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Prospective Teachers' Comprehension Levels of Special Relativity Theory and the Effect of Writing for Learning on Achievement

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Abstract: In the present study, the comprehension levels of special relativity theory in prospective teachers who take the Introduction to Modern Physics lesson in the faculty of education science teaching department and the effect of writing for learning on their achievement is researched. In the research, a control group pre-test post-test quasi-experimental research model was used. Research data were obtained by using open-ended questions prepared by the researcher. The lesson was conducted in the beginning by using the verbal-written explanation method. Then each student in the experimental group wrote a summary which clearly explains the special relativity theory for a high school student within the framework of the writing for learning activity. By contrast, the control group students solved the problems related to the subject in the course book. A total of 73 students (51 female and 22 male) studying at the second grade in the 2011-2012 academic year participated in the study. The research findings showed that the comprehension levels of special relativity theory in prospective teachers were low; the result obtained by the qualitative and quantitative comparison of the post-test results of the experimental and control groups and their achievement percentage in the exam were in favor of the experimental group. Furthermore, 87.2% of the students who wrote down their opinions about the activity of writing for learning understood the special relativity theory; and the activity of writing for learning was effective in learning the special relativity theory.

Introduction

Special relativity is the theory put forward by Albert Einstein in 1905 and it examines the results of the non-existence of a universal reference system. There are two postulates which form the basis of special relativity theory. 1) Physics laws are expressed with the same equations in all the reference systems which move at a stable speed. 2) The speed of light in space (c =3.10^8 m/s) is the same for every observer no matter its movement status (Beiser, 1995; Serway & Beichner, 2000; Yildiz, 2005). Length, time and mass are relative according to special relativity theory. According to the theory, the length of a moving spacecraft looks shorter to a stable observer on earth in the direction of relative motion. The length of an object at a speed of 0.9c appears to be shortened as given in the Lorentz transformation at a rate of $L/L_0=(1-(0.9c)^2/c^2)^{1/2}$ =0.436; 43.6% as required by the $L/L_0=(1-(0.9c)^2/c^2)^{1/2}$ equation (Beiser, 1995). A moving clock seems to be working more slowly than another stable clock near the observer which is identical to the first one. If the time interval measured with a moving clock according to observer is t and the time interval measured with an identical stable clock near the observer is $t_{0,}$ the relation between them is given with the $t=t_0/(1-v^2/c^2)^{1/2}$ equation (Beiser, 1995; Serway & Beichner, 2000;Yıldız, 2005). The relativity of mass is that the mass of a moving object (particle) according to an observer which is measured by the same observer (m) is bigger than its mass (m_0) when it is stable according to itself. According to special relativity theory, moving mass is found with the $m=m_0/(1-v^2/c^2)^{1/2}$ equation (Beiser, 1995; Serway & Beichner, 2000;Yildiz, 2005).

In the twentieth century, great interest was shown in two writing movements that were reflected in curricula. The first one appeared thanks to the progressive education approach of Dewey which started in the 1930s and continued until the 1950s. The second one is the movement which started in the 1970s and has continued until today. As part of the above mentioned second movement, writing has been a teaching activity widely-used over the entire world in many levels of education and in the field of science (Anson, Schwiebert & Williamson, 1993; Bazerman & Russel 1994; Fulwiler, 1986; Martin, D'Arcy, Newton & Parker, 1994; McLeod, 1992; Pearce, 1984; Russell, 1991).

Klein (1999) states that writing activities (diary, summary, letter, article etc.) help students to think critically and to form a new knowledge store besides helping them to become individuals who can communicate well. Klein (1999) points to four hypotheses related to writing considering some research in the field (Bereiter & Scardamalia, 1987; Britton, 1982; Flower & Hayes, 1980, 1981; Newell, 1984; Young & Sullivan, 1984). The first hypothesis (spontaneous) is that writers generate information while writing. Namely, they generate information without planning or control. The second hypothesis, called "forward search" claims that writers materialize their opinions in their writings, when they re-read this writing, new inferences based on it are generated. The third hypothesis (genre structures) argues that writers use genres in order to establish a relationship between text elements and they bring together the elements of the information. The last hypothesis, called "backward search", indicates that writers choose scientific objectives which can be effectively expressed; they obtain satisfactory objectives from them and they change their knowledge in order to reach conclusions.

The opinions of writers can change in the writing process. Thus, opinions are revealed in the writing process itself. While re-thinking and re-expressing, writers in the end give a final shape to their opinions. The information changing model is a general feature of expert writers as opposed to amateurs (Tynjala, 1998). The difference between the information-telling model and the information-changing model explains why simply answering study questions is not as effective as a studying strategy as writing an article. Study questions can be answered by using an information transfer strategy, however, article writing employs strategies which require information change and a higher thinking process such as writing with a purpose, writing, editing and concluding (Tynjala, 1998).

Much research about the use of writing as a tool which improves thinking and learning has been conducted (Mason & Boscolo, 2000). In their studies of learning by writing, Langer and Applebee (1987) state that writing about a subject increases a writers' knowledge, helps the writer to organize his/her ideas and this contributes to the learning experience. Writing activity forces the writer to express his/her ideas more clearly and precisely. The use of writing as an intellectual activity is an important strategy for planned/intentional learning (Bereiter, 1990, 1994; Bereiter & Scardamalia, 1989).

In their studies, where study groups were composed of prospective science teachers, Yildiz and Buyukkasap (2011a, b, c) concluded that the achievement percentage of students who wrote letters to final-grade high school students about the photoelectric effect, Compton scattering and the Heisenberg Uncertainty Principle as a writing for learning activity was higher than the achievement percentage of the control groups. In the same studies, the experimental group students indicated that they understood the subjects they wrote letters about and that writing for learning activities were effective in learning these subjects effectively.

One of the subjects that physics education researchers are intensely interested in is the teaching and learning of quantum physics especially of university level. It is seen that pedagogical studies in this subject are more focused on conceptual learning, visualization, mathematical thinking and problem-solving (Didis, Ozcan & Abak, 2008). Styer (1996) determined the conceptual mistakes of students in quantum subjects such as quantum states and identical particles. Some researchers (Singh, Belloni & Christian, 2006) have researched conceptual mistakes regarding the Schrödinger wave equation and revealed that these conceptual mistakes resulted from wrong generalizations. In the same research, the researchers determined that even though they solved mathematical problems, students could not make qualitative explanations of the questions. In his study of quantum physics lessons, Sen (2000) emphasized that conducting quantum physics lessons at high school physics lesson level could provide important advantages. The findings that Mashhadi and Woolnough (1999) obtained in their research on how electron and photon concepts are visualized in the perceptions of high school students showed that students had various non-scientific representations in their perceptions. Pospiech (2000) argues that the mathematical structure of quantum physics hides the philosophical aspect of the theory. Ireson (2000) emphasizes that mathematical structure does not constitute a problem and the main problem concerns the interpretation. Strand (1981), states that the reason why quantum physics subjects are difficult to teach in high school is the insufficient mathematical background of the students. Ke, Monk and Duschl (2005), state that solving mathematical equations in exams is not an indicator that students understand quantum mechanics concepts. The study conducted by Didis et al. (2008) revealed a variety of ways of describing quantum physics. In that study, it was seen that students used a "microscopic system" the most for description and they considered the "Heisenberg uncertainty principle" the most important principle in quantum physics.

As stated in most of the research studies that have been conducted of mostly on university level and on prospective teachers (Didis, Ozcan & Abak, 2008; Ireson, 2000; Ke, Monk & Duschl, 2005; Mashhadi & Woolnough, 1999; Pospiech, 2000; Singh, Belloni & Christian, 2006; Styer, 1996; Sen 2000; Yildiz & Buyukkasap, 2011a, b, c), many conceptual problems can be experienced in teaching the quantum physics subject since it contains many abstract concepts. It is considered necessary to make extensive use of writing for learning activities for them to provide effective and meaningful learning (Yildiz & Buyukkasap, 2011a, b, c) as supportive activities which facilitate conceptual changes in students (Mason & Boscolo, 2000) and which enable concepts to be structured in a successful and permanent way.

Purpose of the Research

1) To determine the comprehension levels of special relativity theory of the prospective science teachers who take the obligatory Introduction to Modern Physics lesson in a university,
2) To examine the effect of writing for learning activities on the achievement of prospective science teachers.

Method
Pattern of the Research

In this research which has qualitative and quantitative patterns, open-ended questions which enable students to freely express their opinions about the research subject, and to simply reveal their scientific opinions (Akgun, Gonen & Yilmaz, 2005; Bauner & Schoon, 1993) were used. A quasi-experimental research model where pre-test and post-test were applied and which involved a control group was used in order to determine students' opinions about special relativity theory in the Introduction to Modern Physics lesson, and the effect of writing for learning activities on their achievement. The lesson was conducted in the groups by a "verbal and written expression" method (Akdeniz, Bektas & Yigit, 2000). Each student in the experimental group wrote a summary to clearly explain the special relativity theory for a high school student. The summary was written for high school students as special relativity theory is conducted only in the last grade of high school according to the curriculum. Control group students solved the problems related to special relativity theory in the course book.

Study Group

The study group was composed of a total 73 second grade students studying in the faculty of education, elementary science teaching department of a public university in the 2011-2012 academic year. Thirty nine of them (13 males and 26 females) were in the control group; and 34 of them (9 males and 25 females) were in the control group. The groups were organized by drawing between the students from two classes (class A and class B) in the second grade of the science teaching undergraduate program.

Application

The stages of the application made in the research are given below:
1) The groups were set a test composed of open-ended questions about special relativity theory at the beginning of the semester.
2) The correct answer for each question and the grading for each process of this answer were determined at the end of a joint deliberation by 3 experienced academics. The document prepared in this study was used in order to determine the pre-test post-test success grades of prospective teachers. When the results were examined, it was seen that the pre-test grade means of the groups were close to each other (11.5 and 12.7); based up on t-test results the difference between the grades of groups was not statistically significant ($p=0.672$; $F=2.435$; $df=71.000-70.595$) and it was possible to consider the groups as identical before the application (Table 7).
3) The subject matter of the research was taught in accordance with the curriculum. Then a directive on when and how submit the summary about writing for learning was distributed to the students in the experimental group. It was examined by all the students; necessary explanations were made and the questions of the students were answered in a detailed way. In the directive of writing for learning activity, it is stated that the activity should be in the form of a summary. It states clearly and in detail for whom the summary is to be written, the subject of the summary, that it should be scientific, when and how to deliver it and how it would be assessed.
4) Two weeks after explaining the writing for learning activity directive, the summaries written by the experimental group students for high school students were delivered to the researcher. At the same time, the control group students were asked to solve problems about special relativity theory in their course books.

5) Then, the post-test was applied on the experimental and control groups on the same day. Furthermore, only the experimental group students were asked additional questions in order to ascertain their opinions about the writing for learning activity.
6) In the days following the application of the post-test, "open-ended sensitizer interviews" about the advantages that writing for learning activity provides were realized with some students who were randomly selected from among all the students who participated in the activity (Rubin, 1983; Yildirim & Simsek, 2011).

Data Collecting

Some research data were obtained by using six open-ended questions prepared by the researcher. Three experienced academics, who had conducted the Introduction to Modern Physics lessons in previous years, and who worked in the same faculty, were asked to examine the research questions and to state their opinions. In line with their comments, necessary corrections were made. A preliminary study was conducted by asking the research questions to third-grade students who had taken the Introduction to Modern Physics lesson in the previous year before applying them on the research groups. It was concluded that the open-ended questions were suitable by considering the data of this preliminary study. Before teaching the subject matter of the research, after the special relativity subject was completed and the summaries were delivered to the researcher, a post-test was applied to the groups. Moreover, after the students had completed their writing for learning activities during the semester, a mid-term exam, which covers all the subjects in accordance with the curriculum, was given. The total correct answers that students gave to the questions about the special relativity theory in the mid-term exam were considered as an achievement criterion. The number of correct answers was evaluated; and the control and experimental groups were compared (Table 9).

Data Analysis

Three experienced academics worked in collaboration in order to assess the answers that the students had written for the open-ended questions of the research. The correct answers to each of the questions and the grading of each process of these questions were determined by common consent in the study. This document was used in order to determine the pre-test post-test grades of students. At the beginning and at the end of the application, pre-test and post-test were applied to both the experimental and the control groups. Their grades were interpreted by independent 2 sample t test (SPSS 13 package statistics program) and compared with each other. The significance degree was set at 0.05. While analyzing the alternative answers that students gave to the open-ended questions in the post-test, answers were grouped according to their similarity. They were incorporated in related tables under the title of "research findings". The required assessments were made in the "conclusion" part of the study. Furthermore, common examples of the written answers that students gave to the open-ended question, "What do you think of the advantages that writing for learning activity (summary writing) provides you with?", which was asked only of the experimental group students in the post-test, were presented under the related title in the "findings" section of the study.

Findings

Qualitative examination of the effect of writing for learning activities related to special relativity theory on student achievement

In this part of the study, the experimental group, which wrote a summary within the framework of the writing for learning activity, and the control group which solved problems in the course book related to the subject were compared with each other according to post-test results. The lesson was conducted in both groups by using the "verbal-written explanation method" (Akdeniz et al., 2000).

Question 1

According to special relativity theory, what does the length of a moving spacecraft appear to be to a stable observer on earth in the direction of motion?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
It looks shorter	25	64.1	28	82.4
It looks to be shortened as much as $(1-v^2/c^2)^{1/2}$ multiplier	5	12.8	-	-
It looks longer	3	7.7	5	14.7
Other answers (It looks at L_o length, $L > L_o$, it looks very speedy...)	5	12.8	-	-
No answer	1	2.6	1	2.9
Total	39	100	34	100

Table 1: Answers that the experimental and control group students wrote for the question, "What does the length of a moving spacecraft appear to be to a stable observer on earth in the direction of motion?"

Question 2

According to special relativity theory, how do moving clocks work according to a stable observer on earth compared to stable identical clocks?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
It works more slowly	27	69.2	24	70.6
It does not work similarly/It works differently	2	5.1	-	-
Time has relativity; $t=t_0/(1-v^2/c^2)^{1/2}$, $t > t_0$; $t>t_0$	3	7.7	-	-
It works faster.	1	2.6	4	11.8
No answer	6	15.4	6	17.6
Total	39	100	34	100

Table 2: Answers that the experimental and control group students wrote for the question, "According to special relativity theory, how do moving clocks work according to a stable observer on earth compared to stable identical clocks?

Question 3

Is the speed of light (c) different in the motionless reference system for stable A observer and moving B observer? Or not? Why?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
It is the same for both observers because the speed of light is the highest speed.	6	15.4	6	17.6
It is the same for both observers because the speed of light is stable.	8	20.5	7	20.6
It is the same for both observers.	1	2.6	10	29.4
Because the speed of light does not change according to the source and observer.	5	12.8	2	5.9
Speed of light is the same in all motionless reference systems.	7	17.9	-	-
It is different.	2	5.1	2	5.9
It is different. A measures the speed of light higher as it is motionless.	1	2.6	3	8.8
It is different because the reference systems are different.	5	12.8	2	5.9
It is different because it reaches B later as B is moving.	2	5.1	-	-
No answer	2	5.1	2	5.9
Total	39	100	34	100

Table 3: Answers that the experimental and control group students wrote for the question "Is the speed of light (*c*) different in the motionless reference system for stable A observer and moving B observer? Or not? Why?"

Question 4

What is synchronization according to special relativity theory?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
Observers at A and B receiving A signal expanding in the middle of the line which combines A and B points.	8	20.5	5	14.7
For an observer in a moving wagon, light projections coming out of the source in the middle reach to front and back photocells. They do not reach the stable observer outside at the same time.	8	20.5	-	-
Synchronization is not absolute.	2	5.1	2	5.9
Time difference in perceiving the incidences for observers in different reference systems.	4	10.3	4	11.8
Different perception of an incidence by two different observers.	2	5.1	1	2.9
That either of the twins is late and the other is old.	-	-	1	2.9
Other answers (time expansion, the event that a direction which appears throughout a line increases throughout each line...)	7	17.9	15	44.1
No answer	8	20.5	6	17.6
Total	39	100	34	100

Table 4: Answers that the experimental and control group students wrote for the question, "What is synchronization according to special relativity theory?"

Question 5

According to you, what are the equations (correlations, formulas) related to special relativity theory?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
$L=L_0(1-v^2/c^2)^{1/2}$, $t=t_0/(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$	13	33.3	5	14.7
$L=L_0/(1-v^2/c^2)^{1/2}$, $t=t_0/(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$	5	12.8	-	-
$L=L_0/(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$	4	10.3	4	11.8
$L=L_0(1-v^2/c^2)^{1/2}$, $t=t_0/(1-v^2/c^2)^{1/2}$	4	10.3	1	2.9
$L=L_0(1-v^2/c^2)^{1/2}$, $t=t_0/(1-v^2/c^2)^{1/2}$, $E_0=m_0c^2$, $E=mc^2$	1	2.6	-	-
$L=L_0(1-v^2/c^2)^{1/2}$, $t=t_0(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$	1	2.6	-	-
$t=t_0/(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$, $p=m_0v/(1-v^2/c^2)^{1/2}$	1	2.6	-	-
$L=L_0(1-v^2/c^2)^{1/2}$, $E_0=m_0c^2$	1	2.6	-	-
$L=L_0(1-v^2/c^2)^{1/2}$	1	2.6	3	8.8
$m=m_0/(1-v^2/c^2)^{1/2}$	1	2.6	5	14.7
$t=t_0/(1-v^2/c^2)^{1/2}$, $E=mc^2$	1	2.6	-	-
$L=L_0(1-v^2/c^2)^{1/2}$, $t=t_0(1-v^2/c^2)^{1/2}$	1	2.6	-	-
$P=m_0v/(1-v^2/c^2)^{1/2}$	-	-	8	23.5
Other answers ($E=E'+E_k$, constant velocity a=0,...)	-	-	4	11.8
No answer	5	12.8	4	11.8
Total	39	100	34	100

Table 5: Answers that the experimental and control group students wrote for the question, "What are the equations related to special relativity theory?"

Question 6

What does the expression, "Basic laws of physics are the same in all motionless reference systems" remind you of? What is it related to?

Student Answers	Experimental Group		Control Group	
	Number of Students	%	Number of Students	%
It reminds me of the special relativity theory of Einstein	10	25.6	16	47.0
It is one of the hypotheses of special relativity theory	6	15.4	-	-
It states that basic laws of physics are not relative	3	7.7	4	11.8
It is related to the first (1st) law of Newton	3	7.7	1	2.9
It is about the fact that speed of light is stable and the highest speed limit in nature	2	5.1	-	-
It reminds me of the synchronization principle	-	-	4	11.8
Other answers (about time's relativity)	6	15.4	4	11.8
No answer	9	23.1	5	14.7
Total	39	100	34	100

Table 6: Answers that experimental and control group students wrote for the question "What does the expression "Basic laws of physics are the same in all motionless reference systems" remind you of? What is it related to?"

Quantitative examination of the effect of writing for learning activities related to special relativity theory on student achievement

Groups	N	Arithmetical Mean	Standard Deviation	Conclusion
Test	39	11,54	13,318	$t_{(71)}$= - 0,419; P=0,672 > 0,05
Control	34	12,74	10,735	

Table 7: T test results for the pre-test grades of the experimental and control groups for special relativity theory

Groups	N	Arithmetical Mean	Standard Deviation	Conclusion
Test	39	53,51	16,024	$t_{(71)}$=3,930; P=0,0001 <0,05
Control	34	40,03	12,817	

Table 8:T test results for the post-test grades of the experimental and control groups for special relativity theory

According to Table 8, the arithmetic mean of post-test grades of experimental group for special relativity theory is X=53.51, while the arithmetic mean of post-test grades of control group is X=40.03. There is a significant difference between the arithmetic means of the post-test grades of experimental and control groups ($t_{(71)}$=3,930; P=0,0001< 0,05).

Students' Achievements Based on the Answers They Gave to the Questions Related to Special Relativity Theory in the Exam Made within the Framework of the Academic Calendar

Subject	Achievement Rate of Experimental Group Students (%)	Achievement Rate of Control Group Students (%)
Special relativity theory	70.3	60.6

Table 9: Experimental and Control Group Students' Rate of Giving Correct Answers to the Questions Related to Special Relativity Theory in the Mid-term Exam

The total correct answers that students gave to the questions about special relativity theory in the mid-term exam with test questions were considered as an achievement criterion (Table 9). When the exam results of the students are compared, it is seen that the experimental group students' rate of giving correct answers to the questions about the writing for learning activity is higher than that of the control group. This finding shows that students who wrote a summary of special relativity theory are more successful than who did not write a summary.

Student Opinions on the Writing for Learning Activity (Summary) about Special Relativity Theory

Thirty four of the experimental group students (87.2%) gave written positive answers and 5 of them (12.8%) did not give any written opinion (either negative nor positive) about the question, "What do you think of the advantages that writing for learning activity (summary writing) provides you with?" which was asked in post-test. In the subsequent interviews (open-ended sensitizer interview), students gave answers similar to those they wrote before for the same question. In the interviews, it was seen that the students' answers were confirming the opinions they had stated in writing before and they were very similar to each other. Common and representative examples of these original written answers are given below.

I strengthened my knowledge, I better understood the subject, I compensated for my deficiencies. With this way, I had the opportunity to study.
It helped me to better comprehend the subject. It helped me to question what I know and what I do not know about the subject about which I wrote a summary. It caused me to think about the question, "How can I better understand the subject?"
It enabled me to understand the subject.
It really helped me to better comprehend the subject. I made at least a little preparation for this lesson even though I am a lazy student.

When all the opinions are examined, it can be seen that students express that they learn to organize scientific thoughts with their own sentences; to make comments, to associate main thoughts in a subject, to concisely present the information by organizing it and they remember more easily the subjects about which they write summaries as was also stated in some research studies (Dogan & Cavus, 2008; Uzoglu, Gunel & Buyukkasap, 2008).

The reason why students' opinions were determined in the post-test is the researcher's intuition that students may be more aware of the advantages and problems they have while answering the post-test questions; and they can write their opinions about their achievements and failures in a more sensitive and accurate way.

Discussion of Results

Important findings were obtained at the end of the analysis of data obtained in the part of the research where the students' comprehension level of special relativity theory was qualitatively researched. It is important that the experimental group students wrote the answer, "It looks to be shortened as much as the $(1-v^2/c^2)^{1/2}$ multiplier" for the question what does the length of a moving spacecraft appear to be to a stable observer on earth in the direction of motion? (12.8%). This answer is an expression which can be written by students who think more profoundly and who have a better comprehension than the students who were expected to write "Its length looks shorter." The answer, "Speed of light is the same in all the motionless reference systems" that the experimental group students wrote (17.9%) for the question "Is the speed of light (c) different in the motionless reference system for stable A observer and moving B observer? Or not? Why?" is also remarkable. The answer, "Light projections which come out of the middle source for an observer in a moving wagon reach the front and back photocells at the same time. They cannot reach them at the same time according to a stable observer outside." (20.5%) that the experimental group students wrote for the question, "What is synchronization according to special relativity?" is an answer which can be written only by students who are one step ahead of the others in terms of understanding the subject. It is seen that this answer was not written by anybody from the control group. The rate of students who could correctly write the equations which show that time, length and mass are relative ($t=t_0/(1-v^2/c^2)^{1/2}$, $L=L_0(1-v^2/c^2)^{1/2}$, $m=m_0/(1-v^2/c^2)^{1/2}$) is 33.3% for the experimental group students and 14.7% for the control group students. It is significant that only the experimental group students (15.4%) answered, "It is one of the hypotheses of special relativity theory" for the question, "What does the expression "Basic laws of physics are the same in all motionless reference systems" remind you of? What is it related to?"

In the part of the research which qualitatively examines the effect of the writing for learning activity for teaching special relativity theory on the academic achievements of students, the post-test grades of the experimental and the control groups were interpreted by independent two sample t test and they were compared. It was seen that the results of this comparison showed a significant difference for special relativity theory in favor of the experimental group students. When the results of a mid-term exam which was applied after the writing for learning activity in accordance with the academic calendar were examined, it was seen that the percentage of giving correct answers to the test questions about the subject of the summary they wrote was higher for the experimental group than for the control group. When the experimental and the control groups are compared, these rates are 70.3% and 60.6% in favor of the experimental group.

Yildiz and Buyukkasap (2011a, b, c) are in parallel with the results of the present study. When students' opinions about writing for learning activities on special relativity theory are examined, 87.2% of them (this rate is 100% of the students who expressed their opinions in writing) stated that the summaries they wrote made scientific knowledge permanent (Rivard & Straw, 2000) and helped them to learn the abstract subjects which are difficult to learn (Hohensell, Hand & Staker, 2004). When the researcher continued to examine the positive opinions (whose percentage is given above), it was seen that students express that they learn to organize scientific thoughts with their own sentences; to make comments, to associate main thoughts in a subject, to concisely present the information by organizing it and they remember more easily the subjects about which they write summaries as was also stated in some research studies (Dogan & Cavus 2008; Uzoglu et al., 2008).

The "Verbal-written explanation" method was used in the groups for the Introduction to Modern Physics lesson. Using writing for learning activity in addition to this method in the experimental group resulted in a significant difference between the post-test grades of the experimental group and the control group (Table 8). Students in the experimental group who applied writing for learning activity for learning special relativity theory were more successful than the students in the control group. In other words, it was concluded that writing for learning activities were effective in increasing the students' comprehension levels of special relativity theory (Yildiz & Buyukkasap, 2011a, b, c). This result shows that this activity can be used as an efficient method for teaching special relativity theory in quantum physics subjects in the Introduction to Modern Physics lesson. Because these activities facilitate students' conceptual changes (Mason & Boscolo, 2000) it enables them to successfully and permanently structure the related concepts.

Conclusion

Research studies (Tynjala, 1998; Mason & Boscolo, 2000; Yildiz & Buyukkasap, 2011a, b, c) indicate that writing for learning activities which realize conceptual changes in students by facilitating them and that make students discover and structure the information by centralizing it, and the instruction techniques which involve these activities, can be useful. For this reason, it could be proposed that teachers should use writing for learning activities in the instruction of an abstract subject such as special relativity theory in a field which has abstract subjects such as quantum physics. At the end of this study, suggested to carry out writing for learning activities with other activities such as the diary, short story, brochure, poster and article for making significant contributions to the field.

References

Akdeniz, A. R., Bektas, U. & Yigit, N. (2000). Ilkogretim sekizinci sinif ogrencilerinin temel fizik kavramlarını anlama duzeyi. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, *19*, 5-14.

Akgun, A., Gonen, S. & Yilmaz, A. (2005). Fen bilgisi ogretmen adaylarinin karisimlarin yapisi & iletkenligi konusundaki kavram yanilgilari. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, *28*,1-8.

Anson, C. M., Schwiebert, J. E., & Williamson, M. M. (1993). *Writing across the curriculum: An annotated bibliography.* Westport, CT.: Greenwood Press.

Bauner, M., & Schoon, I. (1993). Mapping variety in public understanding of science. *Public Understanding of Science*, *2* (2), 141-155.

Bazerman, C., & Russell, D. (1994). Introduction: The rhetorical tradition and specialized discourses. In C. Bazerman & D. Russell (Eds.), *Landmark essays on writing across the curriculum* (pp. 17-38). Davis, CA: Hennagoras Press.

Beiser, A. (1995) Concepts of modern physics, McGraw-Hill

Bereiter, C. (1990). Aspects of an educational learning theory. *Review of Educational Researcher*, *60* (4), 603-624.

Bereiter, C. (1994). Constructivism, socioculturalism, and Popper's World 3. *Educational Researcher*, *23* (7), 21–23.

Bereiter, C. & Scardamalia, M. (1987). *The psychology of written composition*. NJ: Lawrence Erlbaum Associates, Hillsdale.

Bereiter, C., & Scardamalia, M. (1989). *Intentional learning as a goal of instruction*. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honour of Robert Glaser* (pp. 361-392). NJ: Erlbaum: Lawrence Erlbaum Associates, Hillsdale.

Britton, J. (1982). Shaping at the point of utterance. In Pradl, G. M. (ed.), Prospect and retrospect: Selected essays of James Britton, Boynton/Cook Publishers, Inc. Montclair, NJ, 139-145. (Reprinted from Reinventing the rhetorical tradition, by Freedman, A. & Pringle, I. (eds.), (1980). Conway, A. R., L and S Books., for the Canadian Council of Teachers of English)

Didis, N., Ozcan, O. & Abak, M. (2008). Ogrencilerin bakis acisiyla kuantum fizigi: Nitel calısma. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, *34*, 86-94.

Dogan, N. & Cavus, S. (2008, Agustos). *Informal ogrenme ortamlarında fen konularının ogrenilmesine yazma etkinliginin etkisi.* VIII. Ulusal Fen Bilimleri & Matematik E itimi Kongresinde sunulan bildiri, Abant Izzet Baysal Universitesi, Bolu.

Flower, L. S. & Hayes, J. R. (1981). A cognitive process theory of writing. *College Composition and Communication*, 32, 365-387.

Flower, L. & Hayes, J. R. (1980) The cognition of discovery*:* Defining a rhetorical problem*. College Composition and Communication*, 31, 21-32.

Fulwiler, T. (1986). *The argument for writing across the curriculum*. In A. Young & T. Fulwiler (Eds.), *Writing across the disciplines: Research into practice* (pp. 21-32). Upper Montclair, NJ: Boynton/Cook Publishers, Inc.

Hohensell, L., Hand B., & Staker, J. (2004). Promoting conceptual understatnding of biotechnology: Writing to a younger audience. *American Biology Teacher*, *66* (5), 333-338.

Ireson, G. (2000). The quantum understanding of pre university physics students. *Physics Education*, *35* (1), 15-21.

Ke, J. L., Monk, M., & Duschl, R. (2005). Learning introductory quantum mechanics. *International Journal of Science Education*, *27* (13), 1571–1594.

Klein, P. D. (1999). Reopening ınquiry into cognitive processes in writing-to-learn. *Educational Psychology Review*, *11* (3), 203-270.

Langer, J. A., & Applebee, A. N. (1987). *How writing shapes thinking: A study of teaching and learning.* Urbana, IL.: National Council of Teachers of English.
Martin, N., D'Arcy, P., Newton, B., & Parker, R. (1994). The development of writing abilities. In C. Bazerman & D. Russell (Eds.), *Landmark essays in writing across the curriculum* (pp. 33-49). Davis, CA: Hermagoras Press [Reprinted from Writing and learning across the curriculum, 12-34 (1976), Ward Lock Educational UK].
Mashhadi, A., & Woolnough, B. (1999). Insights into students' understanding of quantum physics: Visualizing quantum entities. *European Journal of Physics*, *20*, 511–516.
Mason, L., & Boscolo, P. (2000). Writing and conceptual change. What changes? *Instructional Science*, *28*, 199–226.
McLeod, S. H. (1992). Writing across the curriculum: An introduction. In S. H. McLeod & M. Soven (Eds.), *Writing across the curriculum: A guide to developing programs* (pp. 1-11). Newbury Park, CA: Sage.
Newell, G. E. (1984). Learning from writing in two content areas: A case study/protocol analysis. *Research in the Teaching of English*, 18, 265-287.
Pearce, D. L. (1984). Writing in content area classrooms. *Reading World*, *23*, 234-241.
Pospiech, G. (2000). Uncertainity and complementarity: The hearth of quantum physics. *Physics Education*, *35* (6), 393–399.
Rivard, P. L., & Straw, B. S. (2000). The effect of talk and writing on learning science: An exploratory study. *Science Education*, *84*, 566-593.
Rubin, H. J. (1983). *Applied social research*. Columbus, OH: Charles E. Merrill Publishing.
Russell, D. R. (1991). *Writing in the academic disciplines: 1870-1990: A curricular history.* Carbondale, IL.: Southern Illinois University Press.
Serway, R. A. & Beichner, R. J. (2000). *Physics For Scientists and Engineers with Modern Physics*, Chapters 1-39 (5th Edition). Saunders College Publishing.
Singh, C., Belloni, M., & Christian, W. (2006). Improving students' understanding of quantum mechanics. *Physics Today*, *59* (8), 43–49.
Strnad, J. (1981). Quantum physics for beginners. *Physics Education*, *16*, 88-92.
Styer, D. F. (1996). Common misconceptions regarding quantum mechanics. *American Journal of Physics*, 64, 31–34.
Sen, A. I. (2000). Kuantum fizigi alan ogretimi konusunda Almanya'da yapilan tartısmalarin son durumu. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, *19*, 122-127.
Tynjala, P. (1998). Writing as a tool for constructive learning: Students' learning experiences during an experiment. *Higher Education*, 36(2), 209-230.
Uzoglu, M., Gunel, M., & Buyukkasap, E. (2008, Agustos). *Ogrenme amacli yazma aktivitelerindeki varyasyonun ilkogretim seviyesinde fen konularını ogrenmeye etkisi*. VIII. Ulusal Fen Bilimleri ve Matematik Egitimi Kongresi'nde sunulan bildiri, Abant Izzet Baysal Universitesi, Bolu.
Yildirim, A. & Simsek, H. (2011). *Sosyal bilimlerde nitel arastırma yontemleri*. Ankara: Seckin Yayincilik.
Yildiz, A. (2005). *Ilkogretim bolumleri icin modern fizik,* Gunduz Egitim ve Yayincılıik, Ankara.
Yildiz, A. & Buyukkasap, E. (2011a). The Level of understanding of the photoelectric phenomenon in prospective teachers and the effects of "writing with learning" on their success rates. *Educational Sciences: Theory & Practice*, 11 (4), 2259-2274.
Yildiz, A. & Buyukkasap, E. (2011b). Prospective teachers' levels of understanding Compton effect and the impact of writing activities for learning purposes on academic success. *International Journal of Human Sciences* 8 (1), 1643-1664.

Yildiz, A. & Buyukkasap, E. (2011c). Prospective teachers' levels of understanding Heisenberg uncertainty principle and the impact of writing activities for learning purposes on academic success. *Journal of Turkish Science Education*, 8 (4), 134-148.

Young, R. & Sullivan, P. (1984). *Why write?* A reconsideration. In Conners, R. J., Ede, L. S., and Lunsford, A. A. (eds.), Essays on classical rhetoric and modern discourse, 215-225. Carbondale, IL.: Southern Illinois University Press.