 2: The Criticisms to the CCT

Researcher	The focus of the criticism	Explanation
Pintrich et al. (1993)	Motivation	Affective characteristics such as motivation are associated with cognitive processes. Motivation in conceptual change should be considered.
Sinatra & Pintrich (2003)	Intentional CC	Not only cognition but also to be willing to cognition are necessary for conceptual change.
Vosniadou (1999)	Classical Structure of CCT	Classical structure of CCT requires sudden change. Instead of CCT, enriching the restructuring of concept.
Clement et al. (1989)	Construction of Knowledge	In CCT, pre-conceptions which are compatible with scientific knowledge are not regarded as an opportunity for conceptual change.
Chan et al. (1997) Dykstra et al. (1992)	Cognitive Conflict	There is a probability that students may not feel dissatisfied with his / her existing conceptions.
Dreyfus et al. (1990) Chan et al. (1997)	Cognitive Conflict	Even though cognitive conflict would be meaningful for teachers there is no guarantee for the students.
Scott et al. (1992)	Cognitive Conflict	Even though cognitive conflict created, there is no guarantee that result is conceptual change.
Limón (2001)	Cognitive Conflict	Students should be motivated to content, conceptual ecology should be activated.

Structure of CCM which requires sudden changes has been criticized for being classical by some researchers. (Vosniadou, 1994; Vosniadou & Ioannides, 1998). Instead of a sudden change from the existing concept to a scientific one as CCM suggested Vosniadou (1994) emphasized the enrichment of pre-conceptions or restructuring. According to the author, conceptual change is a gradual change of the model that describes the universe in the student's mind. Clement, Brown & Zietsman (1989) noted the importance of the students' conceptions to be in compliance with their scientific concepts. Examples given by the researchers are important for an understanding of their proposal. Student can often resist the condition that the steady-state bodies apply a force. However, it is a readily accepted condition for the same student that spring applies force in the opposite direction to the compressing force. In this case, the information students have about the spring can be used as a "*bridge*". Thus, connection between pre-concepts and new concepts can be established, so additions can be made to the previous concepts. According to Vosniadou (1994) the accommodation process occurs in a developmental way by enrichment of pre-conceptions. It is not easy to change the concepts that have been describing the daily life of students over the years suddenly.

In some studies which included instructions based on conceptual change, researchers reported that in many cases students were unable to create meaningful cognitive conflict and felt dissatisfied with their pre-conceptions (Chan, Burtis & Bereiter, 1997; Dykstra, Boyle & Monarch, 1992). Dreyfus et al. (1990) and Chen et al. (1997) have reported that although it is significant for teachers, cognitive conflict may not be as meaningful for the students. Furthermore, even though students feel dissatisfied and the cognitive conflict occurs, it may not result with conceptual change (Scott, Asoko & Driver, 1992). Also, students must be willing for conceptual change (Sinatra & Pintrich, 2003). It is stated that students should be motivated on the learning topics and context. Besides, if the students' conceptual ecology cannot be activated, cognitive conflict cannot be created (Limón, 2001).

Warming Trend in Conceptual Change

Tyson, Venville, Harrison & Treagust (1997) has proposed a conceptual change model consisting of three dimensions. The authors criticized the consideration of only cognitive elements in the CCT, stated that conceptual change models need new components like ontological, epistemological and social / affective dimensions. They advocate that if the concepts are classified in the wrong ontological category actually, it makes students to have difficulties to learn new concepts. In this context, it can be said that they have a parallel logic with Chi et al. (1994)'s proposals. Researchers asserted that in order to transfer the wrong categorized concepts to the right category, besides students' cognitive element, the ontological perspectives of the knowledge and the social / affective characteristics such as motivation should also be taken into account.

Alsop & Watts (1997) emphasized the importance of not only cognitive but also affective elements on conceptual change and developed a conceptual model with a four-dimensional structure; cognitive, affective, conative and self – esteem. Researchers emphasize the features of the new concept such as intelligibility, plausibility and fruitfulness as proposed by Posner et al. (1982) in cognitive domain. Alsop & Watts (1997) stated that the decrease in the interest of the students keep them from believing scientific knowledge. In their conceptual change model Alsop & Watts (1997) suggested "*Conative*" including subgroups such as control, action and trust. Conative is a dimension that includes students' awareness of features of the new concepts and action for cognition. It is a dimension that associated with affective rather than cognitive such as motivation. Motivation concept is not addressed directly in the model, but it is related to conative. However, metacognition was not addressed in the cognitive domain. However, in the Conative dimension "*Control*" subgroup is concerned with students' recognizing of the characteristics of new concepts. For this reason it can be said that metacognition is indirectly involved in this model.

According to Alsop & Watts (1997), Self Esteem consisting of subscale dimensions such as Image, Confidence and Autonomy has an effect on conceptual change. These dimensions include the students' own statements about how much they trust themselves while learning science. Image is students' perceptions about their ability to relate encountered realities with scientific knowledge. The confidence is insisting on learning despite the difficulties encountered and the autonomy is related to the motivation of students in order to overcome questions or academic tasks. In the conceptual change models proposed by Tyson et al. (1997) with Alsop & Watts (1997), although it is seen the effects of affective factors discussed, factors proposed by Pintrich et al. (1993) and Sinatra & Pintrich (2003) such as motivation, self-efficacy beliefs and metacognition are not taken into account thoroughly.

Yıldız (2008) conducted a study by teaching with metacognitive orientations based on 5E model and found that metacognition had an effect on conceptual change. The author integrated motivation and metacognition on Alsop & Watts (1997)'s Four Dimensional Model of Conceptual Change. As being an affective add-on, motivation rose the temperature. Moreover, metacognition is a hot-cold contribution for not only as a concept which is at the level of cognition but also as a concept which is about motivation (Pintrich, 2003).

The question about one's affective characteristics and how these characteristics would interact with the features of the new concept was answered seriously by Dole & Sinatra (1998). The Authors cited Pintrich et al. (1993) and proposed Cognitive Reconstruction of Knowledge Model (CRKM) called warming trend in conceptual change. In this model, motivation is seen as a complementary factor of conceptual change. According to Sinatra & Pintrich (2003) if students are not motivated, they will not be able to solve the relationship between scientific concepts with their own. It is argued in the CRKM that power, stability and consistency of students' preconceptions have an effect on conceptual change (Dole & Sinatra, 1998; Sinatra, 2005). If the students' ideas are weakly linked and inconsistent with the conceptual framework, conceptual change is most likely to occur. Not only dissatisfaction but also social context has been identified as potential motivators in CRKM. According to Dole & Sinatra (1998), the non-motivated students can be motivated by seeing that another peer is motivated.

Posner et al. (1982)'s definition of "*new concept*" is called "*message*" in CRKM. The Authors expressed how message and individuals' affective characteristics interact and how they affect engagement continuum. Comprehensibility, plausibility, coherent and compelling have been identified as the characteristics of the message. The message that contains a high level of these characteristics is more likely to be accepted (Lombardi & Sinatra, 2010). According to the researchers, engagement continuum is an important condition for conceptual change but does not guarantee it. However, if there is no engagement continuum, conceptual change does not occur or resulted as a weak conceptual change. However, if there is no conceptual ecology and message is not perceived as comprehensible and plausible, in this case it is necessary to look for the presence of peripheral cue. If there is, peripheral cue present weak conceptual change can occur, if not, there is no conceptual change.

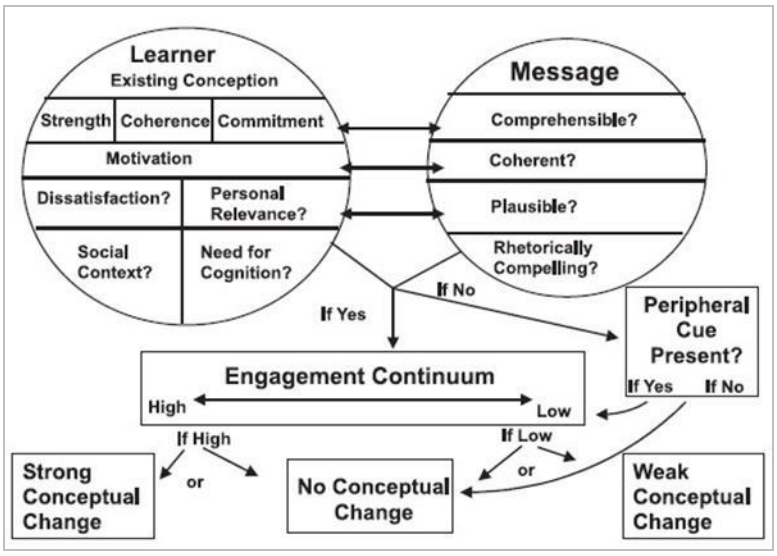

Figure 1: Cognitive Reconstruction of Knowledge Model

The Elaboration Likelihood Model (ELM) proposed by Petty & Cacioppo (1986) has made a significant contribution to CRKM. Showing quite similarities with ELM, Systematic versus Heuristic Information Processing proposed by Eagly & Chaiken

(1993) has an important contribution on CRKM. According to ELM, knowledge is processed in two different ways: central route processing and peripheral route processing. Messages are examined in depth in the central route processing. If individuals identify the value of the message and find it reliable, persuasive and well structured, ignoring whether the conflict or not with their original message, they will consider it as useful. Attitudes will change towards the message and it will most likely be accepted. If the message is misperceived, it will be faced with the boomerang effect and is likely to be rejected. The second way of knowledge processing "*peripheral route processing*" is not based on the understanding and testing the importance of presented argument or message. Peripheral route processing is based on peripheral characteristics of message or peripheral cue. It is based on the charm of the received message, the attractiveness of the resource, the sensational slogans carried by the message and the transmission quality. In the peripheral route processing, mental abbreviations and superficial summaries are made. If the message is weak or too complicated or the learners are not qualified enough, peripheral route processing is used. Students who are aware of Einstein's popularity can believe in Einstein's Special Theory of Relativity and start to advocate it firmly. The teacher's attitudes indicating his/her agreement on one condition enable students to think that they need to listen well or students can say "*teacher is always right*" to avoid from the information process. This situation can be seen in Figure 1 as a peripheral cue.

Hot Trend in Conceptual Change

Gregoire (2003) proposed Cognitive Affective Model of Conceptual Change (CAMCC). The author said that Dole & Sinatra (1998) had established the CRKM by combining ELM and CCM but noted that there are also shortcomings of this model. According to Gregoire (2003), the authors have argued that peripheral cues could be added to the engagement continuum, but they left it open to what extent peripheral cues will affect the existing cognitive processing. CRKM also may explain the effect of motivation on the conceptual change but cannot explain the effect of the subliminal factors such as fear and anxiety on acceptance level of the reform message. Although there are similarities between CAMCC and CRKM, CAMCC includes more emotional factors such as stress and threat appraisals. CRKM could not make it obvious how the emotional and subliminal factors affect belief change.

Fazio (1986) have described the relationship between attitude change and behaviour. In his model automatic and constructive nature of cognition was underlined. The Author expressed how automatic evaluations effect the individuals' interpretation of an event. In CAMCC, automatic evaluation of message -shown in Figure 2 as an "*implicates self*" stage - occurs automatically before evaluating the characteristics of the message. In what way the reform message will be processed depends on the automatic evolution in stage "*implicates self*". Gregoire (2003) defines CAMCC as a hot conceptual change. Especially stage "*implicate self*" and explaining of the effect of peripheral cues on conceptual change are the temperature raising the constructs in the model. It is also noted that experiencing reform message is effected by fear and anxiety. Moreover, the author noted that resources, self-efficacy beliefs, motivation and abilities effected cognitive processes thus they would be effective on conceptual change.

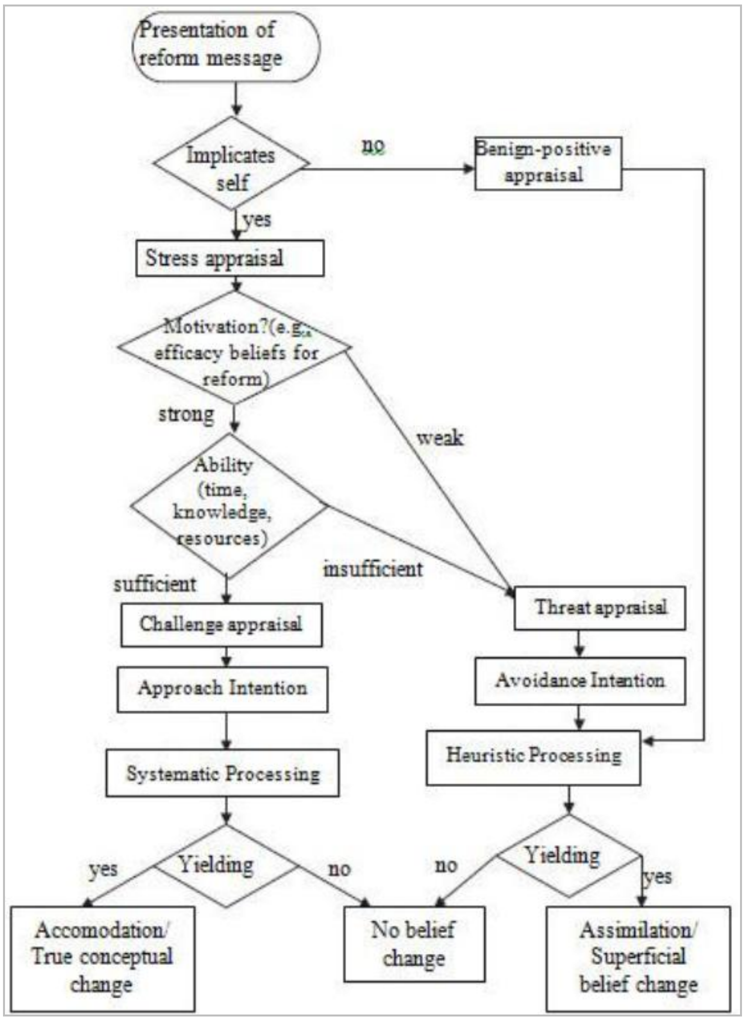

Figure 2: Cognitive Affective Model of Conceptual Change

Theoretical Framework

Numerous studies, which have been conducted from the beginning of 1990s up to now, show that hot constructs such as motivation are undeniable elements in conceptual change. In CCT only cognitive conflict is seen as the most important motivator for conceptual change. However, according to Pintrich et al. (1993), conceptual change is affected by affective characteristics such as motivation, self-efficacy beliefs, the students' interest and goal orientation. After Pintrich et al. (1993)'s revolution, researchers began to add affective factors to the conceptual change models. Chi, Slotte & de Leeuw (1994) noted that the conceptual change occurred when the concepts switched from one ontological category to the other. The Authors proposed three ontological categories: matter, processes and mental states. The third category is connected to affective factors such as emotions.

Table 3: Conceptual Change Models from Cold to Hot

Theorist	Conceptual Change Model	Contribution to Conceptual Change	The criticized aspects of the model
Posner et al.	CCT / CCM	1. Assimilation / Accommodation 2. Cognitive conflict 3. Intelligibility, plausibility and fruitfulness of new concept.	1. Affective factors are not taken into account. 2. Require sudden change. 3. Preconceptions have not been seen as an opportunity.
Chi et al.	Theory of CC	1. Ontological categories 2. Stated that conceptual change is the change of ontological categories.	1. Cannot explain how cognitive and affective elements interact. 2. Cannot explain how affective elements effect conceptual change.
Tyson et al.	Three Dimensional Model of CC	1. Conceptual change has an ontological, epistemological and social / emotional perspectives	1. Lack of metacognition 2. Lack of knowledge processing.
Alsop & Watts	Four Dimensional Model of CC	1. Defines features of the new concept similar to Posner et al. 2. Conative, Self Esteem and Affective three dimensions were added to the CC.	1.Motivation clearly is not contained in the model 2. Lack of metacognition 3. Lack of knowledge processing 4. Cannot explain the impact of the peripheral cues
Yıldız	Metacognition Based Four-Dimensional CC Model	1. Integrated the metacognition to CC. 2. Added motivation clearly to Alsop & Watts's model.	1. Cannot explain the impact of the peripheral cues 2. Lack of knowledge processing
Dole & Sinatra	CRKM	1. Defines how affective and message characteristics interact. 2. Heuristic and systematic processing was adapted to CC model. 3.Proposedtheimpact of peripheral cues on CC.	1. The automatic evaluation of message is not taken into account. 2. Metacognition was defined as the upper limit of "Engagement Continuum" section, but its effect on CC is not clear. 3. Effect of peripheral cues on CC is not clear.

Gregoire	CAMCC	1. The effects of peripheral cues on CC are defined more clearly. 2. The effect of automatic evaluation of message on CC was expressed.	1. Lack of metacognition

CC: Conceptual Change

In their studies Tyson et al. (1997) and Alsop & Watts suggested a multidimensional structure of conceptual change including affective characteristics (Table 3). Dole & Sinatra (1998) have emphasized information processing in conceptual change and have also described the impact of motivation on conceptual change in their CRKM called warming trend. Gregoire (2003) has emphasized the automatic evaluation of message and emotions such as fear and anxiety. In order to show how these constructs effect conceptual change, Kural (2015) has proposed hot conceptual change.

The hot construct motivation has a relation with self-efficacy beliefs (Pintrich & Schunk, 1996; Pintrich, 2003; Tuan, Chin & Shieh, 2005). Furthermore self-efficacy beliefs are related with metacognition, so metacognition has an effect on motivation (Flavell, 1987; Pintrich, 2002). Yıldız (2008) has demonstrated the positive effect of metacognition on conceptual change and has added cold – hot construct metacognition on a model that belongs to Alsop & Watts (1997). Although CRKM classified engagement continuum as a low cognitive engagement and high metacognitive engagement, effect of metacognition on conceptual change has not been defined thoroughly in this model. Furthermore, metacognition did not significantly find its place in CAMCC. In this context, Yıldız (2008)'s study has a critical importance in terms of making a cold – hot contribution on conceptual change model. As a result, theoretical background of this study is based on CCM, CRKM and CAMCC. Furthermore, this study is effected by Yıldız (2008)'s study in which the author integrated metacognition to conceptual change model. In all these studies mentioned above what researchers contributed to conceptual change and criticized aspects of their model have been discussed in Table 3.

Conceptual change literature shows that a number of studies are based on cognitive conflict / dissonance (Stavy & Berkovitz, 1980, She, 2002, 2003, 2004; Lee & Byun, 2012; Hadjiachilleos, Valanides & Angeli, 2013). Lee & Byun (2012) proposes a cognitive conflict as a first essential factor of conceptual change. Hadjiachilleos et al. (2013) proposed that cognitive conflict associates with affective characteristics. Although above-mentioned limitations of cognitive conflict continue to be a topic of criticism (Limón, 2001; Zohar & Kravetsky, 2005), it is clear that it is still one of the most important element in conceptual change.

Problem

If the history of conceptual change that starts with Pintrich et al. (1993)'s revolution and summarized above has been regarded, the need to answer question "*How do we teach?*" shows itself dominantly. The period after the CCM, how to apply the model to science teaching was discussed and many teaching models based on CCM were developed by researchers (Nussbaum & Novick, 1982; Champagne, Gunstone & Klopfer, 1985; Brown & Clement, 1989). In CRKM and CAMCC, the authors explain conceptual change with cognitive and affective constructs but their study remains at the level of cognitive - affective psychology. CRKM and CAMCC have a little explanation of how the reform message will be presented and have little evidence in science teaching point (Zhou, 2010). According to Taasoobshirazi & Sinatra (2011), conceptual change researches remain at the theoretical level and large numbers of experimental studies have not been conducted in recent years. Moreover, there is almost no number of teaching model proposed based on hot conceptual change. How metacognition can be added to a teaching model based on hot conceptual change? How a teaching model can be established that has an implication for how to motivate students? Zhou (2010)'s answer to these questions is argumentation approach. Zhou (2010)'s Argumentation Approach in Teaching Science (AATS) model has an impact of motivation and turns up the temperature in science teaching. But this model only emphasizes argumentation method to motivate students. How can we turn up the temperature in the point of science teaching? Is enough effort spent in the literature for the creation of meaningful cognitive conflict? In science classes, how can instructors struggle with heuristic information processing? Our answers to these questions are not only argumentation approach but also metacognitive orientation. In this study, in order to raise temperature in science teaching perspective, we identified motivational and metacognitive strategies.

In this paper, a cognitive conflict based teaching model supported by motivational and metacognitive strategies has been proposed for hot conceptual change. It is named Teaching Model for Hot Conceptual Change (TMHCC). In their study, Posner et al. (1982) examined students' conceptual change about the modern physics issue Special Relativity Theory of Einstein. In this study, it has been thought that it would be appropriate to test the proposed teaching model by teaching modern physics concepts on which students preconceptions thought to be limited and which are rather discrete. In this paper, how proposed model was applied in science class will be presented but the TMHCC's success in modern physics teaching will not be the subject of the paper.

A New Teaching Model for Hot Conceptual Change

In this research, we recommended a new model for science teaching named Teaching Model for Hot Conceptual Change (TMHCC). As having a look at the model we proposed generally, it could be said that the Posner et al. (1982)'s CCM could be seen. However, looked deeply into the model it could be understood that it is not as "*cold*" as it is seen from the point of conceptual change approach. The processes of TMHCC in Figure 5 are shown below under these headings.

a. Motivating Students to Learning Context

In the conceptual change literature, cognitive conflict is a must for conceptual change (Lee & Byun, 2012; Hadjiachilleos, Valanides & Angeli, 2013). For meaningful cognitive conflict, students should be motivated to the content and should be aware of the interesting sides of the subject (Limón, 2001; Sinatra, 2005). The term "*intention*" was emphasized as an essential factor in conceptual change. If this intention does not exist, students do not change anything (Sinatra & Pintrich, 2003). Therefore, the first step of the proposed model in this research is identified as "*Motivating Students to Learning Context*". In this part, the teacher enables students to be aware of the interesting sides of the subject and their equivalence in their daily lives. This is also the part that the learning objectives are presented.

b. Elicit Students Ideas and Preconceptions

It is very important for a teacher whose teachings will be based on the strategy of conceptual change to focus on in-class discussions to determine the students' cognition on the given subject. If teaching based on conceptual change is expected to be effective, the teacher should identify the preconceptions of his/her students during the teaching period (Yıldız, 2008). According to Limón (2001), preconceptions of students should be activated to provide a conceptual change. Moreover, looking into the studies of conceptual change, it is observed that they are based on the logic that preconceptions should be elicited and cognitive conflict should be created (Stavy & Berkovitz, 1980; Chan et al., 1997). Thus, the part "*Elicit Students' Ideas / Preconceptions*" was added to TMHCC. In this part, the ideas of students are elicited and it is tried to proceed with the conceptual ecologies by asking questions that will arouse their metacognition. Almost all teaching models which are proposed based on cold conceptual change consist of teaching processes that elicit students' preconceptions (Nussbaum & Novick, 1982; Cosgrove & Osborne, 1985; Champagne, Gunstone & Klopfer, 1985; Niedderer, 1987; Brown & Clement, 1989). Furthermore, She (2002)' s Dual Situated Learning Model

(DSLM), which can be accepted as a start in warm conceptual change, and Zhou (2010)'s AATS, which can be accepted as the innovator of warming trend in science teaching, consist of the parts that students' preconceptions were elicited. In AATS student – student argument is used in order to elicit students' preconceptions. However, in TMHCC student – teacher argument is also recommended. A teacher helps students to recognize the concepts of their own and their friends' by cognitive guidance. Also, the teacher asks questions for metacognitive orientation (why your expression is comprehensible / plausible) to facilitate students to be aware of their preconceptions and to prepare them for meaningful cognitive conflict.

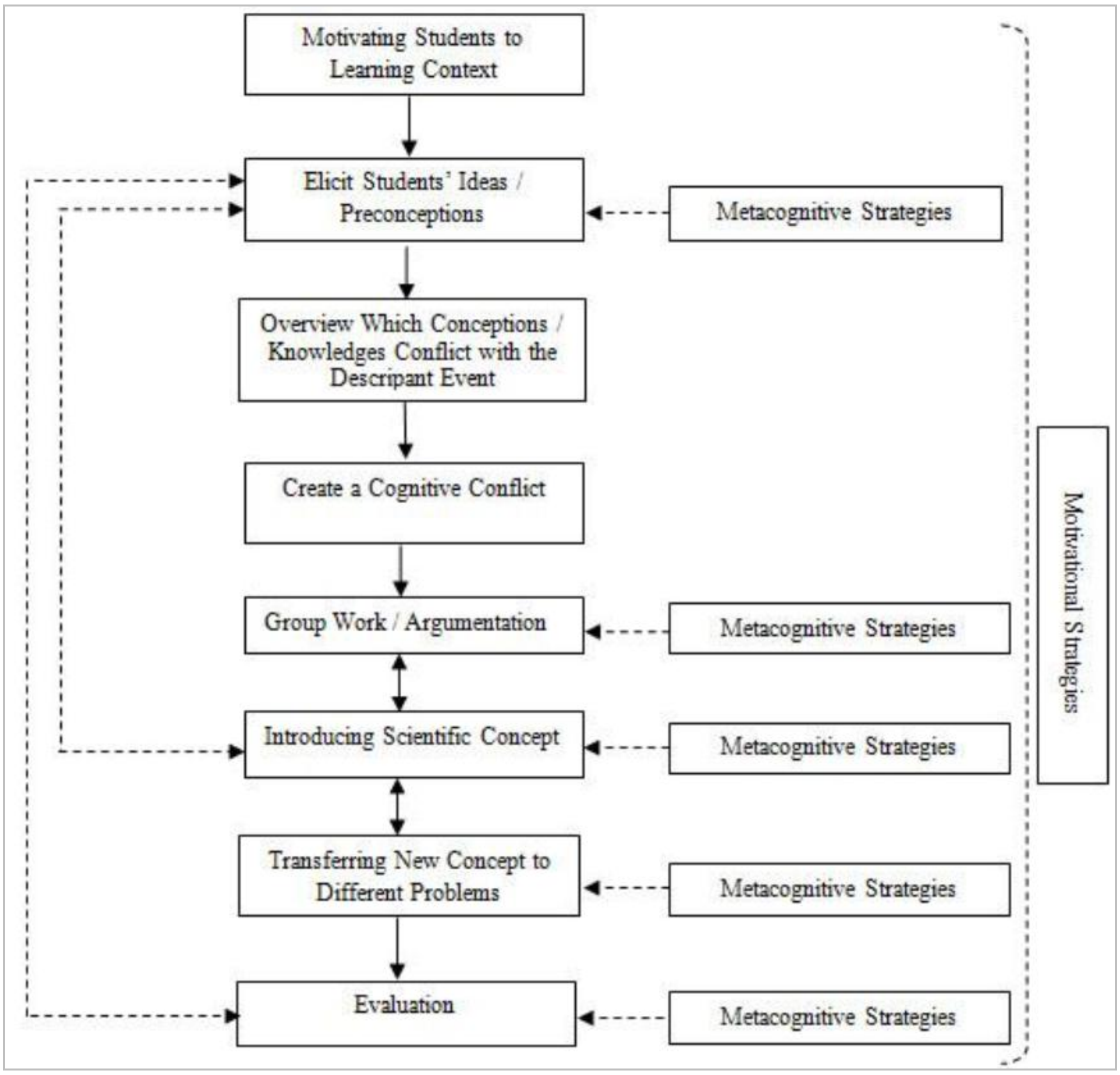

Figure 3: Teaching Model for Hot Conceptual Change

c. Overview Which Conceptions / Knowledge Will Conflict With the Discrepant Event

She (2002) emphasized the change in ontologic and epistemologic basis of concepts in conceptual change with Dual Situated Learning Model (DSLM). Researcher stated that

DLSM was founded by the effect of cognitive psychology theorist such as Piaget (1974), Posner et al. (1982), Sternberg & Frensch (1996), Steinberg & Clement (1997) and Rea-Rramirez & Clement (1998). According to the author, students' preconceptions should be taken into consideration, motivation should be risen when students feel dissatisfaction with that concept and a new mental set should be constructed for the new concept. From the authors' point of view, there are four basic principles of conceptual change. First of all, conceptual change is founded on situated learning elements such as pre-existing mental sets. Secondly, cognitive dissonance should be formed in students, and then a new mental set should be presented. Thirdly, students' motivations and beliefs should be encouraged in the stage of cognitive dissonance. Lastly, conceptual change should encourage students' epistemologic and ontologic beliefs about the concept. Author stated that DSLM was founded based on radical conceptual change and this radical conceptual change is based on the classification of weak and radical restructuring as Vosniadou & Brewer (1987) did in conceptual change. She (2002) connects radical conceptual change to the CCT proposed by Posner et al. (1982). The utterance "*dual*" means that the model is based on two important functions for conceptual change. One of them is cognitive dissonance and the other one is providing new mental sets to the student. In DSLM, new mental sets should be comprehensible, plausible and fruitful and these features are the legacy of Posner et al. (1982). The author proposed a teaching model that includes six stages for conceptual change. The first stage in the model is that in order to teach the planned concept necessary preconditions, or in other words mental sets, should be identified. It is in harmony with the statement "*there should be a conceptual ecology for conceptual change*" which was proposed in the studies of Posner et al. (1982) and Hewson & Hewson (1984). In the second stage, students' ideas and preconceptions are elicited. The first stage of model laid the groundwork for the second stage. In other words, inadequate mental sets of students are identified based on the explanations in the second stage. These three stages in the model proposed by She (2002) became the source of inspiration to the model proposed in this survey.

Some of the researchers (Dreyfus, Jungwirth & Eliovitch, 1990; Chan et al., 1997; Vosniadou, 1999; Tsai, 2001) think that students cannot form a meaningful cognitive conflict. Moreover, some students may not become dissatisfied with their existing concepts. According to some other researchers (Chinn & Brewer, 1998; Gorsky & Finegold, 1994; Mason, 2000; Kang, Scharmann & Noh, 2004), a discrepant event does not guarantee the cognitive conflict. From Posner et al. (1982)'s study up to now, creation of cognitive conflict has become one of the most basic problem for teaching strategies or models based on CCM. In Limón's (2001) point of view, one of the most important reasons for not forming the cognitive conflict is the students' inadequate preconceptions. If the students' preconceptions or knowledges have inadequate to conflict with the discrepant event, cognitive conflict does not occur as the teacher presents the reform message. As it was stated before, it is necessary for a student to be aware of the preconception that conflicts with the discrepant event for conceptual change. Therefore, a third part "*Overview Which Conception / Knowledge Will Conflict with the Discrepant Event*" is added to the model that is used in this survey. This part is equal to the third part of DSLM.

d. Create a Cognitive Conflict

The fourth stage called "*creating a cognitive conflict*" in the teaching model is a legacy of Posner et al. (1982). The authors expect teachers to include the students' anomalies against current concepts to the teaching atmosphere. Only in this way can students be motivated to change their preconceptions with scientific one and to notice the features of new concepts. Also the fourth and the fifth stages of DSLM are the stages of planning and applying the teaching events. In the fifth stage, opportunities are given to the students to create new mental sets by becoming dissatisfied with the existing concepts. It could obviously be observed that She (2002) mentions the concepts of cognitive dissonance and dissatisfaction, and includes these two concepts into teaching stages. Zhou (2010)'s model, which is the leader of warming trend in science instructions, includes the stage of creating a cognitive conflict. It is a well-known fact that cognitive conflict is essential in many studies of conceptual change literature.

e. Group Work / Argumentation

In Zhou (2010)'s opinion, when researchers generally focus on conceptual change, this makes students to become passive in facing cognitive conflicts and as a result the student can choose memorizing instead of mastering it. In addition, the author expresses that he managed warming trend in science teaching by argumentation method and it becomes the source of the model in this survey. According to Wentzel (1991), students aim at making friends, influencing peers and gaining the appreciation of the teacher besides understanding the subjects academically. From Tao and Gunstone's point of view (1999), computer assisted cooperative learning enables students to construct their experiences and to understand shared events. Furthermore, Palmer (2005) and Zhou (2010) emphasized that applying the argumentation method in class raises the motivation and contributes positively to creation of conceptual change. According to Limón (2001), argumentation and peer-work enable students to create more active cognitive conflict. Although their CCM has been called as a cold conceptual change, Posner et al. (1982) accept that having Socratic discussions in conceptual change period is an essential role of the teacher. As considering all these factors, the fifth part of the model in this survey is called "*Group Work / Argumentation*".

Güngör (2010) found out that in-class activities effect students' motivations and affective characteristics positively by working with more than a thousand students. In his study, it has been found that the activities like working in a group, discussing the opinions of the group and asserting his / her opinion motivate the student to the lesson. These activities are accepted as the strategies that rise motivation of the TMHCC. These strategies could be combined with teaching based on a conceptual change.

Güngör (2010) reached the outcome that assigning students academically and giving them academic and motivational feedback raises motivation. Providing clear, realistic and accurate feedback can help students to get motivated (Pintrich, 2003; Pintrich & Schunk, 2002). Students are given academic and motivating feedback in Group work / Argumentation part and this is the most obvious evidence that the "*teacher*" factor, ignorance of which in conceptual change was criticized by Gregoire (2003), is taken into consideration in this survey. Furthermore, in group work and argumentation stage students are asked questions like "*why your expression is comprehensible / plausible*" or "*did you really understand the presented material*"- that will challenge their metacognition. In this stage of TMHCC, teacher tries to make metacognitive orientations to provide meaningful cognitive conflict.

f. Introducing Scientific Concept

In teaching models after Posner et al.'s study (1982), an approach based on cognitive conflict and then reaching an agreement could be observed (Stavy & Berkovitz, 1980). "*Introducing scientific concept*" is added to the model to give opportunities to students for changing their preconceptions with new and scientific one. The sixth stage in the model is the part that the teacher is the most active but the information has never been given directly. Student – student and student – teacher argument methods have been used as an instructional and motivational strategy. Also we agree with Zhou (2010)'s proposal about this stage in which students' results from group work and argumentation can be used as an opportunity to introduce scientific concept. The analogies and discussions have a potential to promote motivation (She, 2002). These methods are also used to foster motivation. In this part, students are given an opportunity to rethink and discuss the conflict between the preconceptions and the new concepts. Students will also have the opportunity to evaluate the comprehensibility, plausibility and the fruitfulness of the new concepts by questions that can challenge their metacognition.

g. Transferring New Concept to Different Problems

It was stated that researchers criticized classical structure of CCM that required a sudden change (Vosniadou, 1994; Vosniadou & Ioannides, 1998). Researchers recommend a conceptual structure that is improved by experiences instead of a sudden conceptual change with a cognitive conflict. Conceptual change should occur progressively with experiments and observations (Vosniadou, 1994). As this is also considered in this survey, a seventh part called "*transferring new concept to different problems*" is added to TMHCC. In this part, students will improve their experiences by encountering the problems especially in their daily lives. The stimulating and interesting academic tasks, activities and materials are given to students to motivate them (Pintrich & Schunk, 2002; Pintrich, 2003) It can be stated that the sixth and the seventh parts of the model are the parts of accommodation. However, it can be said that in our TMHCC we try to enrich accommodation phase.

Students are given opportunities for transferring knowledge to different physical conditions, so they are able to test the plausibility and the fruitfulness of the new concept. In these parts, students are tried to be persuaded that the new concept is comprehensible, plausible and fruitful by metacognitive strategies. In She's (2002) DSLM; however, the sixth stage is the part that students transfer the learned concept, or in other words the new mental sets, to other physical conditions. In the Zhou (2010)'s model, this stage is the stage of "*apply*". Student – student or teacher – student arguments are used as motivational strategies.

h. Evaluation

The eighth and the last stage shown in Figure 3 is the "*evaluation*" stage. Students are asked some questions such as what their conceptions are before and after the instruction, whether there is any change or not in their conceptions, and if there is a change, which parts in the instruction cause this change. In evaluation part, in order to challenge the metacognition (in both knowledge of cognition and regulation of cognition aspects), the teacher asks students if their preconceptions and new conceptions are different or not, if there is any difference, what has caused this change and whether they have a positive outcome in this teaching period or not. Teacher tries to elicit useful and interesting part of activities and the utility of content learned as a motivational strategy (Pintrich, 2003). Zhou (2010)'s AATS had a great contribution to addition of this stage to TMHCC.

Motivational Strategies in TMHCC

It could be seen that a new period started in conceptual change with Pintrich et al. (1993). Palmer (2005) stated that motivation, one of the most essential affective factors, should be taken into consideration more. In this survey, motivation is accepted not only as a passive variant whose change is observed, but also motivational strategies are put forward. These motivational strategies are separated into all stages in our model. A right teaching atmosphere should be created in order to raise students' motivation.

In our study, cognitive conflict can be regarded as a natural motivator for conceptual change (Posner et al., 1982). In TMHCC, one of the most important motivational strategies is the argumentation as Zhou (2010) proposed. Author stated that scientists construct scientific knowledge by not only observations and experiments but also discussions with each other and reasoning from statements which the others claimed. Argument approach has a potential for fostering motivation and it is functional at the point of science teaching.

Beyond the Zhou (2010)'s AATS, in our TMHCC, more motivational strategies have been proposed. Providing clear, accurate and realistic academic feedback can help students to motivate (Pintrich & Schunk, 2002). The tasks presented in Group Work / Argumentation stage were designed to provide opportunities to students to be successful but also challenge them (Pintrich, 2003) and were designed neither too easy nor too difficult (Pintrich & Schunk, 2002). The use of cooperative and collaborative groups motivates students (Pintrich, 2003). Giving students enough time to reach a conclusion and taking their positive outcomes into consideration and giving motivational feedback after the completion of an academic task rise motivation (Güngör, 2010). The analogies and discussions have a potential to promote motivation are also used based on She (2002)'s proposal.

Metacognitive Strategies in TMHCC

Flavell (1979) defines metacognition as the knowledge of one's cognition. Metacognition is defined as the *awareness* that includes planning the problem solving period, observing and evaluation periods as well as the knowledge about one's cognitive period. Studies on metacognition show that it is consisted of two components as "*the knowledge of cognition*" and "*the regulation of cognition*" (Pintrich, 1999). The knowledge of cognition is about what one knows about oneself or his / her cognition (Schraw & Moshman, 1995). Regulation of cognition consists of planning, self-observation and self-evaluation aspects (Schraw, 1998). Planning is about choosing appropriate strategies, defining objectives, organizing the time and activating preconceptions (Schraw & Moshman, 1995). Observing means that students are aware of their performances while solving a problem and that they control their cognitive process periodically. Evaluation means students' self-evaluation at the end of the learning period. It evaluates students' effort and to what extend he / she reached his / her goals at the end of the learning period. Students are expected to evaluate themselves as stated in the saying "*we managed it without a stain on our character*" (Yıldız, 2008).

Students' belief of self-efficacy, cognitive and metacognitive strategies are effective on conceptual change (Pintrich and Garcia, 1991; Pintrich, Smith, Garcia & McKeachie, 1993; Pintrich et al., 1993). Beeth (1998) stated the positive effect of using the materials that orientate metacognition on the aspects of comprehensibility and plausibility in conceptual change. In addition to this, according to Hewson, Beeth & Thorley (1998), metacognitive activities make a concept easier to learn, and thus it could be concluded that conceptual change will be easier, too. Pintrich et al. (1993) stated that belief in self-efficacy was effective in accommodation period of conceptual change. It could be considered that it is important for students to proceed with developing metacognition in the accommodation stage, which consists of internalizing the new concept. In teaching based on conceptual change, Yıldız (2008) showed the positive effect of metacognitive classroom atmosphere on students' learning and thus, she added metacognition to conceptual change.

According to Hennessey (1993), students think about the background of their belief in current concepts and they make it clear by interpreting the contradictory points of new concept to the current one, and he thinks that these are related to metacognition. By taking this interpretation into account, it could be said that if students are given the opportunity to use statements such as "*The new concept is comprehensible because …..*" or "*The new concept is plausible because ……*" in the accommodation stage of conceptual change, students' metacognition improve and a stronger conceptual change occurs. In teaching plans based on the proposed teaching model in this survey, students are expected to evaluate their own expressions on account of comprehensibility and plausibility in the parts that students' preconceptions appear. In addition, in the stage of introducing scientific concepts, opportunities are given to discuss the fruitfulness of new concepts as well as discussing their comprehensibility and plausibility. Especially in group work / argumentation and evaluation parts, questions on account of regulating cognition are asked and students are expected to ask themselves whether they are aware of the presented material or not, or whether they managed it successfully or not.

Motivational and metacognitive strategies mentioned above and used in TMHCC, also theoretical background of these strategies can be seen in Table 4.

Table 4: Motivational and Metacognitive Strategies in TMHCC and Their Theoretical Backgrounds

Stages of TMHCC	Motivational / Metacognitive Strategies	Theoretical Background
Motivating students to learning context	*Students need to be aware of learning topics for motivation.*	Limon (2001)
Elicit students' ideas and preconceptions	*Argumentation* Questions for metacognitive orientation (Why your expression is comprehensible - plausible)	Posner et al. (1982) Zhou (2010) Hennesey (1993) Beeth (1998) Yıldız (2008)
Overview which conception / knowledge will conflict with the descripant event	*Argumentation* Students' conceptual ecology must be activated. She (2002) students' pre – existing mental sets must be elicited for cognitive dissonance.	Zhou (2010) Posner et al. (1982) She (2002)
Create a cognitive conflict	*For conceptual change, cognitive conflict can be seen as a natural motivator.*	Posner et al. (1982)
Group work / Argumentation	*Peers are the potential motivators, Group work, Argumentation* Questions for metacognitive orientation for meaningful cognitive conflict (Why your expression is comprehensible–plausible & Did you understand the material etc.)	Dole & Sinatra (1998) Gregoire (2003) Zhou (2010) Beeth (1998) Hennesey (1993)
Introducing scientific concepts	*Argumentation, Discussion, Analogies* Questions for metacognitive orientation (Why your expression is comprehensible - plausible - fruitful)	Zhou (2010) She (2002) Beeth (1998) Hennesey (1993) Yıldız (2008)
Transfering new concepts to different problems	*Giving academic tasks / problems that challenge students* Questions for Metacognitive Orientation (Why your expression is comprehensible – plausible)	Pintrich (2003) Beeth (1998) Hennesey (1993) Yıldız (2008)
Evaluating	*Eliciting useful and interesting part of activities and the utility of content learned.* Questions for metacognitive orientation (What are your conceptions before and after the instructions, Can you evaluate weak and strong part of instruction? etc.)	Pintrich (2003) Zhou (2010) Yıldız (2008)

Overview of Model

Continuous arrows in the Figure 3 show the outflow. Arrows among the stages "*group work / argumentation*", "*introducing scientific concept*" and "*transferring scientific concept to the new problems*" are bidirectional. In this part, argumentation method is dominant. The questions students ask to each other or to the teacher can cause new problems because of the classroom atmosphere. Thus, the teacher can want students to rework in groups, discuss or come to new conclusions by studying on a simulation. The details of this event will be presented in teaching period. Discontinuous arrows in the model show the interaction among the boxes. For example, in "*evaluation*" stage, the teacher asks students questions and enables them to think about the transition process from old concepts to the new and scientific ones. Therefore, "*evaluation*" stage and "*eliciting student's ideas and preconceptions*" stage are combined to each other with discontinuous arrows. Similarly, the introducing the scientific concept stage and eliciting student's ideas and preconceptions stage are also combined to each other with discontinuous arrows as they interact with each other.

Some Powerful Implications of TMHCC

In this paper, we have tried to focus on a subject which has not been discussed sufficiently for conceptual change literature that has the warming and hot trends especially for the last ten years. She (2002) mentions about the motivation at the stage of cognitive dissonance in DSLM and Zhou (2010) asserts that argumentation method increases the temperature in science teaching. Zhou (2010) becomes the source of TMHCC from this point of view. Unlike other models, more motivational strategies as well were used in this study at all stages of TMHCC to promote conceptual change by fostering motivation. In Table 5, warming teaching models mentioned and the most noticeable features of TMHCC are comparatively shown.

Table 5: Warming Trends in Teaching Models for Conceptual Change and TMHCC

Researcher / Model / Hot Construct	Theoretical Background	Strengths / Weaknesses
She (2002) / Dual Situated Learning Model (DSLM)	Piaget (1974), Posner et al. (1982) CCM / Motivation	1) Each dual situated learning event consist of two functions: a) creating dissonance with students' pre-existing knowledge, b) providing a new mental set. 2) The new mental set should enable students to see the new concept as intelligible, plausible, and fruitful. (as Posner et al. (1982) suggested) 3) Posner et al. (1982)'s term "conceptual ecology" can be seen as a "pre-existing mental sets" in the DSLM. This feature is very important for meaningful cognitive conflict. 4) Motivation is only related with creation of dissonance stage. 5) It lacks metacognition.
Zhou (2010) Argument Approachto Teaching Science (AATS) /	CCM – CRKM – CAMCC / Motivation - Metacognition	1) The author recommended warming trend in science teaching. 2) In this model the temperature in science teaching based on conceptual change is tried to be increased by argumentation method. 3) It focuses on cognitive conflict; however, there is no effort for meaningful cognitive conflict in AATS. 4) Pre – existing mental sets in DSLM aren't taken into consideration in AATS. 5) Metacognition is observed in the last stage, evaluation, in this model. However, metacognition does not take place in the stages that preconceptions are elicited and that scientific knowledge is defended and discussions are made. 6) The Author states that CRKM and CAMCC are the sources of AATS; however, he does not recommend anything on how to struggle with peripheral cues which are the most major obstacles in students' conceptual change.
Authors Teaching Model for Hot Conceptual Change (TMHCC)	CCM – CRKM - CAMCC / Motivation / Metacognition	1) Authors recommended hot model in science teaching. 2) Motivational strategies are used in all stages. 3) As in AATS, in TMHCC not only argumentation method but also motivational strategies such as group work, academic and motivational feedback, etc. were used. 4) Motivation is in relation with self-efficacy and self-efficacy is in relation with metacognition. Therefore, metacognition is a hot construct although it is considered in cognition level. 5) In TMHCC, metacognition was added to the stages that preconceptions are elicited, that discussions are made and that scientific concepts are introduced. It is obvious that in science instruction the temperature is higher than the temperature in AATS. 6) In the model it is anticipated that as metacognition covers more stages, it leads students to engage and move away from heuristic information processing. 7) It is also considered that metacognition will increase the strength of conceptual change of students who use central route processing / systematic processing. 8) Like DSLM, it involves regarding pre – existing mental sets with which discrepant event conflict.

Methodology

We investigated the influences of the TMHCC on the student's conceptual changes, their motivations and attitudes towards physics. The mixed pattern was used in accordance with the problem of the research. In this paper we only criticized how we taught photoelectric effect based on TMHCC.

Sample

The sample of the study consisted of 40 students from two grade 11 science classes in 2012/2013 academic year at an Anatolian Teacher High School of a district in Manisa in Turkey.

Application of TMHCC on the Topic of Photoelectric Effect

In our research, first of all teaching stages, which will be the reflection of each stage in TMHCC, were determined. These stages are shown in Table 6 below. The whole unit of Particle Model of Light and Theories of Atom was taught by using TMHCC. In this paper, only the teaching stages of photoelectric effect are clarified under the subtitles below in order to give an example for how the model was applied.

Table 6: Teaching stages corresponding to the stages of TMHCC

Stages in TMHCC	Teaching Stages
Motivating Student to Learning Context	What to learn?
Eliciting students' ideas and preconceptions	Pondering questions
Overview which conception / knowledge will conflict with the discrepant event	Let's examine the preconceptions
Creating cognitive conflict Group work / argumentation	Mission Science
Introducing scientific concept	Let's introduce with scientific concept
Transferring new concept to different problems	Let's solve a problem
Evaluation	Evaluation

What to learn?

The first stage of the lesson starts with presenting the objectives of the lesson and motivating the students to the content. To do these, students are shown the slides exampled in Figure 4.

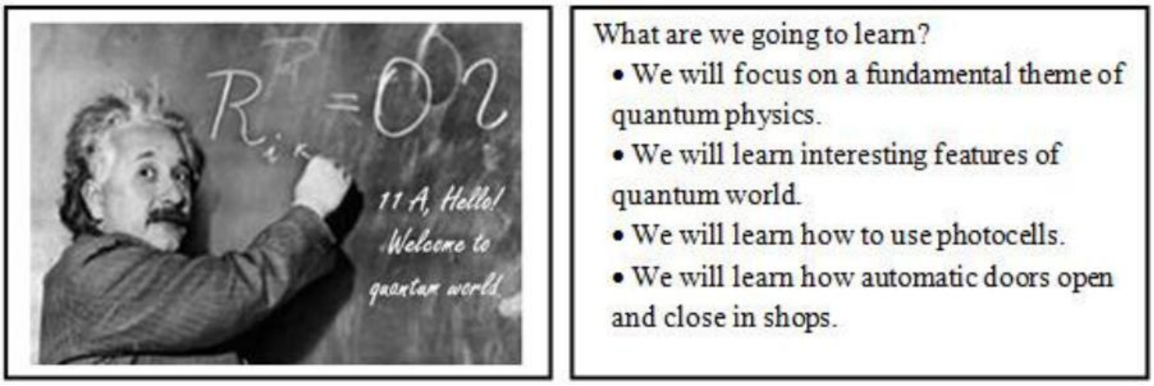

Figure 4: The slides that were shown to the students in "*what to learn*" part of the lesson

Students are told that a fundamental theme of quantum physics will be focused on in the lesson and that they will learn a matter that they encounter mostly in their daily life. Apart from this, students are told that they will learn how photocells and the automatic doors in shops and supermarkets work.

Pondering Questions

The next stage of the lesson is "*pondering questions*" part in which students' preconceptions about photoelectric effect are elicited. In this stage students were given an electroscope and a zinc plate combined its nob. Metal sheet and the electroscope are charged negative and the leaves of the electroscope are open. As shown in Figure 5, monochromatic light comes onto the zinc plate. First of all, students were asked if it was possible or not to change the charge of the electroscope like that. Then, they were asked if the charge of the electroscope could be changed or not by increasing the intensity of light, changing its frequency or changing the type of the metal. In the academic year of 2011/2012, it had been observed that some of the students could not realize that the colour of the light and its frequency were in relation in the pilot phase of the study. Therefore, in the real study, the questions about changing the colour and frequency of the light were asked separately. In order to challenge metacognition, students were expected to evaluate their own answers on the aspects of comprehensibility and plausibility. Students also started to criticize other students' statements in a positive or negative way as they made explanations. Thus, argumentation atmosphere, which was one of the motivational strategies in the model, was created. After the argumentation, teacher had written the given answers on the board and summarized the preconceptions. The teacher thanked students for their effort to create functional and effective discussion atmosphere.

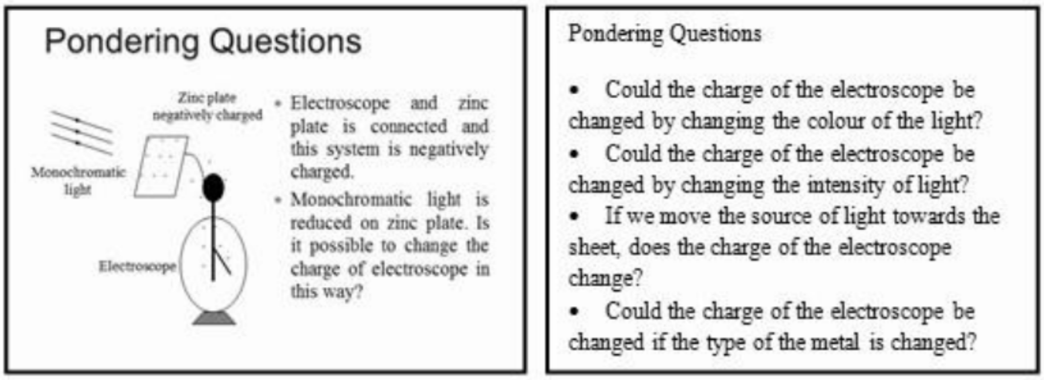

Figure 5: "*Pondering questions*" part

Let's Examine Our Preconceptions

For a more meaningful cognitive conflict, students were asked questions such as what charging the electroscope means and what it means when its leaves are open or closed at the stage of "*examining the preconceptions that will conflict with the discrepant event*" in the research. The slide consisting of the questions asked to the students in the computer assisted presentation is shown in Figure 6.

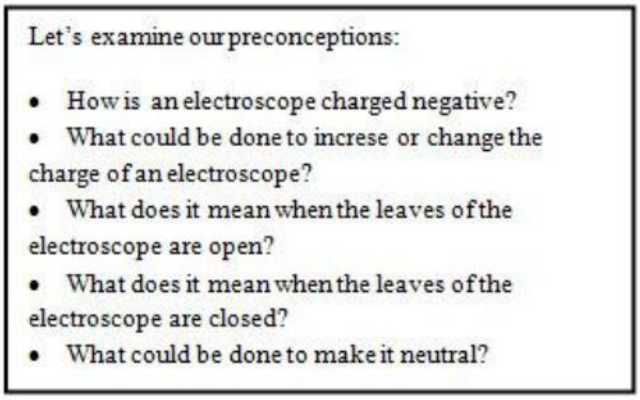

Figure 6: The example of asked questions in the part of "*Let's examine our preconceptions*"

An argumentation approach is used as a motivational strategy in this stage. As it could be understood from Figure 6, first of all it is aimed for students to accept the fact that if the leaves are open, it means that the electroscope is charged and when it loses its charge, the leaves are closed. In the previous year, most of the students in the pilot study replied the questions as "*light isn't charged so it doesn't affect the electroscope*" or "*the charge of the electroscope changes because light is charged*" in the part of eliciting the preconceptions. Therefore, in real study it was thought that students could give similar answers, so the questions in Figure 6 were added to the presentation. At this stage, it is thought that the more students' conceptual ecologies on gaining or losing the charge of an electroscope are activated the more meaningful cognitive conflict they have.

Mission Science

The fourth stage in TMHCC is creating the cognitive conflict and the following fifth stage is the part in which student tries to make explanations about the contradictory event which causes cognitive conflict by working in groups. These two parts in teaching were given under the title "*Our mission is science*". First of all, students watched a downloaded video from the internet to create a cognitive conflict. In the first episode of the video, someone made electrification by rubbing an ebonite stick against a cloth. Then, he touched the electroscope with that ebonite stick and charged it, and it was observed that the leaves of the electroscope opened. Everything was easy for students up to now as there was really an appropriate physical condition to their mental sets based on classical physics. However, when the person in the video moved something that cast blue light on the nob of the electroscope, it was observed that the leaves of the electroscope closed. These stages explained in the video are shown in Figure 7 below.

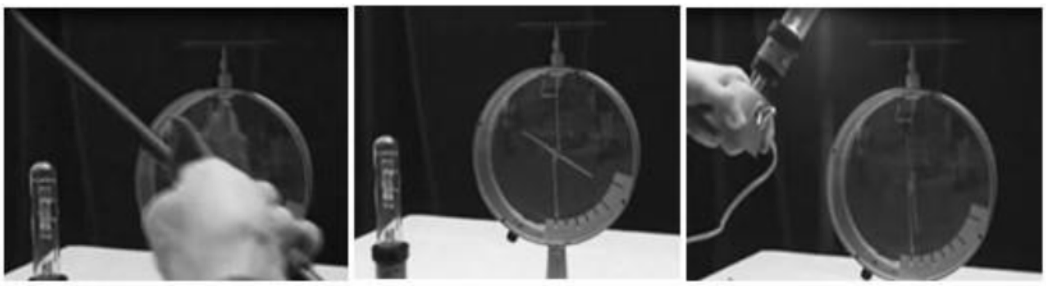

Figure 7: The stages in the video about photoelectric effect in which cognitive conflict created

Students were asked how they would explain this event (Figure 8.a). They were given some time and were expected to answer the question by working in groups. At this stage, for academic and motivational feedback, the teacher joined the discussions by wandering around the groups without answering the questions. The teacher enabled students to observe their explanations deeply by asking them questions and so that he / she could make it meaningful for the other students. Students in groups were given opportunities to ask the other groups some questions. When the time was up, the teacher wanted the group speakers to state the answers of the group. In order to challenge metacognition, groups tried to defend their answer on the point of comprehensibility and plausibility while they were making explanations.

Thus, the process which started with group work ended in class discussion. Up to this stage students had not been given any explanations about the scientific concept. Students were given a new mission and were asked to make it clear by studying on the computer simulation in group. There were two reciprocal plates on one of which another metal was put.

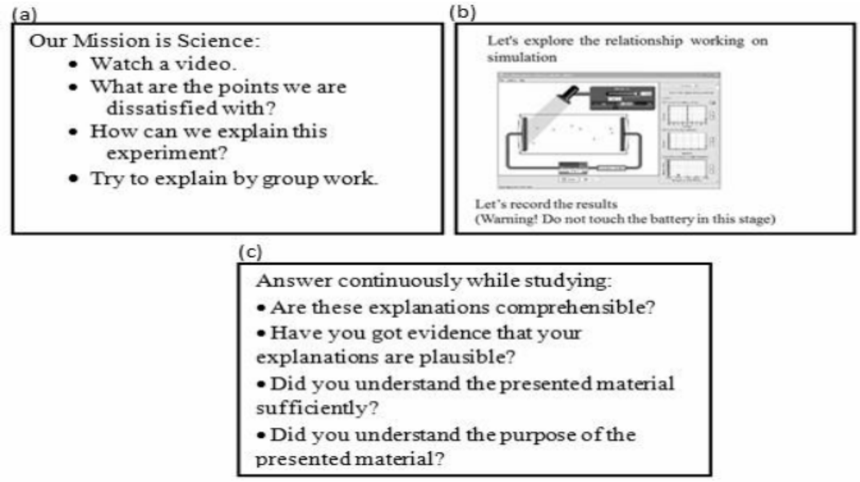

Figure 8: (a) Creation of cognitive conflict and challenge students for group work, (b) simulation about photoelectric effect, (c) metacognitive orientation.

As seen in Figure 8.b, sheets are tied to a battery and an ammeter. Students were especially emphasized not to make any changes on battery voltage. Frequency and intensity of light could be changed in the simulation. Students were given some time and during that period they were expected to observe the valence in ammeter by changing the frequency and intensity in the simulation and note down the consequences.

Metacognitive orientations were done in "*Mission Science*" part, which is the equivalent of "*Group work and argumentation*" stage in teaching. As seen in Figure 8.c, there were some questions proceeding metacognition such as "*Did you understand the material sufficiently?*", "*Did you understand the material?*" under the subtitle of "*Answer continuously while studying*". In addition, the teacher guided the students with questions while wandering around the groups. Finally, the teacher listened to the answers and wrote a summary on the board. These answers were evaluated by both the group speakers and the other students of the other groups on the point of plausibility.

Let's introduce with scientific concept

In this part, in which the teacher is the most active, students are guided to reach the scientific concepts. It was stated to the students that the leaves of the electroscope close as electroscope loses charge. After all the students agreed on this, the teacher asked whether the light is charged or not. In the pilot study in the previous academic year, the answers were based on the logic that "*the light is charged*", so the researcher prepared himself to such notion in the real study. Students were reminded that the light propagated with a speed of light, which was the matter in Special Relativity Theory of Einstein and thought in 10th grade. It was also stated that charged light should carry charges and these charges should have mass and it was emphasized that therefore the charges which had mass never propagate with a speed of light. The teacher reached a conclusion by examining the preconceptions which he / she synthesized with the answers from groups. It was stated to the students that if the light did not carry charge, the loss of the leaves of electroscope could only be explained by the emitting of electrons from the metal plate. The teacher expressed that photons in the light break out electrons and this event was called photoelectric effect by making connection with the previous subject photons, which was taught in black body radiation topic.

"*Introducing scientific concept*" part went on with the teacher's studying on the consequences that students reached from the simulations. The teacher asked students why photoelectric event did not occur in every frequency and why there was an initial frequency. The teacher explained Einstein's explanation of photoelectric effect with these questions. Students in the pilot study in the previous year could reach the outcome that increasing the power did not cause electron emitting in the simulation. Therefore, in the real study carried out the following year, it was thought that students could reach the similar outcomes and the questions in Figure 9 were prepared to be asked.

Students were asked how increasing the intensity of light effected in the case that the light could not emit any electron. While some groups could answer immediately, some others could not answer. Students were given some time and asked to study the simulation on this point. Thus, all the students could observe that increase in the intensity was not enough to emit electrons.

Acceptances of Modern Physics

- Why doesn't the increase of intensity cause electron to emit?
- What is the point classical physics lacks of?
- Which acceptance of modern physics does electron disturbance confirm when the frequency of light increases?

Figure 9: Defending the acceptances of modern physics in teaching photoelectric effect

The teacher especially stated that increase of intensity did not mean energy increase. At this stage, "*Let's examine our preconceptions*" part was revised again and after emphasizing that the intensity of classical wave and energy were directly proportional, it was stated that light could not be thought as a classical wave. It was also mentioned that the case that light emitted the electron after a specific initial frequency could not be explained by classical physics; however, it was a case that could be explained by Planck's particle nature of light logic. Students were asked to evaluate the new information or concepts on the point of plausibility and fruitfulness and thus metacognitive guidance was made. In addition, at this stage discussions on harmonic or in harmonic sides of the preconceptions with the scientific conceptions were enabled.

Let's solve a problem

Students were given new missions on worksheets in "*Transferring new concepts to different problems*" part in the teaching model. For example, students were asked to draw a current - voltage graph in photocell circuit by using the same simulation. Students were given time and the teacher gave academic feedback by wandering around the groups. When the time was up, groups gave their answers and started to defend their conclusion. Afterwards, students went on with the other parts on the worksheet in which problems such as "*what affects the maximum current*" or "*what affects the stopping voltage*". As it could be observed, the objective of this part is to enable students to use the new concept in different physical conditions and to realize how these new concepts help them to solve other problems.

In this stage, as a metacognitional strategy, students were asked why their explanations were plausible and why scientific concept was fruitful. It is thought that students will realize especially how fruitful the new concept is in problem solving part in teaching.

Evaluation

This part totally consists of the questions that proceed the metacognitive mechanism. The "*evaluation*" part in Figure 10 shows the questions that are asked to students. As it could be seen in Figure 10, students were asked to think about the question at the beginning of the teaching and to remember what their ideas were before the teaching. Then, thinking about the current ideas, students were asked to explain what had caused the change if there were any.

Students were asked to explain in what aspects of their preconceptions were unsuccessful in explaining the modern physics concepts and in what aspects the new concept was successful to do this. Students were given opportunities to speak in class to evaluate the strengths and weaknesses of the instruction and gave some recommendations to the teacher for the next lesson.

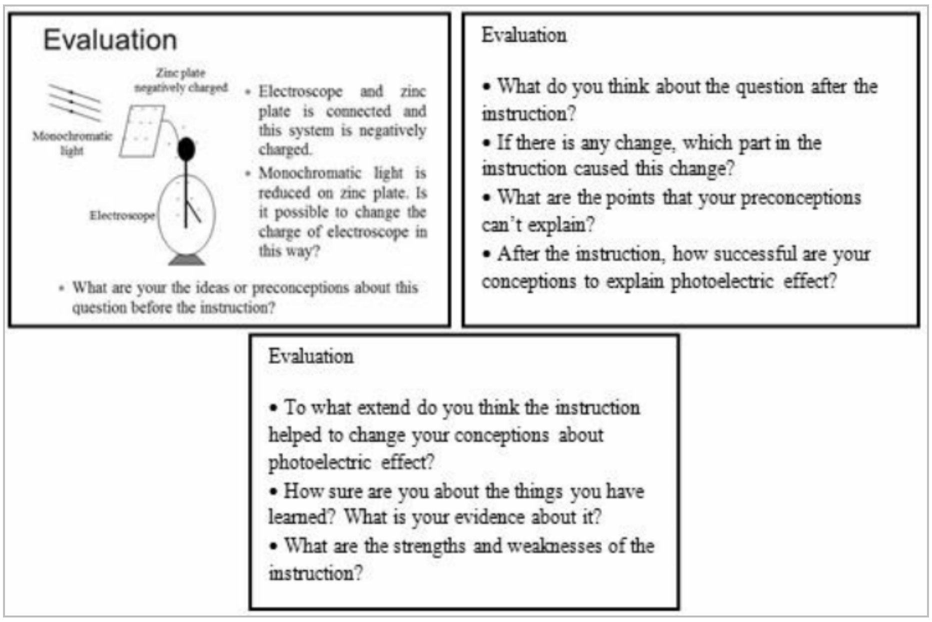

Figure 10: The slides are exampled from "*Evaluation*" part

Concluding Remarks

In this paper, we tried to summarize conceptual change literature which started with Posner et al. (1982)'s CCT and came to an end with Gregoire (2003). This study not only makes why CCT was called cold and classical clear but also asserts the criticisms about CCT in the literature on the point of cognitive conflict. This study also explains the period of combining the affective / hot concepts after Pintrich et al. (1993) with conceptual change models. Zhou (2010) stated that conceptual change literature ended in Hot Conceptual Change (CAMCC) had very few evidence in science teaching and added argumentation method to a teaching model based on conceptual change as a hot factor. Thus, the author stated that he recommended the warming trend in science teaching. From this point in this paper, we recommended hot trend in science teaching (TMHCC) by spreading the motivational strategies in Zhou (2010)'s AATS to all stages. Also cold–hot construct metacognition was integrated to the stages that the preconceptions were elicited, that group work and argumentations were made, and that scientific concepts were introduced.

> "*Epistemologically speaking, the use of argument helps students to get dissatisfied with their preconception and become more open to scientific concepts. Pedagogically speaking, the use of argument will motivate students to become more engaged in the learning process and provide students with opportunities to learn how to respect and be respected in a community*"
>
> *Zhou (2010; p.109)*

But what can we do for a meaningful cognitive conflict and how can we struggle with heuristic processing during instructing science? We suggested that -as She (2002) did- regarding activation of knowledge or preconceptions that conflict with discrepant event and metacognitive strategies provide a meaningful conflict. Yıldız (2008) found that metacognitively orientated class atmosphere provided students to be more metacognitive. From this point of view, it can be said that metacognitive orientation in TMHCC challenges students to be more metacognitive. Also, Linnenbrink & Pintrich (2003) asserted that students, who are metacognitive in their learning process, are more actively and cognitively engaged. So they are more likely to find anomalies and to live dissatisfaction. It has been thought that the metacognitive strategies in TMHCC have a potential to challenge students to move away from heuristic processing to systematic processing. We believe that with TMHCC we started hot trend in science instruction.

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