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Effect of Meaning Making Approach on Students' Conceptual Understanding: An Examination of Angular Momentum Conservation

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Abstract

The aim of this study is to analyze the effect of meaning making based instruction regarding angular momentum conservation on the change of two 11th grade students' alternative ideas they have before instruction. Case study model is used in the research. Conceptual test (implemented before the instruction, right after the instruction and fifteen weeks after the instruction), semi-structured interviews and video recordings of the teaching process were used for data collection procedure. It is eventually seen that these two students do not have scientific ideas about angular momentum conservation before instruction whereas they have scientific ideas after the instruction. One student made scientific explanations in delayed post-test while the other student had an alternative idea. In the after instruction interviews, the student who had scientific ideas indicated that she found the new concept understandable, reasonable, and useful, whereas the student who had alternative ideas stated that he found the new concept understandable and reasonable but not useful. According to the results, durable conceptual change does not occur in the students' ideas who did not find the new concept useful. Based on our results, various studies can be performed regarding permanent conceptual change in students' ideas.

Introduction

Studies performed in science education about various subjects with students from different ages concluded learning is easier in environments where students are active (Duit, 2009; Johnson & Johnson, 1987). Vygotsky, the leader of social constructivist theory, indicated learning occurs within social environment (Duit & Treagust, 1998; Jones & Brader-Araje, 2002; McMahon, 1997). Vygotsky states learning occurs when the individual interacts with his/her environment, studies, talks and internalizes the information he/she gains (Campbell, Oh, & Neilson, 2012). Social interaction plays an important role in social constructivist learning theory. That is, the level and quality of the interaction between the teacher and students in class environment affect learning. Learning gets easier for students if there is a scientific interaction between the teacher and the students (Cummins, 1986).

Social constructivism states people may handle the same event from different conceptual frames according to their daily experiences; and thus, their perceptions may be different (Kim, 2001; Lodico, Spaulding, & Voegtle 2006). Daily experiences of people affect the things they newly learn. Students bring various prior knowledge and concepts to classroom environment as a result of their daily experiences, even if they have not received instruction about the relevant subject (Driver & Bell, 1986; Driver & Oldham, 1986; Duit & Treagust, 2003; Osborne & Freyberg, 1985). The knowledge originated from the daily experiences of people may not always be compatible with scientific facts. These types of knowledge that is not compatible with scientific facts are named as misconception, alternative concept, intuitive beliefs, etc. in the literature (Eaton, Anderson, & Smith, 1984; Gilbert & Swift, 1985; Hewson & Hewson, 1984; McKloskey, 1983). In this study, we used the term "alternative concept" for ideas that are not compatible with scientific facts. Hewson and Hewson (1983) defines alternative concept as ideas that are encountered even after instruction and not compatible with scientific facts. As mentioned in this definition, alternative concepts can be encountered both before and after instruction. Students will have difficulty in learning scientific facts as long as they have alternative concepts regarding a concept (Chi & Roscoe, 2002). It is important to reveal the students' alternative concepts about the subject as much as it is important to change these concepts towards scientific ideas, which is called the conceptual change.

Theoretical Background

Conceptual Change

Duit and Treagust (1998) indicated students strongly believe in alternative concepts and exceedingly resist changing alternative concepts. Alternative concepts can be encountered in students even after a formal instruction (Hewson & Hewson, 1983). In addition, alternative concepts pose a challenge against learning scientific knowledge (Driver, 1989). For this reason, studies on conceptual change have gained importance in science education literature. Many theories have been brought forward to explain the nature of conceptual change because conceptual change in students is not an easy process. The conceptual change theory that forms the theoretical framework of many conceptual change studies is developed by Posner, Strike, Hewson and Gertzog (1982). Posner et al. (1982) suggested four basic conditions for conceptual change. First of all, the student should feel dissatisfied with his/her current ideas and should find the new concept understandable, reasonable and useful respectively in order to actualize conceptual change. Posner et al. (1982) indicated that conceptual change might be actualized if these four conditions were met respectively. Pintrich, Marx and Boyle (1993) criticized Posner's theory on conceptual change arguing that the theory did not include effective factors and indicated one cannot ignore factors such as motivation, attention and attitude in learning. Pintrich et al. (1993) adopted social constructivist learning theory in their theory on conceptual change and they indicated the learning process is significantly affected by the interaction among students and their teacher in classroom environment. They argued that students should learn within social groups instead of classroom environments where they learn individually. Strike and Posner (1992) revised their conceptual change theory upon this criticism. They mentioned the importance of motivation, misconceptions and conceptual ecology in their conceptual change theory. They indicated students' motivation and purposes, which are parts of their conceptual ecology, affect their learning. In their conceptual change theory, they stated misconceptions that are not present before instruction may emerge depending on the content of instruction and argued that conceptual change is a hard and demanding process.

Carey (1985) discussed conceptual change under two categories which are weak conceptual change and strong conceptual change. While the relations between concepts change during weak conceptual change, the concepts themselves change during strong conceptual change and this is the hard one to achieve (Carey, 1985). Hewson and Hewson (1984) indicated, for conceptual change in the instructional strategy suggested by Posner et al. (1982), the student shall be dissatisfied with his/her own idea only if he/she finds the new idea intelligible, plausible and fruitful. In another study, Hewson (1992) explained conceptual change with elimination of the current situation, the steps of change and expansion from one situation to another. In this theory, Hewson indicated the change in the students' ideas is resistant to the conventional instruction methods. Vosniadou and Brewer (1994) approached conceptual change from the perspective of conceptual development. They explained conceptual development as gradually removing the constraints, assumptions, beliefs and mental models. Vosniadou (1994) categorized the students' ideas under three mental models, which are “initial”, “synthesis” and “scientific”. In the initial mental model, the students' ideas are different from scientific knowledge (Vosniadou & Brewer, 1992). In the synthesis mental model, students add scientific knowledge to their current mental models without changing these structures. In scientific model, students develop models that are compatible with scientific knowledge. It is indicated that conceptual change occurs when the students' ideas in the synthesis model change to scientific model. Vosniadou and Ioannides (1998) stated conceptual change might occur on its own as a result of the students' interaction with their environment; however, this does not happen very often. They emphasized that conceptual change originated from instruction occurs more often, yet the instruction should include all items that students need for change in order to actualize conceptual development. Chi, Slotta and Leeuw (1994) defined conceptual change as the transition of the concept from the incorrect ontological category in which concept placed to the scientific ontological category to which the concept belongs. Chi et al. (1994) placed all concepts under three types of ontological categories and these categories have different ontological qualities. This theory separates conceptual change into two groups, which are strong and weak conceptual change. In strong conceptual change, the change occurs if the ontological category changes whereas, in weak conceptual change, the change occurs if the concept moves in the same ontological category.

Conceptual change theories are different from each other in terms of the way the conceptual change occurs. This study aims to analyze the change in the students' ideas within a social environment. The theoretical framework of the study is the conceptual change theory of Strike and Posner (1992) which is based on the conceptual change theory of Posner et al. (1982) and which underlines the importance of social interaction. This theory states that the new concept should be intelligible, plausible and fruitful in order to actualize conceptual change. This situation provides a strong framework for analyzing the data obtained from student interviews and open-ended surveys in terms of conceptual change.

Meaning Making Approach

Vygotsky, the leader of social constructivism, states that meaning making is the inherent perception that takes place in social content (in cited by Campbell et. al., 2012). Meaning making can be defined as the mental structures formed by the learner as a result of his/her social interactions. Social constructivist theorists indicate meaning making takes place during social activities as a result of the social interactions between the participants (Jonassen & Land 1999). In the meaning making process, Barnes and Todd (1995) emphasized that students construct their own knowledge as a result of interactions with other students. Lemke (1990) defined meaning making as social semiotics and underlines the importance of the social structure of learning. He explained the question and answer process between teachers and students in his study and formed the basis of "patterns of discourse" in meaning making. Scott (1998) emphasized the importance of the communication between student and teacher in meaning making.

Mortimer and Scott (2003) indicated learning takes place in social environment and the learning process is a complex one. They stated meaning making approach can be used in order to explain the learning process. Mortimer and Scott explained the framework of meaning making with these following steps: "teaching purposes", "content", "communicative approach", "patterns of discourse", and "teacher interventions". Unlike the studies that research on the effects of communicative approach (Buty & Mortimer, 2008; Chin, 2006; Mercer, 2008; Scott, 1998) and patterns of discourse (Cazden, 2001; Erikson, 1996; Lemke, 1990) on learning, they stated the five steps of meaning making approach are effective on learning as a whole. Below are the steps of meaning making approach of Mortimer and Scott (2003).

Teaching purposes. Influenced by Vygotsky's perspective on teaching and learning, Mortimer and Scott (2003) formed their educational purpose as a result of their observations regarding the science classes where teachers and students are in interaction. Teachers may determine different purposes during instruction in terms of these educational purposes (Scott, Mortimer, & Aguiar, 2006). The introduction and conclusion parts of a lesson can be arranged according to different educational purposes. The purposes of instruction can be listed as follows: revealing the problem, discovering and working on the students' ideas, introducing and developing scientific story, providing guidance to students for working with and internalizing scientific ideas, providing guidance to students for implementing and expanding the usage of scientific opinion, giving responsibility and supporting the development of the scientific story.

Content. The content of the social language spoken by students and teachers when talking about science is classified as daily and scientific. The ideas of students that are gained with experience and that are not compatible with scientific knowledge are named as daily language. It is indicated that the content of daily and scientific speech can be within the description, explanation, and generalization content and it can also be classified as experimental or theoretical. Leach and Scott (2002) indicated it is possible to use scientific language only after relevant instruction. The main purpose of instruction is to enable students to use scientific language in meaning making process.

Communicative approach. Mortimer and Scott (2003) indicated this step is at the center of the meaning making process. The communicative approach aims to reveal different ideas of students (Buty & Mortimer, 2008). Lemke (1990) stated that teachers are more effective in class speeches. Lemke underlined the fact that learning science is to learn speaking science and it is not very possible to learn science in a classroom environment where students do not talk. Mortimer and Scott (2003) analyzed the discussions between teacher and students under two dimensions, which are dialogical-authoritative and interactive-non-interactive. The best student-centered approach is the one with dialogue and interaction. In this approach, teacher asks questions to reveal students' ideas and does not comment as right or wrong but rather provides the continuance of communication (Mercer, 2008). Teacher considers these ideas even if they are different from the scientific knowledge (Chin, 2006). The best teacher-centered approach is the non-interactive/authoritative approach. In this approach, the teacher presents the ideas he/she thinks useful. Authoritative communication approach focuses on information transfer; it is closed to new voices unless they support the transferred information and is result-oriented (Scott, 1998). The communication approach performed with dialogues includes many voices, is open to new voices to develop meaning, and is not result-oriented (Scott, 1998).

Patterns of discourse. Lemke (1990) explained learning science with the dialogue process between teacher and students. It is indicated that one should emphasize how the science meanings can be achieved from the initiation-response-evaluation (I-R-E) process between teacher and students. Edwards and Mercer (1987) suggested teacher-student dialogue process that is similar to initiation-response-feedback (I-R-F) approach where process is controlled by teacher. Unlike evaluation, feedback enables students to take a more active role

(Chin, 2006). Mortimer and Scott (2003) emphasized that there are no student answer after teacher's feedback in the dialogue process, the question-answer chain can be extended and underlined the I-R-F-R-F dialogue (student's response (R) and teacher's feedback (F)). This approach is more student-centered than triple approaches and provides more flexibility for the students to express their ideas.

Teacher interventions. Teacher intervenes in the instruction process and aims to develop scientific meaning and make students reach this meaning (Mortimer & Scott, 2003). Teacher interventions are intended to provide the continuance of instruction. Scott (1998) indicated that teacher interventions aim to develop scientific knowledge and to support students in making meaning and maintaining the narrative. Teacher's interventions in the instruction process are in the following ways: “shaping ideas”, “selecting ideas”, “marking key ideas”, “sharing ideas”, “checking student understanding” and “reviewing”.

Although meaning making has been used in studies for a long time, a formal structure that consists of five steps was created by Mortimer and Scott (2003) for the first time. The usage of these five steps of meaning making shall provide an insight for this study as well as for other studies in terms of conceptual durability.

The Relation between Conceptual Change and Meaning Making Approaches

Meaning making forms the main purpose of all conceptual change approaches (Furberg & Arnseth, 2009). Hallden, Scheja and Haglund (2008) indicated conceptual change is the awareness of separating the concepts from each other and there is a meaning making process for these concepts. All conceptual change theories aim to generate scientific meanings in students' minds after instruction. Mortimer and Scott (2003) defined the meaning making approach as the change of ideas that conflict with scientific knowledge and used the term “restructure” for this process. In meaning making approach, information is not directly transferred from teacher to students or between friends, but students form their own meanings in their minds by interacting with each other in a social environment and with their teacher. Students have the right to control their ideas in the instruction process they are in. Students may feel like a stranger to scientific knowledge and the scientific knowledge may not be compatible with their current mental structures. In this case, an effective instruction is necessary. It is important to use conceptual change approaches in instruction in order to enable students to form scientific meanings. After defining conceptual change simply as the process of scientific meaning making, we aim to investigate the effect of a conceptual change study (where the meaning making approach is used) on the students' ideas.

Importance of the Research

The fact that students' alternative ideas are an obstacle for instruction makes the change of these ideas necessary. Conceptual change process is a complex one and conceptual change in students’ ideas may not be actualized easily. Various conceptual change methods are used to change the students' ideas that are not compatible with scientific knowledge. This study uses the conceptual change theory that is developed by Posner et al. (1982) and revised by Strike and Posner (1992) in terms of social content. Strike and Posner's (1992) emphasis on social environment in conceptual change process caused the framework of meaning making approach (Scott & Mortimer, 2003) to form the basis for conceptual change in this study. Adapting the fact that learning, which is the determinant of instruction, occurs in social environment, the meaning making approach aims to enable conceptual change in students as a determinant of educational effectiveness.

Determining whether the conceptual comprehension and conceptual change is actualized or not in students’ ideas long after the instruction gives us an idea about the efficacy of the instruction (Clark, 2006). Because of this situation, researchers argue about durable conceptual change (Georgides, 2000; Trundle & Bell, 2010; Saçkes & Trundle, 2016). Georgides (2000) defined durable conceptual change as the student's maintaining a newly learned scientific concept even after a long time following instruction. Gauld (1986) indicated that conceptual durability becomes more interesting and important in studies that investigate the durability of alternative concepts instead of studies where the students generally seem to accept scientific concepts (in cited by Georgides, 2000). Investigating conceptual durability in conceptual change studies is important for revealing the actual ideas in students' minds. Thus, the studies that investigate long-term conceptual durability can be a guide. Trundle and Bell (2010) indicated there are not many studies that investigate conceptual durability and pointed out to the gap in this field. However, the presence of the scientific concept in student's mind even after a long time is an important case for actualizing conceptual change (Georgides, 2000). This is why it is crucial to investigate whether a conceptual change that occurs in students' ideas right after instruction can be permanent even after a long period of time and to discuss the effect of instruction on these change processes.

Although there are conceptual change studies on various physics concepts, there is no study encountered regarding the change in high school students' ideas about the conservation of angular momentum. In their study carried out with college students, Palmieri and Strauch (1963) indicated college students have difficulty in understanding the concept of angular momentum conservation during laboratory classes. However, there are no studies encountered for revealing the ideas of high school students about this concept and/or conceptual change. The students in high school, who cannot generate scientific ideas for the concept of angular momentum conservation, will not be able to understand Kepler's 2nd law that is the law of equal areas. Conservation of angular momentum is a prerequisite to understand further concepts. Students who can understand this concept will be able to explain some events they encounter in their daily lives. For example, they will be able to explain the movements of sportsmen when they roll in the air, the reason why ice skaters open and close their arms during their performances and reasons of many similar events. This is why the conservation of angular momentum should be constructed scientifically.

Purpose of the Research

This study tries to determine the effect of meaning-making based instruction on conceptual change. Within this scope, the ideas of two 11th grade students before instruction, after instruction and fifteen weeks after instruction were observed. The purpose here is to analyze the effect of meaning making approach on conceptual change. Accordingly, this study seeks answers for the following questions:

1. In which response category the ideas of students about the angular momentum conservation take place before instruction, after the instruction based on meaning making approach and fifteen weeks after this instruction?
2. Does the instruction based on meaning making approach affect the conceptual change processes of 11th grade students?

Method

This study uses case study as a qualitative research method in order to define the ideas of high school students regarding the conservation of angular momentum. Case study builds a cause effect relation between data and argues that observations should be made in their actual contexts (Cohen, Manion, & Morrison, 2005). This study consists of pre-test and interviews, instruction, post-test and interviews, and delayed post-test and interviews sections.

Participants

This research is carried out with two 11th grade students who study in a state high school in the west side of Turkey. During instruction, classroom environment is separated into twelve studying groups and the two volunteer students in one group are randomly determined among groups. One of these students is female and the other is male, both are sixteen years old. Physics teacher indicated these students have a medium level of success in physics lesson. These students have not received formal instruction about angular momentum until the time of this study. Students discuss the ideas intergroup and share their ideas with other groups.

Data Collection Tools

Open Ended Questions

Two open-ended questions about the conservation of angular momentum were used for researching two students' ideas. When developing the questions, the questions were initially analyzed by five physics educators in terms of content validity and necessary corrections were made as a result of expert opinions. On questions experts suggest using the figures about the question and want students to explain their ideas. Questions were given to the fifty five 11th grade students from another high school before and after angular momentum instruction. Necessary corrections were made according to the obtained findings and after the questions were implemented on one hundred thirty three 10th grade students who have not received instruction about angular momentum. The questions were finalized after these two pilot schemes.

The two questions about the conservation of angular momentum that were used with two students as follows:

Q1: An ice skater sometimes opens her arms (See Figure 1) and sometimes closes them (See Figure 1) when swirling during her performance. Please explain the reason of the ice skater's movement.

Figure 1. An ice skater performing

Q2: As seen in Figure 2, sportsmen or swimmers who jump off a high platform pull their legs towards themselves when they want to roll in the air. Please explain the reason of this behavior.

Figure 2. A swimmer diving

The fact that these students had not yet received formal instruction about the conservation of angular momentum was considered when preparing these two questions and the questions were selected from daily life. The conceptual understanding test was given to the students one week before instruction, one week after instruction and fifteen weeks after instruction.

Semi-structured Interviews

Semi-structured interviews were carried out with these students one by one after pre-test, post-test and delayed post-test in order to analyze the reasons of these students' answers to the questions in the concept test. The aim was to determine how effective the instruction was in the change process if the change in students' ideas was observed during the interviews carried out after instruction. All interviews are performed in an atmosphere where the researcher and the students can talk freely. All interviews are recorded by the recorder. The interviews before instruction lasted for nearly twenty minutes, whereas this time went up to forty minutes after instruction and also delayed post-test. Interviews were held in the physics laboratory.

Video Recordings

The instructional process was recorded with two cameras. One of these focused on two students while the other one focused on the teacher and the other groups in classroom environment. All students were aware of the video recordings and 180 minutes of recording is made with two cameras throughout two lessons about the conservation of angular momentum. The reason why the classroom environment was recorded was that the researcher might not obtain detailed instructional processes by observation and the camera can portray the interaction between the students and the teacher in detail. Video recordings were used so as to immediately reveal the students' social interactions in meaning making process.

Data Analysis

Analysis of the Open Ended Questions

In the analysis of the open-ended questions, the daily-scientific, description-explanation-generalization, and experimental-theoretical analysis categories used by Mortimer and Scott (2003) in explaining the content of classroom interaction were utilized together. The students' answers, which were consistent with scientific knowledge, were placed under scientific category whereas those, which were not consistent, were placed in everyday answer category. An answer that included the expressions, purposes and findings of the idea was placed under description category, an answer that conveyed the aspects of the theoretical model and a specific fact was placed under explanation category, an answer that included description and explanation free from any content was placed under generalization category.

If the same answer was about the students' discovering the content themselves, it was placed under empirical category, whereas the answers of the students that explained the content verbally were placed under theoretical answer category. Students' answers were grouped as three-steps: daily or scientific, description or explanation/generalization, and experimental or theoretical. Below are the examples of students' answers for the categories used in the analysis of the questions in the concept test.

In the first question, the student's answer "The skater swirls faster when she closes her arms because our angular speed were inversely proportional with radius. Speed decreases as the radius increases. Speed increases as the radius decreases was placed under "scientific-explanation-theoretical" answer category because it was consistent with scientific knowledge, indicated speed and radius were associated with each other in the conservation of angular momentum, and gave theoretical information about the subject.

The questions were analyzed by a secondary researcher independently from the primary researcher so as to provide higher reliability of the analysis. The consistency percentage between the two researchers in this study was calculated as 92%. The consistency being over 90% indicates the consistency between the two researchers is high (Miles & Huberman, 1994) and it can be concluded that the analysis does not include any subjectivity of the researcher.

Analysis of the Semi-structured Interviews

The data collected with the semi-structured interviews performed after pre-test, post-test and delayed post-test were analyzed with descriptive analysis method. The aim of the descriptive analysis method was to arrange and comment on the collected data according to pre-determined themes (Seidman, 2006). The findings obtained from these interviews were used in order to explain the reasons of the students' answers to the concept test and to explain the conceptual change after instruction, if any.

In the analysis of the data collected with the interviews after post-test and delayed post-test, the states of student's finding the newly used information "intelligible", "plausible" and "fruitful" used by Posner et al. (1982) in identifying if the conceptual change occurred were utilized. Although the student does not express that he/she finds the new concept intelligible, plausible and fruitful, it can be understood from his/her sentences that he/she thinks so. From the sentences of students' answers, Thorley (1990) developed conceptual change state analysis categories in order to determine whether the three necessary prerequisites of conceptual change suggested by Posner et al. (1982) were used. These categories are explained briefly in Table 1.

Regarding these categories, the expressions in the students' sentences during the interviews were analyzed and it was determined whether the student finds the concept intelligible, plausible and fruitful or not. For example, a student that states he learned the conservation of angular momentum better with his experiment and observations formed a sentence that corresponds to the laboratory experience state analysis category and indicated he found this concept reasonable, although he did not say it directly. Another example shows that a student who says "she swirls faster as the distance to the center decreases, I conclude this from my implications" used an expression that is consistent with the cognitive structure state analysis category and found the concept reasonable.

Table 1. Analysis categories of conceptual change developed by Thorley (1990)

States of conceptual change	Analysis categories and descriptions of conceptual change states
Intelligibility	• Intelligibility analogy (analogy or metaphor to represent the concept) • Image (use of pictures or diagrams to represent the concept) • Example (real-world example of the concept) • Language (linguistic or symbolic representation of the concept)
Plausibility	• Other knowledge ('reasoned' consistency with other high-status knowledge) • Laboratory experience (consistency with laboratory data or observations) Plausibility analogy or P Analogy (another conception is invoked) • Past experiences (particular events consistent with the concept) • Epistemology (consistency with epistemological commitments) • Metaphysics (refer to ontological status of objects or beliefs)
Fruitfulness	• Real mechanism (causal mechanism invoked) • Fruitfulness power (the concept has wide applicability) • Promise (look forward to what new concept might do) • Compete (explicitly compare two competing concepts) • Extrinsic (associate new concept with experts)

Analysis of the Video Recordings

The content analysis of the data collected with the video recordings was performed in this research. Content analysis, one of the qualitative data analysis methods aims to come up with concepts and relations that can explain the data collected from the research (Berg, 2001). Similar data were gathered and arranged under certain categories. A video recording of ninety minutes in total were transcribed by the researcher. Abbreviations were used when transcribing the data obtained from the video recordings.

In this system, every speaker was represented by a letter, the conservation of angular momentum is coded according to the sequence number with its initials as "CAM" and the time interval of every dialogue was identified. For example, the teacher with "T", researcher who carried out the interviews with "R", the two students who were selected among other students in the class and whose instructional process was recorded was coded with name of Ali and Ayşe and other students were coded with the letter "S". For instance, the researcher's speech on the 17th line of the conservation of angular momentum was coded as "17-R".

The two lesson-hour video recordings about the conservation of angular momentum were divided into two sections and analyzed. This was because there were discussions in the first lesson section about the students' work on the conservation of angular momentum and there were practices in the second section regarding the conservation of angular momentum. The two lesson sections aimed at different purposes were analyzed separately by the same analysis categories. The meaning making approach of Mortimer and Scott was used in the analysis of the video recording transcription. The course content was analyzed with appropriate subcategories of the five stages of meaning making which are "teaching purposes", "content", "communication approach", "interaction models", and "teacher interventions" and for all subcategories it is explained the discussion take place in the classroom.

Instruction Process

An instruction of the two lesson-hour was carried out in order to enable the students to make meaning about the conservation of angular momentum. Regarding the conservation of angular momentum, the instruction for teaching the torque concept before instruction lasted for two hours and the instruction based on meaning making about Kepler laws lasted for one hour. Throughout the instruction, students studied in intergroup that consisted of two students each and each group shared their discussions with other groups in the classroom. The teacher instructed all the groups in the same way in the classroom. These groups provided the students with a learning environment where they can discuss their ideas about the conservation of angular momentum, search for a solution to a problem, and comment together on the collected data.

Following the instruction on the conservation of angular momentum, meaning making approach teaching purposes activities for the relevant subject were as follows:

Opening up the problem: At this teaching purpose using with concept of the momentum of moving objects in the linear trajectories that they have learned in this unit, it was provided to debate with group of friends what the angular momentum of moving objects in a circular trajectories was.

Exploring and working on students' views: Working with a group of friends, students were provided to showing the relationship between the rotation of the rotating body radius draw a graph momentum and chart interpretation.

Introducing and developing the scientific story: Draw attention of students to the subject and begin the instruction with a story about angular momentum conservation in order to uncover their prior knowledge.

Guiding students' work with scientific meanings and supporting internalization: Students with their friends in the group gave examples about the events that angular momentum was protected and were provided to indicate how to use these events at angular momentum conservation.

Guiding students to apply and expand on the use of the scientific view and handing over responsibility for its use: A student was selected from the classroom and this student sat on the swivel chair. Two equiponderant dumbbells were given to the both hands of the student. Student swirled on the chair with his arms open at first and continued to swirl by closing his arms. The student continues to swirl by opening his arms and then closing them. Meanwhile, other students observed the movements of their classmate who swirled on the chair. Same activity was repeated with several different students from the classroom. As seen in the activity, students stated they could swirl faster when arms were closed and slower when arms were open. In conclusion, it was explained that there was an inverse proportion between the moment of inertia and the angular momentum in the conservation of angular momentum. At the end of the lesson, students were asked to give examples from their environment about the conservation of angular momentum.

Maintaining the development of the scientific story: At the end of the instruction, students were asked to explain scientific story given at the beginning of the instruction by using the information they learned about the concept of angular momentum conservation.

Results

Students' Opinions and Conceptual Change Process

In this section, results of answers given by the two students in pre-test, post-test and delayed post-test and the findings obtained from the instruction process between the two students were shown in detail.

Categories containing the answers given by Ali and Ayşe in the concept test on conservation of the angular momentum were presented in Table 2.

Table 2. Categories of explanations on conservation of angular momentum

Student	Pre-test	Post-test	Delayed post-test
Ali	No conceptual understanding	Scientific *(Description-Theoretical)*	Everyday *(Description-Theoretical)*
Ayşe	Everyday *(Description-Theoretical)*	Scientific *(Explanation-Theoretical)*	Scientific *(Explanation-Theoretical)*

Findings acquired through analysis of interviews conducted after post-test and delayed post-test with Ali and Ayşe by using situation analysis categories defined by Thorley (1990) were presented in Table 3.

As seen in Table 3, Ali, after instruction activity, found the newly learned concept intelligible and plausible, but not fruitful. Meanwhile Ayşe, after instruction activity, found this concept intelligible, plausible and fruitful, therefore fulfilling all three conditions for realization of conceptual change.

Table 3. Findings acquired through analysis of interviews

Conditions of Accommodation	After Instruction	
	Ali	Ayşe
Intelligible	+	+
Plausible	+	+
Fruitful	-	+

Ali presented no idea for the questions in the pre-instruction concept test on conservation of angular momentum. An excerpt from the interview with Ali before the instructional activity is presented below.

> R: Let's look at the second question. You did not answer it. What do you think about this question?
> Ali: Well… does the direction of the movement change? The sportsman may have been distracted. I don't know really.

As seen in this interview excerpt, before instruction activity, Ali did not have any general or scientific ideas on conservation of angular momentum. After instruction activity, this student answered both of the questions in the conceptual test with "speed increases as radius decreases in conservation of angular momentum". The student's answer was in the scientific-description-theoretical answer category. This student also gave the answer "when it opens its flaps it spins faster, because its radius is bigger, but when it closes its flaps it spins slower, because it has reduced its radius vector" in the delayed post-test. The student was confused about the relation between radius and speed in conservation of angular momentum. Since the student's explanation was theoretical, the answer given by this student was in the everyday-description-theoretical answer category.

An excerpt from the interview with Ali after delayed post-test is presented below.

> R: How much of a role did instruction activity have in changing your opinion regarding angular momentum?
> Ali: Since I did not have any information regarding angular momentum before, I just accepted what was taught (Plausibility-Other Knowledge). But I have forgotten it now.
> R: Didn't it make sense to you?
> Ali: It made sense then (Intelligibility - Exemplar) but I didn't repeat it, and the formulas were just memorized anyway. I forgot it because I didn't repeat it.
> R: And maybe the subjects have been difficult, were these concepts difficult to learn?
> Ali: This is a subject I haven't seen before. It was the first time I tried to learn and I found it difficult.

In the interview after delayed post-test, Ali did not mention that he found his newly learned concept useful. Therefore, the student was not able to utilize his newly learned concept in different contexts and this concept failed to be permanent for the student. The instruction activity on conservation of angular momentum was not effective for this student in meaning formation. During the instruction process the student was influenced by in-class discussions and gave scientific answers after instruction. However, since this student did not find the new concept useful, his answer after instruction was in the everyday category. It was observed in the interview after delayed post-test that the student found the new concept reasonable at the time of learning it, but then the concept did not stay permanent for them. It was observed that the instruction activity could not be effective for the student to find the new concept as useful. Instruction activities could not help the student form scientific meanings and no permanent conceptual changes took place for this student.

Ayşe answered the questions in pre-instruction conceptual test with "the sportsmen moves faster as air force decreases". This answer given by Ayşe before instruction activity was in the "everyday-description-theoretical" category. An excerpt from the interview with Ayşe after pre-test is presented below.

> R: Why does the sportsman gather his legs when he attempts to do a flip-flap?
> Ayşe: He aims to move faster in the air.
> R: How?
> Ayşe: To stay longer in the air?
> R: How does this happen?
> Ayşe: It may be because of the force of the air. The force applied by the air.
> R: What kind of force is this?
> Ayşe: Air force decreases. He can stay longer in the air and do various movements. (Everyday)

Ayşe answered the first question on conservation of angular momentum, after instruction activity, as "in conservation of angular momentum, the skater increases her speed when she closes her arms" and similarly, the second question as "the sportsman speeds up as he gathers his legs". This student was included in the "scientific" category since she gave scientific answers to both questions.

Findings acquired during the interview with Ayşe after instruction activity are listed below.

> R: Was the instruction activity effective on your opinions?
> Ayşe: Yes, it was. We can understand more easily with experiments and observation. (Plausibility-Laboratory experience)
> R: What experiment was that?
> Ayşe: There was the one we did with dumbbells. I believe these experiments will have a role in our life. (Intelligibility-exemplar)
> R: What did that activity teach you?
> Ayşe: The activity taught me that I should not spread my arms or anything if I want to be fast. (Fruitfulness-real mechanism)

In post-instruction interview the student expressed that she found the new concept intelligible, plausible and fruitful and gave the scientific answers after instruction activity. In the delayed post-test, the student provided the same answers as she gave in the post-test. This student, similar to the post-test, was in the "scientific" category in the delayed post-test. In the interview after delayed post-test, the student mentioned that she found her newly learned concept intelligible, plausible and fruitful. Conditions of comprehensibility, coherence, and usefulness, which are required for realization of conceptual change, as indicated by Posner et al. (1982), were fulfilled in this student. As a result, permanent conceptual change was observed in the student and the student preserved their ideas concordant with scientific information even long time after instruction. The instruction activity, which aimed to form meaning, was effective in changing this student's idea on conservation of angular momentum and the permanent conceptual change effectively actualized with the student.

Based on these findings, we can say that the instruction activity, which was aimed at meaning formation regarding conservation of angular momentum, was effective in terms of changing student opinions. While Ali did not present any ideas at the beginning, his ideas after instruction corresponded to scientific information; however, this student's answer in the delayed post-test is in the "everyday answer" category. The fact that this student did not find his newly learned concept useful may have prevented realization of permanent change in the student's ideas. The instruction activity aimed at meaning formation was not effective for this student in finding the new concept as useful. Ayşe, while having alternative ideas related to conservation of angular momentum at the beginning, provided scientific answers in the post-test and delayed post-test. In the interviews, this student mentioned that she found the new concept as intelligible, plausible and fruitful. The instruction activity aimed at meaning formation was effective for this student to permanently structure the scientific information. For this reason, permanent concept change was observed with this student and the student was able to provide scientific answers even long after instruction activity.

Findings Acquired in Instruction Process Analysis

Findings Acquired in Analysis of First Section - Conservation of Angular Momentum

In this section, dialogues between teachers and students regarding conservation of angular momentum were analyzed in accordance with meaning formation (Mortimer & Scott, 2003) approach and findings acquired during this analysis are presented below.

Below is an excerpt from a dialogue wherein Ali and Ayşe discuss their opinions and other students in the classroom explain their opinions.

> 17-T: Why do ice skaters open and close their arms during their show? Let's discuss this.
> 18-Ali: Well. What was that we indicated with L?
> 19-Ayşe: Angular momentum.
> 20-Ali: Can it be due to angular momentum?
> 21-Ayşe: Yeeeah
> 22-Ali: It's due to angular momentum. mr^2w

23-Ayşe: Do we think that they decrease their momentum by reducing their radiuses, since the mass is already fixed? She goes away from the center when she spins this way. When they gather their arms they reduce their radiuses.
24-Ali: Therefore?
25-Ayşe: Their angular momentums by reducing their radiuses.
27-Ali: An ice skater's radius increases when she opens her arms. (**Scientific**)
28-T: OK friends, it seems over?
29-S: She increases her momentum by increasing her radius.
30-T: What do you say? Your friend said she increased the momentum by increasing the radius.
31-S: It makes sense.
32-T: Yes?
33-S: Now the ice skater's arms are open while spinning. Normally, when she gathers her arms she starts spinning a little faster. (**Scientific**)
34-S: No.
35-T: What do you say? What do you say?
36-S: Now the skater has to spread her arms in order to spin. Won't she spin faster when she spreads her arms? (**Everyday**)
37-Ayşe: She spins faster when her arms are gathered. (**Scientific**)
38-T: We can try, friends.
39-S: Let's try.

In this dialogue, students' opinions on conservation of angular momentum before instruction were discovered. In the line '17', the teacher asked the students to discuss with their friends in their groups about the reasons related to the arm gathering and spreading movements of the ice skater while spinning and the step of 'problem opening', which is the first step in the purposes of instruction, was initialized. In this instruction purpose, the aim was to sensually and intellectually draw interests of the students to development of the scientific story. Ali and Ayşe discussed the reason why the ice skater did this movement and explained their ideas within the classroom. This discussion starts with the line '18' and ends at '39'. The communication approach occurred among these students is the 'interactive/dialogue communication approach' because the students listen to each other's opinions and comment on these opinions.

A dialogue process, wherein students could comfortably explain their ideas, was experienced between the teacher and the students. Therefore, the communication approach between the teacher and the students is an 'interactive/dialogue' communication approach. In lines '28', '32', and '35', the teacher intervened (controlling student comprehension) by asking the students to explain their ideas. In line '30', the teacher intervened again (marking key idea) by repeating the student answer in the previous line. Throughout this dialogue, student answers were scientific as well as alternative. For example, while in the line '33' the student gave the scientific answer that speed increases while radius decreases, in the line '36' they exhibited an everyday answer in that they said the speed increases together with radius. The students, while explaining their scientific opinions in the classroom, explained their alternative ideas within the classroom. This dialogue is an example for an instruction situation where students can discuss and explain their ideas in an interactive classroom. The students can get influenced by alternative ideas as well as scientific ideas they discuss among themselves.

The following is an excerpt (233-240) from a dialogue where conservation of angular momentum was discussed between the teacher (T) and the students (Ali and Ayşe). While the first dialogue is a dialogue where the students discussed their opinions among themselves at the beginning of the lesson, the second dialogue is a dialogue where students discussed and explained to the teacher their opinions during the activity.

233-T: r is increasing. Your spinning radius is increasing. Friends, the same goes for the opposite. Your speed, angular speed, increased. When was your speed increasing?
234-Ayşe: When you gathered your arms. (**Scientific**)
235-T: When we gather them. So what will the moment of inertia be in this case?
236-Ayşe: It decreases, sir. (**Scientific**)
237-S: It decreases. (**Scientific**)
238-T: It decreases. Why does it decrease?
239-Ayşe: Because the radius decreases. (**Scientific**)
240-T: Because we reduce the radius vector. The inertia moment decreased and angular speed increased when r reduced. Is this understood, friends? Is there anything missed? OK, then how about we ask this... We told you that when you multiply inertia moment and angular speed you get angular momentum. Right? How does the magnitude of angular momentum vary?

In these dialogues, the discussion after the activity on conservation of angular momentum takes place. In the line '233' the teacher starts with asking a question, the student answers in the line '234', the teacher provides feedback and asks another question in the line '235', the students give their answers in lines '236' and '237' and the teacher provides feedback in the line '238'. This interaction is the ‘I-R-F-I-R-F’ interaction model. Ayşe provided answers on conservation of angular momentum in lines '236' and '239'. Throughout this dialogue, an 'interactive/dialogue' communication approach was occurred between the teacher and the students. The teacher was asking questions aimed at discovering the students' opinions and the students were explaining their opinions within the classroom. The teacher intervened (marking key ideas) by repeating student answers in lines '235' and '238'. In line '240', the teacher intervened again (revising) by summarizing results of the activity they carried out in relation to conservation of angular momentum at the beginning of the lesson. In line '240', the teacher summarized the result of the experiment and at the end of the activity, checked the meaning formed by the students. In this dialogue, the teacher asked the students in the classroom about their opinions and the students explained their opinions within the classroom. In this discussion environment, the teacher intervened with the instruction process in order to enable the students to form meanings in terms of reaching information. As a result of these interventions, the students were provided with the opportunity of explaining their ideas and critical points in these ideas were highlighted.

Findings Acquired in Analysis of Second Section – Conservation of Angular Momentum

Findings acquired through analysis of instruction in relation to applications directed to conservation of angular momentum are listed below.

The following dialogue is an excerpt from a dialogue between Ali and Ayşe where these students discussed the reasons why sportsmen gather their legs as they flip-flap. This dialogue, different from the other two dialogues, is an example for a dialogue where students discussed their opinions at the end of a lesson.

> 400-T: …Why do high-jumping sportsmen pull their legs to their chests when they intend to do a flip-flap? Write the reason, can you? You remember, sportsmen gather their legs towards their chests when they want to do flip-flaps.
> 401-Ali: What do we write?
> 402-Ayşe: His speed increases when he gathers his legs. When the high-jumping swimmers intend to do flip-flaps in the air, they pull their legs towards their chests. Why does this movement make them spin faster? What must they do to move slower? To move faster.
> 403-Ali: Well. They reduce the radius.
> 404-Ayşe: Yes. They reduce the radius. If they want to move slower, they increase the radius. They spin faster. (**Scientific**) What must they do to move slower?
> 405-Ali: They must increase their radius, that is, they must spread their legs. (**Scientific**)
> 406-Ayşe: They must spread their legs.
> 407-Ali: They increase their radiuses.
> 408-R: What do you say, friends? Why do sportsmen gather their legs when they attempt to do flip-flaps? Yes, B..?
> 409-S: They gather their legs, it reduces their radius. Therefore they increase their speed. Consequently they move more easily. It's related to angular momentum. (**Scientific**)

In this dialogue, the students were discussing about an example on conservation of angular momentum. The dialogue started with a question of the teacher asking why sportsmen gather their legs when they attempt to do flip-flaps. This question was asked for the purpose of 'supporting development of scientific story'. In this instruction goal, the students were expected to implement their newly learned information on various situations. With this question, the teacher asked to utilize conservation of angular momentum in order to explain the movements of sportsmen. Content of the students' dialogue was within the content domains of scientific language, theoretical and generalization. Students generalized the movements of sportsmen while explaining conservation of angular momentum. The communication approach between Ali and Ayşe, which starts at the line '401' and ends at '407', matched up with the 'interactive/dialogue' communication approach. Throughout this discussion, the students discussed and explained their opinions on the requirement that sportsmen must reduce their radiuses in order to do faster flip-flaps.

After group discussion, the teacher asked the students about their opinions and listened to their answers. This communication approach between the teacher and the students is an example of 'interactive/dialogue' communication approach. In line '408' the teacher intervened (controlling student comprehension) by asking the students to explain their ideas to the classroom. In line '410', the teacher intervened again (marking key ideas) by repeating the student answer in the previous line. In line '408' the teacher asked a question to the students to prompt them to explain their ideas, in line '409' the student answered, in line '410' the teacher provided feedback, and the 'B-C-G' interaction model occurred throughout this dialogue. The opinions discussed by Ali and Ayşe related to conservation of angular momentum also corresponded to scientific information. The opinions expressed by Ali and Ayşe in lines '404' and '405' were within the 'scientific answer' category. It is observed in this dialogue that the students were able to implement their newly learned concept in various learning contexts.

Ali and Ayşe provided scientific answers in regards to conservation of angular momentum. Instruction was effective for the students to form a scientific meaning regarding this concept. Activities contributed to students' processes of meaning formation and enabled students to structure the scientifically accepted information, that is, actualization of conceptual change. During instruction and discussions among the students and between the students and the teacher, the students frequently expressed their opinions. The interaction model between the teacher and the students exhibited differences as trilateral and multilateral chain. The teacher intervened at various times during the instruction process in order to help students form scientific meanings. Content of the instruction differed at different parts of the lesson and this completely varied according to the purpose of the instruction.

Conclusion and Discussion

While no scientific answers related to conservation of angular momentum were encountered in the pre-test of the two students monitored throughout this study, their answers in the post-test were placed within the scientific answer category. While the answer given by Ayşe in the delayed post-test was placed within the scientific answer category, the answer given by Ali was placed within the everyday answer category. At the end of instruction, Ayşe reached the scientific information and preserved this information long after the instruction, while the information learned by Ali during the instruction did not stay permanent. As a result, while permanent conceptual change was actualized by Ayşe, a conceptual change was also actualized by Ali and this student expressed their everyday opinions during delayed post-test. This situation shows us once again that permanent conceptual change is difficult to actualize in students' ideas. Similar to the results of this study, Georgides (2000), in their study, reported that metacognitive instruction method was effective in changing opinions of primary school students at 5th class related to the concept of electricity; however, few students were able to preserve their scientific opinions eight months after the instruction. In their study on phases of the moon and lunar eclipses, Küçüközer (2013) reported that many pre-service teachers continued to provide answers in regards to scientific information during a delayed post-test 22 months after the instruction; however, there were still pre-service teachers unable to preserve their opinions.

Trundle, Atwood and Christopher (2007) indicated while some preservice teachers preserved their scientific information six months after the instruction on phases of the moon, other preservice teachers reverted back to their alternative opinions before instruction. It is not an easy process to provide permanent changes in students' opinions and permanent conceptual change may not always actualize in students' opinions. Posner et al. (1982) expressed that, in order to conceptual change to actualize, the student should find the new concept intelligible, plausible and fruitful. In this study, Ayşe, who was able to preserve her scientific opinion in the interviews long time after the instruction, found the new concept intelligible, plausible and fruitful. This student fulfilled the conditions required for conceptual change and exhibited permanent conceptual change. Ali found the new concept intelligible and plausible; however, he did not express the fruitfulness of this concept. While a short-term conceptual change was observed in this student after instruction, this student expressed his opinions in everyday language weeks after instruction. The conditions required by Posner et al. (1982) for conceptual change are also required for actualization of permanent conceptual change. As a result of this study, it is observed that no permanent conceptual change can be mentioned if all conditions required for conceptual change are not fulfilled in a student's mind. Learning environments where students find the new concept intelligible, plausible and fruitful are also needed for actualization of a permanent conceptual change as well as a conceptual change.

The alternative concept "the sportsman moves faster as air force decreases" in the pre-test related to conservation of angular momentum in Ayşe's mind and the alternative concept "he spins faster when he spreads his arms, because his diameter is bigger, he spins slower when he gathers his arms, because he has reduced his radius vector" in Ali’s mind were encountered. Ayşe's opinions she expressed before the instruction were originated from daily experiences. The alternative opinion expressed by Ali in the delayed post-test was learned during the instruction and it was originated from the fact that the student did not find the scientific information useful and incorrectly structured the information. Within our knowledge, these alternative concepts were first encountered in this study.

Ali and Ayşe provided different answers in the delayed post-test implemented at the end of the same instruction process. While the answer given by Ayşe was placed within the scientific answer category, the answer given by Ali was placed within the everyday answer category. Different conceptual change processes occurred in the ideas of the two students who formed meanings through discussing their opinions with each other within the same instruction process. Rahm (2004) reported that students make different deductions from identical experiences. In this study, it was observed that two students reached to different meanings through the same instruction process. For this reason, it should not be expected that students reach to the same cognitive structures in the same learning environments and it should not be forgotten that each student has an individual learning process.

In this study, it was observed through the analysis of the instruction process with meaning formation approach that while the ideas expressed by the students at the beginning of the lesson were in everyday language, the students’ statements after the instruction process were mostly compatible with the scientific information. Leach and Scott (2002) similarly expressed that no scientific language was encountered in pre-instruction students. An instruction aimed to form meanings was effective in exchanging opinions of students, which were in everyday language, with scientific information. Communication approaches between the teacher and the students during the instruction process exhibited differences in different periods of the lesson and the communication approach among the students was mostly interactive. Similarly, Buty and Mortimer (2008) expressed that communication approach exhibited differences as per utilization of everyday and scientific language and the role and behaviors of the teacher in science classes. In this study, the teacher provided feedback, rather than evaluation, to student answers in the interaction model and, as also expressed by Chin (2006), this process led the students to take a more active role in this process. While the instruction process was generally a student-active process, the teacher attempted to enable the students to reach scientific meanings through a variety of guidance.

Recommendations for Future Studies

No studies researching the effect of meaning formation instruction on the change and conceptual permanence in student opinions related to conservation of angular momentum were encountered within the literature. Opinions of high school students on this concept were researched in this study. Studies researching opinions of high school and university students, and even physics teachers, on conservation of angular momentum, can be conducted. Results acquired in these studies can be utilized in defining difficulties encountered during teaching conservation of angular momentum and defining teacher efficiency in this subject. Studies wherein different conceptual change approaches that might be effective in teaching of this concept to high school and university students are utilized should be conducted. Therefore, methods that might be effective in teaching of this subject can be identified.

This instruction aimed to form meaning has been effective in one of the two students in terms of conceptual durability. Meaning formation approach can be utilized in teaching of different physics or science concepts and its effect on conceptual change and durability can be researched. Among meaning formation studies, most of them investigated communication approach and interaction model steps among the five steps of this approach. Mortimer and Scott (2003) discussed the meaning formation approach in five steps as a whole and expressed that all of these five steps must be taken into account in order to define authenticity of meaning formation. For this reason, the number of studies that includes all of these steps must be increased.

Researches on conceptual durability wherein delayed post-test is performed after longer periods of time and changes in student opinions are analyzed can be conducted. Studies that discuss the effect of instruction on conceptual durability by comparing answers given by students after instruction and long after instruction can be conducted. Studies with much longer times between post-test and delayed post-test will be precursors for understanding whether conceptual changes actually occur in students’ opinions.

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