JOURNAL OF EDUCATIONAL AND INSTRUCTIONAL STUDIES
IN THE WORLD
February 2016, Volume: 6 Issue: 1 Article: 09 ISSN: 2146-7463

THE EFFECT OF COMPTON SCATTERING TEACHING BASED ON HOT CONCEPTUAL CHANGE ON STUDENTS' CONCEPTUAL CHANGE

Assoc. Prof. Dr. M. Sabri Kocakülah
Balıkesir University
Necatibey Education Faculty
TURKEY
sabriko@hotmail.com

Dr. Mehmet Kural
Ministry of National Education
TURKEY
mehmet_kural1@hotmail.com

Abstract

The aim of this study is, within the framework of Teaching Model for Hot Conceptual Change, to investigate the effect of cognitive conflict based Compton Scattering teaching that was supported by motivational and metacognitive strategies on students' conceptual change. The sample of the study in which mixed method design was used consists of 40 students from two grade 11 classes at an Anatolian Teacher High School in Turkey. Data were collected with Modern Physics Concept Test (MPCT) and semi-structured interviews. MPCT was administered as pre, post and delayed post tests which were followed by semi-structured interviews with a total of 14 students, including seven students from each class. Data gathered from MPCT were analyzed by using content analysis and tabulated. Also, students' responses to interview questions were coded and personal development tables were created. The research findings show that students' views about Compton Scattering cannot be related with the scientific view before instruction. However, it has been found that the instruction based on TMHCC is considerably successful in helping students to change their conceptions after instruction. Also, students' insistent misconceptions after the instruction were identified and these misconceptions were associated with the stages of instruction to reveal the limitations of instruction in this study.

Keywords: Conceptual change, hot conceptual change, teaching physics, Compton scattering.

INTRODUCTION

According to Conceptual Change Theory (CCT), which was proposed in the early 1980s in order to explain conceptual change, students try to use their existing conceptions when they encounter a new situation. This phase is called "assimilation". However, students' existing conceptions sometimes may not allow them to explain new phenomena successfuly. In this condition, students need to change or reorganize their existing conceptions. This phase is called "accommodation" in conceptual change (Posner, Strike, Hewson and Gertzog, 1982).

Many teaching strategies have been proposed for use in conceptual change based teaching. These can be divided into three groups: (1) *Discripant Event*, (2) *Conflict between ideas, (*3) *Development of ideas.* In plethora of studies, it has been proved that aforementioned strategies have a positive effect on learning (Dreyfus, Jungwirth ve Eliovitch, 1990; Scott, Asoko ve Driver, 1992). However, researchers have stated that CCT has a limitation. The one of the criticisms made to CCT is the structure that takes into account only the cognitive elements (Pintrich, Marx and Boyle, 1993; Vosniadou and Ioannides, 1998; Limon, 2001; Duit and Treagust, 2003).

According to researchers, CCT takes into account only cognitive elements but does not consider affective factors such as personal interest, motivation etc. (Pintrich et al., 1993). For this reason CCT was called as cold conceptual change. It has been proposed that the process of conceptual change and components of motivation should be linked (Pintrich et al., 1993). Furthermore, it has been asserted in some research that students may not experience cognitive conflict and they may not experience dissatisfaction with their preconceptions.

Dole and Sinatra (1998) have emphasized the effect of heuristic and systematic information processing on conceptual change and they have also described the effect of motivation on conceptual change in their Cognitive Reconstruction of Knowledge Model (CRKM). In CRKM, the positive effect of high cognitive engagement and systematic information processing on conceptual change was emphasized. Furthermore, authors explained the conceptual change of students who used heuristic information processing with peripheral cues, so they classified conceptual change as weak and strong. In CRKM, authors linked futures of reform message with students' affective characteristics.

Gregoire (2003) proposed Cognitive Affective Model of Conceptual Change (CAMCC) in which automatic evaluation of reform message had been seen as an identifier of what kind of information processing would be used. The CAMCC explained the impact of emotions such as fear and anxiety on conceptual change and Gregoire (2003) asserted that hot trend in conceptual change was started. On the other hand, Yıldız (2008) showed the positive impact of metacognitively oriented class atmosphere on conceptual change and proposed a new conceptual change model.

It has been seen in the literature that conceptual change models has been experiencing an affective revolution and addition of the affective characteristics of students to conceptual change models has become a new trend. Furthermore, it has been noticed that these studies remained in the domanin of cognitive-affective psychology and they had a little evidence in science teaching perspective. At this point, the question of "how should we teach?" must be answered again. A few number of teaching models based on warm and hot conceptual change have been found in the literature. Hence, taking into account that teaching models integrating cognitive and affective dimensions are sparse in the literature, Kural (2015) proposed Teaching Model for Hot Conceptual Change (TMHCC). Whether such a model provides conceptual change for students at high levels or not is the problem of this study. The aim of this study is to investigate the effect of teaching based on cognitive conflict and supported by metacognitive and motivational strategies on students' conceptual change related to Compton scattering topic.

METHOD

In this study, mixed method was used as a research design due to the nature of problem of the study. Only the success of TMHCC in helping students at the point of changing their conceptions about Compton scattering has been discussed. For this reason, in quantitative part of research, authors avoided from comparing groups, so a single group pre-test post-test design was used.

Furthermore, particular attention was paid to give qualitative descriptions by focusing on what students meant about conceptions which had been examined. These descriptions hierarchically ranked and response categories were created. Therefore, it can be said that phenomenology was used in the qualitative part of study (Marton, 1986; Smith and Eatough, 2007).

Sample

Convenience sampling method was used in this research (Patton, 1987). 40 grade 11 students, who were at an Anatolian Teacher High School of a district of Manisa in Turkey in 2012/2013 academic year, were chosen for sample.

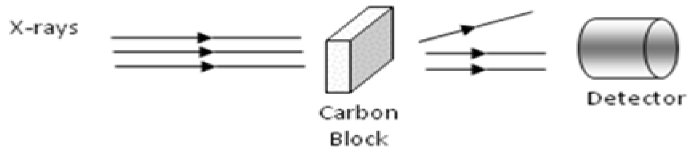
Data Collection

Modern Physics Concept Test (MPCT) was applied as pre test and post test in order to determine students' conceptions or views before and after the instruction. Five months after the instruction, MPCT was applied

JOURNAL OF EDUCATIONAL AND INSTRUCTIONAL STUDIES
IN THE WORLD
February 2016, Volume: 6 Issue: 1 Article: 09 ISSN: 2146-7463

again as a delayed post test for diagnosing strength of students' conceptual change and determining whether conceptual change was permanent or not.

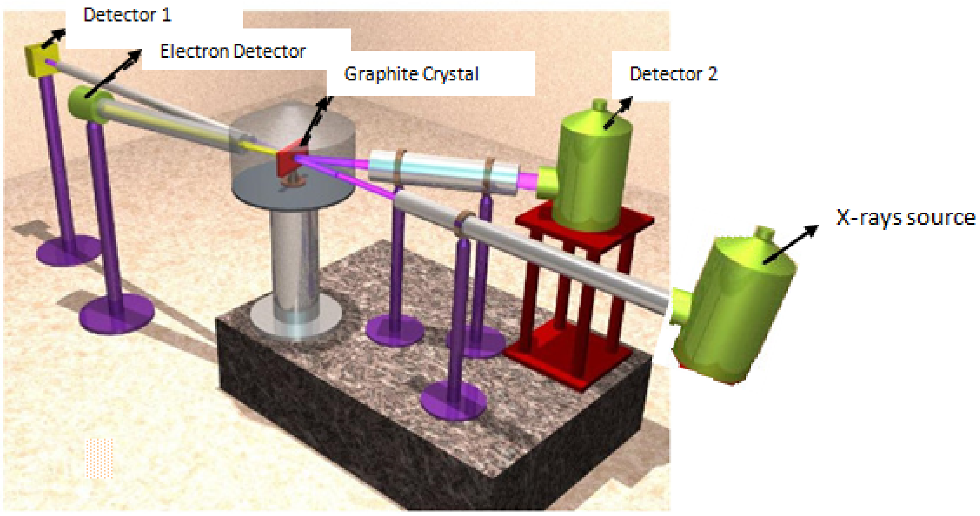
MPCT consists of 11 open-ended questions, which were written by researchers and taken directly from the literature or modified slightly. The validity of the test was provided by concept map based on Grade 11 Teaching Program of Physics Course and approved by panel of two experts in the area of physics education. The question dealing with Compton scattering in MPCT, which was applied as pre test and post test, is shown in Figure 1.



X-rays are sent to carbon block. In detector, wavelength of X-rays has been measured. After experiment it has been seen that some of X-rays scattered and some of them didn't. Also wavelength of X-rays which scattered from carbon increased. But there is no change for X-rays not scattered. Explain these results.

Figure 1: The question about Compton scattering in pre and post tests.

In the delayed post test, the question was changed but new question was prepared in the same context with the pre-post test question as shown in Figure 2. The aim of this application is to determine how students transfer their conceptions to new situations.



X-rays are sent to graphite crystal. Answer these questions below.

a) Any time, electron detected in electron detector, X-ray detected in Detector 2.

b) The wavelength of X-rays which detected in Detector 1 is small than the wavelength of X-ray detected in Detector 2.

Figure 2: The question about Compton scattering in the delayed post test.

Semi-structured interviews were used for in-depth examination of students' conceptual change as another data collection instrument. The audio records were transcribed and coded. Coding reliability was ensured by secondary researcher, who was expert in the area of physics education.

Data Analysis

Content analysis method was used to determine students' concepts and relationships between those concepts. Firstly, experts and researchers agreed on the full responses for questions. Secondly, pre, post and delayed post test data were coded. Inter-coder reliabilities between the researcher and a second coder were calculated to be as 90% for the pre test, 95% for the post test and 95% for the delayed post test responses.

Data gathered from semi-structured interviews were used for data triangulation purposes to support data gathered from MPCT. Furthermore, students' responses in pre, post and delayed post applications of semi-structured interviews were coded in the categories which were created after the content analysis of MPCT. Tables that show personal devolopment of students who joined the interviews were also created.

FINDINGS

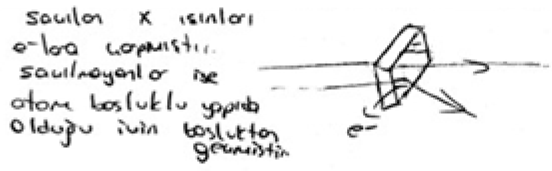
Table 1 was composed by analysing students’ responses to the question about Compton Scattering in MPCT that was administered pre, post and delayed post teaching.

Table 1: Students’ responses to the question about Compton Scattering.

TYPES OF RESPONSES	TEST TYPE		
A. Scientifically Acceptable Responses	Pretest N (%)	Post Test N (%)	Delayed post Test N (%)
1. Full Argument	0	16 (40,00)	21 (52,50)
2. Part of Argument	3 (7,50)	11 (27.50)	8 (20,00)
Subtotal 1	3 (7,50)	27 (67,50)	29 (72,50)
B. Scientifically Unacceptable Responses			
1. Responses Based on Modern Physics	4 (10,00)	13 (32,50)	5 (12,50)
2. Responses Based on Classical Physics	11 (27,50)	0	1 (2,50)
3. Intuitive Responses	12 (30,00)	0	0
Subtotal 2	27 (67,50)	13 (32,50)	6 (15,00)
C. Uncodeable Responses	7 (17,50)	0	0
D. No Response	3 (7,50)	0	5 (12,50)
Total	40 (100)	40 (100)	40 (100)

Findings Obtained From The Analysis of Pre Test Responses

In the pre test, it was found out that there was no full argument. 7.5% of students' responses were coded as part of argument. Student 21's response (S21), which has been coded in that category, has been exemplified below in Figure 3. Also, a part from interview record that belongs to S21 has been presented below.



"*The scattered X-rays collided with electrons. But X-rays, which were not scattered, passed through the cellular structure of the atom*"

Figure 3: Response of student 21 to the question about Compton Scattering in the pre test pre test

S21: *In this question, I think of an atom that has a cellular structure. The X-rays, which are not scattered, pass through the atom. But scattered X-rays collide with protons. There was a scattering experiment. I try to relate this condition with that experiment.*

Researcher: *What do you mean about scattering experiment?*

S21: *There was a scattering experiment. Rutherford did. Alpha particles were passing through a golden plate. Some of them were scattered and some were passing through without changing their direction.*

Researcher: *How the alpha particles change their directions?*

S21: *I think they were colliding with protons and were scattered. The particles, which were not scattered, were passing through cellular structure.*

Researcher: *In the pre test, you wrote "X-rays collide with electrons".*

S21: *Did I? I should not say so. They must collide with protons.*

Researcher: *In fact, do you think that X-rays collide with protons and they are scattered?*

S21: *Yeah.*

Researcher: *What do you say about increase in the wavelength of X-rays?*

S21: *X-rays have different kind of charge. So wavelength of them can change when they collide with protons.*
Researcher: *Why?*

S21: *Is it because they interact with?*

Researcher: *What do you mean by increase in wave length?*

S21: *Is it increase in amplitude of the wave length? Don't know!*

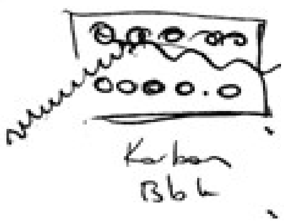
As shown in the dialogue above, student 21 explained the event by relating it with Rutherford's alpha scattering experiment. Student 21 stated that scattered X-rays collide with protons and unscattered X-rays pass through cellular structure of atoms. When the interviewer asked about contradiction between pre test and preinterview responses, student 21 said that she had given wrong answer in the pre test and insisted on the idea that was based on Rutherford's experiment. Furthermore, student 21 stated that X-rays consist of charges. Dialogues with student 21 show the fact that student 21 did not demonstrate scientifically accurate conceptual understanding.

In the pre test, it has been revealed that 10% of students gave scientifically unacceptable responses based on modern physics. Some of these responses were given below.

JOURNAL OF EDUCATIONAL AND INSTRUCTIONAL STUDIES
IN THE WORLD
February 2016, Volume: 6 Issue: 1 Article: 09 ISSN: 2146-7463

S11: *X-rays can change their direction by interacting with atoms or electrons. For this reason, their wavelength can increase. Unscattered X-rays could not encounter with atoms and electrons.*
S12:

Çünkü bloktaki taneciklere çarpan ışık taneciğin çekirdeğine çarparak yön değiştirmiştir ve çarpışmadan dolayı ışık ışını güç kaybedecek şiddeti azalmış doğal olarak frekansı yani dalga boyu artmıştır.



"The rays hitting the nucleus of an atom change their direction. Because of this collision, rays lose power and its intensity is reduced which is resulted in increase in frequency and thus increase in its wavelength."

Figure 4: Student 12' s response in the pre test.

In the pre test, 27.5% of students gave scientifically unacceptable responses based on classical physics concepts. These responses were examplified and a part of dialogue from student 4's preinterview was also given below.

S2: *X-rays do not refract if they do not face with electrons. Howeever, X-rays refract if they encounter with electrons.*

S4: *The carbon block is treated as a flat mirror. Sent rays create the image behind that carbon block.*

Researcher: *What do you say about the condition given in second question?*

S4: *I thought that X-rays were reflected or refracted from carbon block.*

Researcher: *How do you explain increase in the wavelength?*

S4: *...*

Researcher: *How can you interpret the increase in the wavelength of light?*

S4: *I can say decrease in frequency...*

In the pre test, 30% of students gave intuitive response. It has been noticed that when students realize that their mental models based on classical physics are unsuccessful to explain phenomena, they start to make predictions about it. Such responses were examplified below.

S1: *X-rays that are faced with electrons, push each other. X-rays can move faster and their direction may change.*

S34: *X-rays scatter when they hit the carbon. The reason of increase in wavelenght is due to gained energy from carbon during collision.*

S35: *X-rays can scatter from carbon because of their interaction with atoms.*

In the pre test, %7.5 of students left the question unanswered. It has been evident in the pre test that the vast majority of students had scientifically unacceptable views or conceptions.

JOURNAL OF EDUCATIONAL AND INSTRUCTIONAL STUDIES
IN THE WORLD
February 2016, Volume: 6 Issue: 1 Article: 09 ISSN: 2146-7463

Findings Obtained From The Analysis of Post Test Responses

In the post test, 40% of students responses were coded as full argument and 27.5% of them were coded as part of argument that composed scientifically acceptable responses altogether. It can be said that instruction helped some students change their conceptions. A part of dialogues from post interview records that are shown below belongs to students who gave full argument response in the post MPCT.

Researcher: *What do you say about Compton scattering?*

S23: *Photon was sent to carbon block. Photon hits atom. An electron was scattered. Another photon was also scattered.*

Researcher: *Anything else you want to add about Compton phenomenon?*

S23: *Momentums of scattered electron and photon are equal to incident photon's momentum. Energy is also conserved. I remember that light shows the properties of a particle.*

In the pre test and preinterview student 23 gave intuitive responses. In the post test and post interview the same student gave full argument answer. A part of post interview dialogue that belongs to student 4 who gave full argument answer in the post test is represented below.

Researcher: *What occurs to you about Compton phenomenon?*

S4: *I know that momentum and energy are conserved in this event.*

Araştırmacı: *Can you explain this event further?*

D4: *X-rays are sent to a carbon block. Some of X-rays change their direction and some of them do not. The wavelenght of scattered X-rays are increased. If the detector is rotated clockwise, angle of X-rays increase. If the angle increases, wavelength increases too. This event is an evidence for particle nature of light. The momentum and energy is conserved in this event.*

It is clear in the post interview record that instruction helped student 4, who gave scientifically unacceptable responses based on classical physics before teaching, change preconceptions.

After teaching, 32.5% of students responded scientifically unacceptable way based on modern physics. Such responses are presented below.

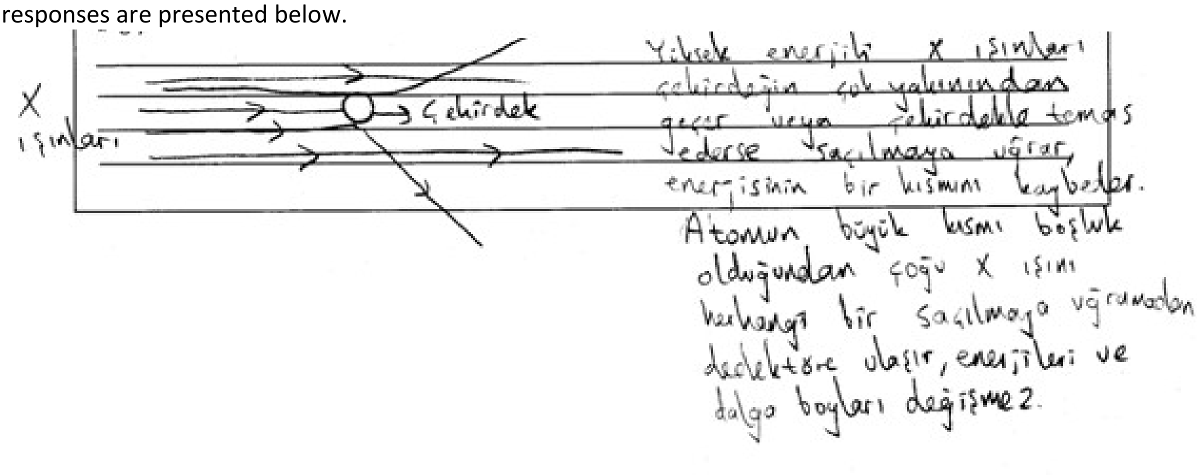


Figure 5: Student 2's response in the post test.

JOURNAL OF EDUCATIONAL AND INSTRUCTIONAL STUDIES
IN THE WORLD
February 2016, Volume: 6 Issue: 1 Article: 09 ISSN: 2146-7463

"If X-rays, which have high energy, pass close to nucleus or get into contact with nucleus, they are scattered and they lose some energy. Most of the X-rays reach dedector without scattering due to majority of the space inside an atom is empty. Thus, their energy and wave length remain constant."

S7: *Some photons strike to nucleus and undergo a change. Some of them move through without changing their directions because of cellular structure of atoms.*

S9: *Carbon block has a cellular structure. Some rays pass through these regions without undergoing a change but some of them strike to nucleus or protons of a substance and lose some amount of energy. Because energy is given, frequency is decreased and wavelength is increased.*

S22: *This is called Compton phenomenon. Some electrons change their wavelength by hitting to nucleus in this phenomenon. Meanwhile, some others pass through the holes.*

A part of post interview record that belongs to student 2 is shown below.

Researcher: *In your response to the conceptual understanding test, you wrote that X-rays are deflected if they pass close to the nucleus. Why do you think so?*

S2: *Rays passing very close or touching to nucleus transfer some energy and diverge. It's because they contact with the nucleus. As I watched at the simulation, rays passing close were scattered.* ***Researcher:*** *Which simulation do you remember?*

S2: *In fact, I remember Rutherford's experiment. An atom with holes is explained there. Those moving close to the nucleus undergo a deflection in that simulation.*

Interview record above shows that students have a firm believe of ''X-rays are scattered when they travel close to the nucleus'' and they base this idea on the simulation about Rutherford's experiment.

Findings Obtained From The Analysis of Delayed Post Test Responses

As can be seen in Table 1, 52.5% of the students gave full argument and 20% of them responded part of argument in the delayed post test. Altogether 72.5% of students reasoned scientifically acceptable arguments and this indicated that those students were able to transfer acceptable ideas and experienced a strong conceptual change.

Table 2 shows details about conceptual change of students interviewed. As shown in the Table 2, student 2 gave full argument in delayed post test while he responded part of argument in the delayed post interview. A part of delayed post interview record that belongs to student 2 is shown below.

Table 2: Personel development of students interviewed

	PRE		POST		DELAYED POST	
CATEGORY	TEST	INTERVIEW	TEST	INTERVIEW	TEST	INTERVIEW
A.1			S1, S4, S12, S23	S1,S4,S12, S20, S23, S24, S25,S31	S2,S4,S12 S16,S21, S23, S24, S31	S4, S12,S21 S23, S24, S25,S31
A.2	S21		S20, S24,	S16	S9, S22, S25	S1,S2,S9, S16, S22
B.1	S12	S12	S2,S9,S16, S21,S22, S25,S26	S2,S9,S21, S22,S26	S1, S20 S26	S20,S26
B.2	S2, S4,S16 S26, S31	S1,S2,S4, S16,S21 S26,S31				
B.3	S1,S9,S20 S22,S23,S24	S9,S20,S22, S23,S24,S25				
C	S25					

Positive Change No Change *Negative Change*

S2: *X-ray caused electron to be emitted. The electron arrived electron detector. Scattered X-ray came to Detector 2.*

Researcher: *What can you say about part b?*

S2: *The decrease in energy causes increase in wavelenght. Unscattered X-rays do not pass graphite straight forward and they do not lose energy, so the wavelength remains small.*

Researcher: *I want to ask something. Can X-rays reflected from the nucleus?*

S2: *I think, X-rays do not interact with nucleus. I do not remember exactly. They are passing through very close to nucleus but not colliding with it.*

Researcher: *Can X-rays collided with nucleus be reflected?*

S2: *I think it is impossible...Actualy it can be... Photon is sent, so atom can be excited.*

Researcher: *Can the nucleus be excited?*

S2: *I do not know.*

Researcher: *When I look your post test response, I can see the explanation based on the view that "X-ray collides with nucleus and is scattered.*

S2: *I am sure about the answer I told you now.*

Researcher: *Did you relate this question with any of topics learned?*

S2: *Compton scattering... I think so.*

Researcher: *What is Compton scattering?*

S2: *X-rays are sent and the electrons are scattered.*

In delayed post interview, student 2 was asked whether his delayed post test response was correct. Student 2 answered that his response in the delayed post test was correct. But when student 2 was asked about reflection of X-rays from a nucleus, he responded that it was possible. As shown in the last part of interview dialogue, Rutherford's experiment has a negative impact on students' conceptual ecology.

The analysis has also shown another interesting situation. Students, who have an idea of "X-rays are reflected from nucleus" before the instruction, change their preconceptions towards scientific conceptions. For example, as shown in Table 2, student 12 gave a full argument in the post and delayed post tests. A part of delayed post interview that belongs to student 12 was given below.

S12: *When an X-ray is sent, it interacts with atom. X-ray gives energy to electron and an electron is emitted. Electron detector detects this particle. X-ray, which leaves the graphite, is detected in detector 2.*

Researcher: *What can you say about part b of question?*

S12: *All of X-rays do not interact with atoms. If the incoming X-ray interacts with atoms and collides with electron, it loses energy and its wavelength increases. But if another X-ray does not interact, its direction does not change and its wavelength remains the same.*

Overall, 72.5% of students gave scientifically acceptable responses in the delayed post test. However, 12.5% of the students continued to respond in modern physics terms in an unacceptable way. All of these responses based on modern physics involve again the notion that "X-rays are scattered when they collide with nucleus or pass close to nucleus". 12.5% of the students did not answer the question five months after instruction.

DISCUSSION AND CONCLUSIONS

Many students (67.5%) reasoned scientifically unacceptable responses to question about Compton scattering in the pre test. Table 3 shows students' reasonings revealed both in the conducted interviews of this research and in Yıldız and Büyükkasap (2011)'s study reported in the literature. In addition, right column of Table 3 shows the misconceptions detected for the first time in this study. As shown in Table 3, students, who gave responses based on modern physics, had the notion that 'X-rays are scattered when they collide with a nucleus or pass close to a nucleus'. In the pre interview, student 12 related his idea with the animation which was about Rutherford's alpha scattering experiment. He tried to relate two phenomena with each other.

In the pre test, most of the responses (37.5%) that were based on classical physics involved "charged light" view. These responses can be seen in Table 3. This kind of responses can be linked with students' insistent and deeply rooted models that are based on classical physics. Students, who do not have Modern Physics concepts, try to explain phenomenon with Coulomb's interaction. Students responded that "X-rays are formed by protons. They are repelled by a nucleus and their direction is refracted''. Here, students were basically using Coulomb' s Law. Such ideas involve Coulomb's interaction and lack of mental models based on modern physics.

Table 3: Misconceptions of students about Compton scattering

Application	Both literature and this research	This research
Pre test and interview	*X-rays consist of protons, they are pulled by nucleus and are scattered.* [Yıldız and Büyükkasap (2011)] *X-rays consist of electrons, they are pulled by electrons and are scattered.* [Yıldız and Büyükkasap (2011)]	*X-rays collide to nucleus and are scattered.* *X-rays are scattered when they pass near nucleus* *X-rays collide to nucleus and are reflected.* *X-rays can change their direction by colliding to electrons or protons.* *The more distanse light covers, the more wavelenght it has.* *If carbon takes electron form X-rays, X-rays are scattered.* *The magnetif field created by electron of carbon can affect X-rays.*
Post test and interview	-	*X-rays collide to nucleus and are scattered.* *X-rays are scattered when they pass near nucleus*
Delayed post test and interview	-	*X-rays collide to nucleus and are scattered.* *X-rays are scattered when they pass near nucleus* *The photoelectric effect and the Compton scattering are same.*

The intuitive responses (30%) like "magnetic field which is created by electrons can affect the X-rays" and ''Light, which strikes to carbon, scatters. Reason for increase in wave lenght as it scatters may be due to energy gained during stroke'' are based on estimations rather than modern or classical physics concepts. Such students mainly made made predictive explanations which could not be based on any law.

One of the most common misconceptions that emerged in the pre test was "X-rays are scattered from the nucleus" view and students who held this view can be separated in two subgroups. First group consists of the students who think that X-rays involve protons and they are pulled by nucleus. Students in the second group were influenced by an animation about that was shown during teaching of 'Structure of an atom' unit in the grade 10 chemistry course and tried to explain Compton scattering by using the animation of Rutherford's alpha scattering experiment.

Analysis results show that 67.5% of students gave scientifically acceptable responses in the post test. The responses, which were scientifically unacceptable and based on modern physics ideas, emphasized the notion that X-rays would be scattered when they hit or pass nearby a nucleus in the post test. As it has been mentioned before, Rutherford's alpha scattering experiment creates a complexity for students, who use heuristic information processing and thus they experience a weak conceptual change. This condition can be seen in CRKM and CAMCC teaching models as peripheral cues. In this study, it has been proved that heuristic processing is one of the major problems and puts a barrier to conceptual change. We have proposed a hot construct metacogntion to struggle with heuristic processing in this study, but there must be some other cognitive and affective factors that we should look for such as reasoning skills (Yıldız, 2008) or personal interests etc.

Only the misconception that we encounter after teaching is ''*X-rays collide with nucleus and are scattered*". Students, who give such responses, can be classified in two subgroups. First group of students like student 21 are those who can not be persuaded to use scientific idea despite the designed hot conceptual change model. Second group involves students who initially do not have the idea of "*X-rays collide with nucleus and are scattered*" but started believing to this notion after teaching. However, many students like student 12, who tried to make explanations by using Rutherford's golden sheet experiment in the pre test and pre interview, were able to give full argument in the post test and post interview.

In the delayed post test, large majority of students (72.5%) responded scientifically acceptable explanations and the number of scientifically unacceptable responses based on modern physics ideas decreased to 12.5%. At this point, we need a closer look into the student 21's conceptual change process. In the post test, student 21 asserted that ''X-rays collide with nucleus and are scattered'', but in the post interview the same student gave full argument. When she was asked to explain the contradiction between these two expressions, she returned to her misconception. This finding implies that she experienced confusion between Rutherford's alpha experiment and Compton scattering just after teaching. Obviously the Rutherford's experiment has a negative effect on students 21's conceptual ecology. However, the same student gave full argument in the delayed post test and delayed post interview. Here, we should pay attention to critiques made by Vosniadou (1994) and Vosniadou and Ioannides (1998) against to the structure of conceptual change theory that requires a rapid change in students' mental states. In this sense, student 21's conceptual change process supports the validity of critiques made by Vosniadou ve Ioannides (1998). Student 21 was navigating between the branches of tree in Thagard (1992)'s terms just after instruction, but a long time after instruction (i.e. five months after teaching) she changed tree as a long term outcoome. Such a situation shows that conceptual change is a process which requires more time and experience for some students.

It can also be concluded that Rutherford's golden sheet experiment may cause confusion in students' mental structures. This indicates that students may process knowledge superficially which in turn cause weak conceptual understanding. It is revealed in this study that peripheral cues, which depend on superficial processing, are the most important barriers to conceptual change.

It is evident from this study that before teaching 67.5% of the students used scientifically unacceptable ideas but 67.5% and 72.5% of the sample have started to use scientifically acceptable ideas in the post and delayed post tests respectively. Despite all the criticisms made, these results show that Posner et. al.'s (1982) Conceptual Change Theory (CCT) is still succesful in implementing conceptual change.

In a broader sense, TMHCC, which was proposed within the framework of CCT, CRKM and CAMCC in this study, helped students to change their preconceptions towards scientific view. It is therefore suggested to consider metacognition as a factor in teaching for the students who process knowledge superficially. Additional activities are also needed to clear the differences between Compton's and Rutherford's alpha scattering experiments during teaching of Compton's scattering. Finally, it is suggested that diagnosing conceptual change and providing new events that conflict with scientifically unacceptable ideas or concepts are required for meaningful learning after completion of teaching related concepts.

WJEIS's Note 1: This study is part of the author's PhD thesis (Mehmet Kural).

WJEIS's Note 2: This study is presented as an oral presentation at 2nd International Congress on Education, Distance Education and Educational Technology- ICDET- 2016, Antalya-Turkey.

REFERENCES

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, 33, 109–128.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990). Applying the "cognitive conflict" strategy for conceptual change–some implications, difficulties, and problems. *Science Education*, 74 (5), 555-569.

Duit, R., & Treagust, D. (2003). Conceptual Change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25, 671–688.

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal process during conceptual change. *Educational Psychology Review*, 15, 117–155.

Kural, M. (2015). Teaching for hot conceptual change: An example of grade 11 modern physics. Unpublished doctoral dissertation, University of Balıkesir, Balıkesir.

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, 11 (4–5), 357–380.

Marton, F. (1986). Phenomenography: A research approach to investigating different understanding of reality. *Journal of Thought*, 21, 29-39.

Patton, Q. M. (1987). *How to use Qualitative Methods in Evaluation*. Newsbury Park, London: Sage Publications Inc.

Pintrich, P.R., Marx, R.W., & Boyle, R.A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, 63 (2), 167- 200.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: Towards a theory of a conceptual change, *Science Education*, 66 (2), 211-227.

Scott, P.H., Asoko, H.M., & Driver, R. (1992). Teaching for conceptual change: A review of strategies, In R. Duit, Goldberg, F. and Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 310-329). IPN: University of Kiel.

Smith, J. A., & Eatough, V. (2007). Interpretative phenomenological analysis, In E. Lyons and A. Coyle (Eds.), *Analysing qualitative data in psychology* (pp. 35-64). London: Sage.

Thagard, P. (1992). *Conceptual revolutions*. Princeton, NJ: Princeton University Press.

Vosniadou, S. (1994). Introduction. *Learning and Instruction*, 4, 3–6.

Vosniadou, S., & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. *International Journal of Science Education*, 20(10), 1213-1230.

Yıldız, E. (2008). The effects of metacognition during the instruction based on conceptual change used with 5E model: An application regarding the force and motion subject in the 7th grade, Unpublished PhD. Thesis, Dokuz Eylül University, İzmir.

Yıldız, A., & Büyükkasap, E. (2011). Öğretmen adaylarının Compton olayını anlama düzeyleri ve öğrenme amaçlı yazma aktivitelerinin akademik başarıya etkisi. *Uluslararası İnsan Bilimleri Dergisi*, 8(1), 1643-1664.