European Journal of Educational Research

Volume 7, Issue 2, 387 - 395.

ISSN: 2165-8714

http://www.eu-jer.com/

The Effect of 7E Learning Model on Conceptual Understandings of Prospective Science Teachers on "de Broglie Matter Waves" Subject *

Meryem Gorecek Baybars **
Mugla Sitki Kocman University, TURKEY

Huseyin Kucukozer
Balikesir University, TURKEY

Received: February 16, 2018 ▪ Revised: March 30, 2018 ▪ Accepted: April 2, 2018

Abstract: The object of this study is to determine the conceptual understanding that prospective Science teachers have relating "de Broglie: Matter waves" and to investigate the effect of the instruction performed, on the conceptual understanding. This study was performed at a state university located in the western part of Turkey, with the Faculty of Education-Science Teaching students (2nd year / 48 individual) in the academic year of 2010-2011. The study was planned as a single group pretest-posttest design. A two-step question was used in the study, prior to and after the instruction. Lessons were conducted using the 7E learning model in the instruction process. When all these results are evaluated, it can be said that the conceptual understanding of the prospective teachers regarding "de Broglie; matter waves" has been taken place. In general, when all the sections are examined, it has been observed that the prospective teachers have more alternative concepts prior to the instruction and more scientific concepts after the instruction. In this process, besides instruction, the prospective teachers have not taken any place in a different application regarding the basic concepts of quantum physics. Therefore, it has been determined that the 7E learning model used in the research and the activities included in the 7E learning model are effective in conceptual understanding.

Keywords: *7E learning model, matter waves, conceptual understanding.*

To cite this article: Gorecek Baybars, M., & Kucukozer H. (2018). The effect of 7e learning model on conceptual understandings of prospective science teachers on "de Broglie matter waves" subject. *European Journal of Educational Research*, *7*(2), 387-395. doi: 10.12973/eu-jer.7.2.387

Introduction

Late in the 19th century, many scientists believed that all of the cases in the field of physics that are needed to be learned were known. According to the scientists, there was nothing left to discover. In addition to that the mathematical formality of Isaac Newton and James Clerk Maxwell was considered as perfect, the estimations based on these theories have been confirmed for years by rigorous, detailed experiments. Classical physicists had created a number of assumptions that focused their ideas and made it very difficult to accept new ideas. According to classical physicists, the universe was like a giant machine built in an absolute time and space frame. A complex movement could be understood as a simple movement of the inner parts of the machine. According to Newton, every move had a cause, and that was happening within the framework of cause and reason. In each of the cases, determinism dominated, that is to say, if the state of the moving one was known at a certain point, it could be determined very easily, at any point in the future as well, even in the past. The properties of the light were completely revealed by Maxwell's electromagnetic wave theory. It was also possible to measure properties of a system such as a temperature and speed, with the desired accuracy; it was not even possible that the observer would affect the measurements. Classical physicists believed that all of these statements were absolutely correct (Mcevoy and Zarate, 2010). After all these assumptions, classical physics peaked with the theory of general relativity (Cushing, 2003).

At the beginning of the 20th century, there were unexpected developments experienced which were called *revolutions* by many people. In 1900, Planck created ideas that pioneered quantum theory. After this, especially in the 1900s and 1930s, studies in this field accelerated and the new theory called quantum mechanics became quite successful in explaining the behavior of atoms, molecules, and nuclei.

The emergence of the quantum physics has not only created new theories but also made it possible to create a new perspective. The quantum physics has also shaped our perspective of nature in a novel way. It should not be

* This study includes a part of the first author's doctoral dissertation.

** **Corresponding author:**
Meryem Gorecek Baybars , Mugla Sitki Kocman University,Faculty of Education, Turkey.
Email: mgorecek@mu.edu.tr

understood only by the physicists that how nature works (Muller and Wiesner, 2002). Understanding quantum physics has become a structure that includes engineers, biologists and chemists, as well as physicists. Because when we look at daily life, many issues can be explained by quantum principles.

For all these reasons, the interest in quantum physics and teaching it, has been increasing rapidly in recent years. In particular, studies on the teaching of quantum physics have become an area of interest for physic educators in recent years. However, when we look at all the studies in the field of physics, one can see that the studies on quantum physics teaching are fewer than the studies on other fields of physics. Also the studies are more focused on conceptual learning, visualization, mathematical thinking, and problem-solving.

Quantum physics is one of the most important fields in physics and even in science, in general. However, the quantum physics is non-physical and the understanding of many subjects of it is quite difficult (Steinberg, Wittman, Bao and Redisch, 1999). Even though it is very difficult to be understood by the students, it is one of the most important subjects to be learned in physics in order to understand nature better. While the students start encountering with the concepts taking place in classical physics almost in the 4th grade of the primary education, the encounter with quantum concepts falls in the secondary education classes. Until the secondary school, students associate the events they face in daily life with classical physics. Especially when we look at the daily life applications of the quantum physics, it is not a matter for only physicists to know anymore. Therefore, it further becomes important that a Science teacher is well trained in this field.

Methodology

Research Goal

The object of this study is to determine the alternative concepts that prospective Science teachers have relating "de Broglie: Matter waves" and to investigate the effect of the instruction performed, on the conceptual understanding.

Participants and Data Collection

The study was planned as a single group pretest-posttest design. The purposive sampling method was used in this study. According to Patton (2014), purposive sampling method allows for in-depth study of the situations thought to have rich knowledge. When the main purposive sampling methods are examined, the type of sampling used in our research is an easily accessible case sample. Because in this method, the researcher chooses a situation that is close and easy to access. For researchers, an easily accessible sample can be preferred in the cases when the time and cost are important. This study was performed at a state university located in the western part of Turkey, with the Faculty of Education-Science Teaching students (2nd year / 48 individual) in the academic year of 2010-2011. A two-step question was used in the study, prior to and after the instruction, in order to determine conceptual understandings of prospective science teachers relating "de Broglie: Matter waves". The question is taken from Fletcher's (1997) thesis study, in order to determine how prospective teachers understand the dual structure of electrons and protons in their minds. The question used in the study is as follows.

Nowadays, we assume that electrons and protons behave like waves alongside the particle character. How do you explain this situation?

a) *Sometimes, electrons and protons may not exhibit some of the properties exhibited by billiard balls or small mass structures.*
b) *Sometimes, electrons and protons may not have a measurable velocity, energy, and momentum.*
c) *Sometimes, electrons and protons exhibit diffraction and interference effects.*

Please briefly explain your answer..

Furthermore, semi-structured interviews with 10 participants were conducted both prior to and after the practice, in order to be able to examine the alternative concepts possessed by the prospective teachers more deeply.

Lessons were conducted using the 7E learning model in the instruction process. This model is a model that can help the teacher in the process of structuring the learning environment. The 7E learning model contains the skills and activities that increase research curiosity, satisfy the expectations of the student, and focus on an active research for knowledge and understanding. At each step of the 7E learning model, it is possible for the students to be involved in the activity and to construct their own concepts. This model, which allows the knowledge to be able to be structured by the student, a consistent conceptual change independent from the content, encourages learning based on experience by drawing students' attention, contributes to the higher-level thinking process. The 7E learning model is a model formed through the revision of 3E, 4E, and 5E models during the course of the historical process. This model was established and interpreted by Bybee (2003) and Eisenkraft (2003). In the 7E transition process, Eisenkraft incorporated "eliciting prior understanding" and "extend" stages to existing E's; whereas Bybee incorporated "extend" and "sharing-idea exchange" stages. The 7E learning model used in this study was the model, as proposed by Eisenkraft. This model comprises of "elicit, engage, explore, explain, elaborate, evaluate and extend" stages. Each stage within the model framework has its own unique importance. The main reason for selecting this model is its incorporation of "eliciting prior information and extend" stages. Eliciting prior information stage intends to find out student's prior knowledge of new concepts and topics. This stage, in fact, is in a way, the definition of a starting point for the lesson. By eliciting prior knowledge of students, it is made possible for the students to actively participate in activities conducted during the lesson and to construct knowledge all by themselves. Within the extend phase, students might learn the application of newly captured concepts in other disciplines. Social constructivist theory suggests that the learning and teaching processes should be defined such as to encourage social interactions. 7E learning model allows teaching environments to be organized so that they would encourage social interactions. 7E learning model was preferred especially for that it evaluates prior knowledge of students; and that, it includes activities that can be used to provide a transition between prior knowledge and scientific knowledge.

Data Analysis

It is much easier to standardize the alternative concepts in students within certain coding and to perform data analysis in this way. According to Hewitt-Taylor (2001), the development of new ideas are provided and more regular information gathering is performed with the studies performed by code building. Trundle, Atwood, and Christopher (2002), Ucar (2007), Sackes (2010) performed data analysis by code building in the study performed. The analysis of the data was performed using the analysis method used by Trundle, Atwood, and Christopher (2006). The reason for the selection of this analysis method is that it uses the interview technique from the qualitative research methods and includes the method of case study data analysis. The answers given by the prospective teachers to the question were examined one by one. Then the coding was determined and the answers given by the prospective teachers in pre-test and post-test were evaluated and analyzed according to this coding system. While the codes and meanings were being created, the codes starting with "SCI." have been edited to mean "scientific" concepts and the codes starting with "ALT." have been edited to mean "alternative" concepts. After the coding was completed, the conceptual understandings of prospective teachers were grouped and correspondingly, frequency schedules and percentage schedules were formed.

If the answers of the prospective teachers include a choice of C which is the correct choice and the 3 determined criteria, these students were included in the level of "scientific" conceptual understanding. The three criteria expected from the prospective teacher are as follows:

1) Diffraction and interference are the characteristic properties of the wave. If electrons and protons exhibit these properties, wave characteristic is present as well as particle characteristic (SCI. WAVE).

2) This event can be explained by De Broglie waves (SCI. de BROGLIE).

3) When the double slit experiment is carried out with electrons, it is observed that electrons are interfering (SCI. EXPERIMENT).

If the prospective teacher has given written or verbal statements in such a way as not to include all of these three codes, the teacher was categorized as "from scientific division". If the prospective teacher has given written or verbal statements in such a way as to include both of the scientific and alternative concepts, the teacher was categorized as "from scientific and alternative division". The prospective teacher not making appropriate explanations for scientific codes and having more than one alternative concept was categorized as "alternative", and the prospective teacher having an alternative concept was categorized as "from alternative division". Except this, the answers not containing a logical explanation were grouped under the category of "No conceptual understanding". In order to compare these conceptual categories statistically, the scientific category was scored as 8 points and the others as was scored as decreasing points. The scores obtained from the concept test prior to and after the instruction were entered into the SPSS 16.0 program, and the difference between the scores was examined using the "Wilcoxon Signed Rank Test from non-parametric tests".

Findings / Results

In this section, the evaluation of the question presented to the prospective Science teachers regarding "de Broglie: matter waves" was mentioned. The answers given by the prospective teachers about "de Broglie: matter waves" prior to and after instruction and the numbers and percentages of these answers are given in Table 1.

Table 1: Teacher candidates' answers given prior to and after the instruction and numbers and percentages of these answers

Answer Types	Pre-Test		Post-Test	
	N	%	N	%
Scientific	-	-	9	18.8
From Scientific Division	13	27.1	30	62.4
Scientific and Alternative	-	-	-	-
From Scientific Division and Alternative	6	12.5	7	14.6
Alternative	17	35.4	-	-
From Alternative Division	5	10.4	2	4.2
No Conceptual Understanding	7	14.6	-	-
Grand Total	48	100	48	100

Pre-instruction:

When the answers given by the prospective teachers prior to the instruction were examined, there were no answers encountered that could be accepted as "scientific" and "scientific and alternative". The percentage of prospective teachers answered in the "from scientific division" category was 27.1%. 12.5% of the prospective teachers answered in the category of "from scientific division and alternative", 35.4% in the "alternative" and 10.4% in the "from alternative division" category. The examples of conceptual categories seen in the prospective teachers are submitted as follows.

From Scientific Division:

If the prospective teachers use at least one or a few of the criteria specified at the scientific level, without using any alternative concepts, they are included in the "from scientific division" level.

Prior to the instruction, the number of prospective teachers in the "from scientific division" category is 13. The examples of answers from this category are submitted below. ("*T*" symbol in the answer section represents the teacher candidate. *T2:* 2nd Teacher Candidate).

T2: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option). They can exhibit diffraction and interference effects in electrons and protons, just like the waves (SCI. WAVE)."

T6: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option). Diffraction and interference are wave phenomena, nowadays, electrons and protons are considered to behave like wave alongside the particle character, therefore electrons and protons exhibit diffraction and interference effects (SCI. WAVE)."

T40: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option). If protons and electrons can behave like waves, diffraction and interference effects can be observed (SCI. WAVE)."

As it can be seen from the answers given above, prospective teachers accept that electrons and protons behave like waves in addition to the particle character, however, they can not clarify this situation scientifically. Similar answers were observed from the other prospective teachers evaluated in this category (T12, T16, T17, T20, T24, T25, T29, T34, T36, T41).

From scientific division and alternative:

If prospective teachers use both scientific and alternative concepts together, then they are included in the "from scientific division and alternative" group. In the prospective teachers' answers, the proportion of "from scientific division and alternative" answers is 12.5%. In this category, there are answers which were marked as the correct answer, which, however, are not scientifically acceptable. The examples of answers assessed in this category are submitted below.

T43: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option). (SCI. WAVE). It is normal for electrons and protons to be in a particulate structure and to behave in this way because they have a certain mass and momentum (ALT. MASS).". However, the fact that it behaves as in wavy structure can be possible when it is very fast at high speed.

T33: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option). (SCI. WAVE). Electrons and protons may maintain their position when they do not have sufficient energy. Or the electrons can make diffraction and interference according to the energy level (ALT. DIFFERENT)

As it can be seen from the answers given above, prospective teachers marked the correct answer, however, they associated the fact that the electrons and protons behave like waves in addition to the particle character, with the causes such as high speed, big mass, and energy level. Similar answers were observed from the other prospective teachers evaluated in this category (T13, T21, T31).

<u>Alternative:</u>

The prospective teachers were included in the "alternative" category when there are not any of the scientific concepts involved and there is more than one alternative concept involved. The prospective teachers evaluated in this category are T4, T7, T14, T15, T18, T26, T27, T28, T30, T32, T38, T39, T42, T44, T45 and T48. The examples of answers assessed in this category are submitted below.

T39: "Sometimes, electrons and protons may not have a measurable velocity, energy, and momentum (B option). (ALT. PROPERTY).We have heard of electromagnetic waves for years, I admit that there is an interaction, however, I do not know exactly what the cause is, my estimation is the speed of it (ALT. SPEED) because, if a particle does not have velocity, it can not create an electromagnetic wave. "

Similar answers were observed from the other prospective teachers from this category. When examining the preliminary interview data with the prospective teachers, it supports the results obtained from the concept test. The quotations obtained from the interviews with prospective teachers are submitted below.

A: In everyday life, we call things like electron-proton as particles. Lately, it became evident that these structures had a wave character in addition to the particle character. How do you explain this situation?

T44: Electron may be exhibiting, but not proton and neutron would not (ALT. ANOTHER)

When the above-mentioned quotations of interviews are examined, it appears that T44 cannot explain the wave structure of electrons and protons. T44 stated that the electron could exhibit these properties but proton could not exhibit the.

<u>From alternative division:</u>

If prospective teachers have one of the alternative concepts, then they are included in the "from alternative division" category. At the beginning of the training, the proportion of "from alternative division" answers is 10.4%. The prospective teachers evaluated in this category are T3, T5, T11, T22 and T46. In the answers assessed in this category, it appears that the prospective teachers marked A or B option from the wrong options, but they did not make any statements on the option marked by them.

When the answers in the "alternative" and "from alternative division" categories are examined, it has been observed that some of the prospective teachers think that electrons and protons have particle characteristic and that they cannot be in the wave structure. Some of the prospective teachers have associated this situation with the measurements, speed, and energy. When all the answers are examined, it can be said that the prospective teachers do not have "scientific" thought prior to the instruction. In none of the answers, prospective teachers mention the double slit experiment or the "de Broglie matter waves". It has rather been observed that prospective teachers have alternative thinking that "*Electrons and protons are particles and do not exhibit wave characteristics".*

<u>After the instruction:</u>

When the answers given by the prospective teachers to the questions from the conceptual test were examined after the instruction, it was observed that the answers were in the categories of "scientific", "from scientific division", "from scientific division and alternative", "from alternative division". When the answers given by the prospective teachers after the instruction, there were no answers from the categories of "scientific and alternative" and "alternative". When the answers of the prospective teachers are examined; while there was no answer in the "scientific" category prior to the instruction, it was observed that 18.8% of the answers after the instruction were "scientific". While the percentage of the prospective teachers who answered in the category of "from scientific division" was 27.1% prior to the instruction, it became 62.5% after the instruction.

<u>Scientific:</u>

The proportion of answers evaluated in the "scientific" category after the instruction was 18.8%. The prospective teachers evaluated in this category are T7, T17, T34, T40, T41, T43, T44, T45 and T46. T46 from these prospective teachers took part in "from alternative division" prior to the instruction, T7, T44 and T45 took part in "alternative", T17, 34, OT40, and T43 took part in "from scientific division and alternative" categories. An example of the answers in this category is given below.

T17: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option) (SCI. WAVE). They exhibit unique diffraction and interference properties of the waves. In the case of the Young double-slit experiment carried out by using an electron gun, the interference pattern was exhibited as waves (SCI. EXPERIMENT). This was first introduced by de Broglie (SCI. De BROGLIE)."

As it is seen from the quotation above, T17 structured the "from scientific division and alternative" thinking that he had prior to the instruction and after the instruction suggested that electrons could exhibit diffraction and interference effects.

From Scientific Division:

After the instruction, the number of prospective teachers in the "from scientific division" category is 30. An example of the answers in this category is given below.

T37: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option) (SCI. WAVE). In the double slit experiment, it makes diffraction and interference like a wave (SCI. EXPERIMENT)."

T32: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option) (SCI. WAVE). As we learned in the lecture, electrons and protons behaved like waves as well as they have particle character. We observed the diffraction of the electrons. We learned it also in the simulation (SCI. EXPERIMENT)."

T29: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option) (SCI. WAVE). Electrons and protons normally behave like particles. However, like from the simulation we watched during the lecture, they behave also like a wave (SCI. EXPERIMENT)."

T47: "Sometimes, electrons and protons exhibit diffraction and interference effects (c option) (SCI. WAVE). It was observed in the double slit experiment (Simulation) (SCI. EXPERIMENT)."

As a result of the interviews made with the prospective teachers after the instruction, it was observed that the answers of T47, T45 and T38 are in the "from scientific division" category. The quotations obtained from the interviews with prospective teachers are submitted below.

A: Nowadays, we assume that electrons and protons behave like waves alongside the particle character. How do you explain this situation?

T47: …… that is, each electron is accompanied by a wave (SCI. De BROGLIE)." That is to say, he thinks like night and day. He is performing experiments on them since the light has a dual structure. After all, in these experiments, in the double slit interference experiment, it exhibits wave characteristics when electron guns are used, they are very surprised when they exhibit interference and diffraction characteristics while they should have behaved like particles. Normally interference and diffraction are the properties of a wave, this makes a breakthrough (SCI. EXPERIMENT).

T45: I remember that. In this experiment we carried out, we sent the electrons in a single slit, we saw a single formation in the back, however, when we had a double slit, it exhibited an interference function, like a wave model. At first, I thought that the electron was only a particle, the double slit experiment I saw, the doctor you made us watch in the lecture, had quantum effect at this point (SCI. EXPERIMENT).

T38: Yes, well, ...there is a young experiment. The young experiment is normally performed with waves since it is performed with the waves, the fringes occurred when it was first performed, but when it was performed with the electrons in a single slit, the particle model was observed, but we also saw it in the simulation you made us watch. In the double slit experiment, this time the electrons exhibit wave, interference characteristics (SCI. EXPERIMENT) Thus, it is known that the electron has both particle and wave characteristics. Previously, it never occurred to me that something which is a particle could have a wave characteristic. Also, it would not come to my mind before that it became a wave from a double slit. It did not even come to my mind that they could pass through the double slit. I thought it would come back in the first simulation by hitting.

As it can be seen from the quoted texts above, the prospective teachers have touched on in-class activities in explaining the wave characteristic of electron and proton. It has been observed that the prospective teachers used experimental evidence while explaining the wave character of electrons and protons.

From scientific division and alternative:

When the answers given by the prospective teachers after the instruction is examined, the proportion of the answer from "from scientific division and alternative" category is 14.6%. The prospective teachers from this category are; T5, T12, T18, T23, T26, T28 and T39. T5 from the prospective teachers is placed in "from alternative division", T18, T26 and T28 are placed in the category of "alternative" prior to the instruction. Other prospective teachers were included in the "from scientific division and alternative" category at the prior to the instruction. The examples of answers from this category are submitted below.

T28: "c option. Sometimes, electrons and protons exhibit diffraction and interference effects. (SCI. WAVE). Electrons and protons can behave like waves and particle as well. In fact, every matter can behave like a wave and a particle. But since the momentum of matters having large masses is large, the wave structure is not observed (ALT. MASS)".

T39: "c option. Sometimes, electrons and protons exhibit diffraction and interference effects. (SCI. WAVE). Because the location, direction, momentum of the electron cannot be known, they are very small particles. Again, according to the events they are present, both characteristics are shown separately (ALT. MASS)".

In answers from this category, the students associated the fact that electron and proton do not exhibit wave structure, with mass.

<u>*From alternative division:*</u>

The proportion of "from alternative division" answers after the instruction is 4.2. The prospective teachers evaluated in this category are T22 and T27. While T22 was in the same category prior to the instruction, T27 was in the category of "alternative" prior to the instruction.

Descriptive statistics of the scores indicating the level of conceptual understanding of the students are shown in Table 2.

Table 2: Conceptual understanding levels of the prospective teachers

	N	Minimum	Maximum	Mean	Standard deviation
Pre-Test	48	.00	6.00	2.8125	2.14035
Post-Test	48	1.00	8.00	6.1458	1.90173

The arithmetic mean of the scores obtained from the answers given by the prospective teachers to the question is observed to be 2.8125 prior to the instruction and 6.1458 after the instruction. The scores obtained from the concept test prior to and after the instruction were entered into the SPSS 16.0 program, and the difference between the scores was examined using the "Wilcoxon Signed Rank Test from non-parametric tests". With the help of statistical data analysis, the results are presented in Table 3.

Table 3: Wilcoxon Signed Ranks Test Results for scores of "de Broglie; matter waves" subject prior to and after the instruction

Post-test- Pre-test	n	Rank mean	Rank Total	z	p
Negative rank	2	11.25	22.50	-5.534*	.00
Positive rank	42	23.04	967.50		
Equal	4				

*based on negative ranks

The results of the analysis show that there is a meaningful difference between the scores of the prospective teachers obtained from "de Broglie; matter wave" subject from conceptual test the prior to and after the instruction ($z = 5.534$, $p < .05$). When the mean and sum of the rank of the difference scores are taken into consideration, it is seen that this difference observed is favored by the positive rank, that is to say, the post-test score.

When the conceptual understanding level results of the prospective teachers relating "de Broglie: matter wave " subject was examined, in the pre-test, it was observed that seven teachers were found to be in the category of "no conceptual understanding ". After the instruction, one of these prospective teachers was evaluated as "from scientific division and alternative", while six of them were evaluated as "from scientific division". While five prospective teachers had a conceptual understanding level of "from alternative division" prior to the instruction, no change was observed in one of the prospective teachers, while two of them were evaluated as "from scientific division", one was evaluated as "scientific" and one was evaluated as "from scientific division and alternative" after the instruction. Prior to the instruction, the number of prospective teachers with conceptual meaning at "alternative" level is seventeen. After the instruction, four of these prospective teachers had a conceptual understanding at the level of "scientific", four at the level of "from scientific division" and three at the level of "from scientific division and alternative". When all these results are evaluated, it can be said that the conceptual understanding of the prospective teachers regarding "de Broglie; matter waves" has been taken place. In general, when all the sections are examined, it has been observed that the prospective teachers have more alternative concepts prior to the instruction and more scientific concepts after the instruction. In this process, besides instruction, the prospective teachers have not taken any place in a different application regarding the basic concepts of quantum physics. Therefore, it has been determined that the 7E learning model used in the research and the activities included in the 7E learning model are effective in conceptual understanding. Especially, within the framework of the activities based on the basic principles of the social constructivist approach, it was provided that the prospective teachers were able to structure their own concepts at every stage. It has been determined that the prospective teachers can identify similarities, differences, and relationships between the concepts in the social environment and that these concepts can be transferred to other environments and utilized in problem-solving.

Discussion and Conclusion

Within the scope of the study, relating "de Broglie; matter waves" subject, since the momentum of matters having large mass is large, the wave structure is not observed. It can be due to the fact that the electrons and protons have a small mass. The alternative concepts that "Electrons and protons are a particle and do not exhibit wave characteristics" have been obtained. Some of the prospective teachers have suggested that electrons and protons may exhibit wave characteristics due to their small mass. In the study, it was determined that the prospective teachers were aware of the dual structure of light but identified the electron as only a particle. Results we obtained are found to be consistent with the results of studies conducted by Olsen (2002) and Ejigu (2014). Olsen (2002) conducted his study with 236 high school students aged 18-19 years. As a result of the study, it was concluded that students do not understand the structure of photons and electrons and use the classical physics when explaining these concepts. In his study, Ejigu (2014) determined that the students speculated on wave-particle duality to be a feature of small particles and speculated further that the electron -being a small particle itself, with high speed, momentum, and energy- might thus demonstrate wave characteristics. In the study conducted by Akarsu, Coskun and Kariper (2011) in order to determine the level of the conceptual understanding, of quantum physics, of the university students, they concluded that the wave-particle dilemma continues to be a complex problem for students, and the dual structure of electrons is between the unknown points. In the study conducted by Ireson (1999) using quantum phenomenon interview in order to determine the opinions of the university students relating quantum physics concepts, the light is always a wave. It is observed that the result that "Electron is always a particle." came to the forefront. Mashhadi and Woolnough (1999) investigated in their study how high school students visualize the concepts of electrons and photons. It has been shown that there are a wide variety of non-scientific representations in students' minds. It has been determined that a large majority of the students think of the electron as a kind of particle and the photon as a bright spherical particle. In the study conducted by Eryilmaz and Sen (2010) with secondary school students, it has been determined that students could not learn the new concepts such as a photon, photoelectron and photoelectric phenomenon in a meaningful way. In their work, Yalcin and Emrahoglu (2017) investigated the transfer of modern physics topics to daily life and reached the conclusion that participants could not transfer the topic of matter waves to daily life.

When studies conducted at different levels of learning are examined, it can be concluded that the students define electrons as only particles. As a result of our research, it has been concluded that most of the prospective teachers define electrons and proton as particles. In their study of investigating the level of prior knowledge utilized while learning quantum physics, Fletcher and Johnson (1999) found out that the students tended to explain quantum physics with regard to their prior knowledge, and that they did not utilize newly learned information regarding the subject matter. It is known that, from primary education, the students meet with the concept of electrons until the university at various stages. However, there is information that, at most of these levels, electrons and protons are sub-atomic particles. Therefore, despite having learnt the material wave concept within the scope of quantum physics; the students made explanations based on their prior knowledge. Olsen (2002) suggested in his study that the students failed to thoroughly explain concepts of photons and electrons since they intended to explain the matter based on classical physics concepts and that knowledge of wave particle trait by itself was insufficient for them to explain such matters. As a result, all these alternative concepts may have been caused by previous the instruction processes.

Investigating studies found in the literature regarding quantum physics, it was observed that many of this reported failure of students regarding the subject (Bethge and Niedderer, 1995; Caliskan, 2002; Eryilmaz, 2014). In order for the students to wholly understand wave-particle duality, they first have to capture concepts of what a wave is and its related properties; what a particle is and its related properties; and concepts such as diffraction and interference (Steinberg et al., 1999). Considering the fact that quantum physics concepts are abstract; that the students are not able to transfer these concepts into their daily lives and even the students being able to make such transfers have non-scientific knowledge regarding the subject; it is expressly revealed that teaching materials are needed for teaching quantum physics. At this point, utilization of material that can effectively fulfill students' perceptions of alternative concepts and thus ensure conceptual change might make concepts more comprehensible. Students must especially be informed more on routine daily applications of quantum physics.

References

Akarsu, B., Coskun, H., & Kariper, A. I. (2011). An investigation on college students' conceptual understanding of quantum physics topics. *Journal of Mustafa Kemal University Institute of Social Sciences, 8*(15), 349–362.

Bybee, R. W. (2003). Why the seven E's. Retrieved June 6, 2008, from: http://www.miamisci.org/ph/lpintro7e.html.

Bethge, T., & Niedderer, H. (1995). Students' conceptions in quantum physics. Submitted to American Journal of Physics (AJP).

Caliskan, S. (2002). *Quantum physics lesson teaching programme proposal: Oscillator example* (Unpublished Master's Thesis). 9 Eylul University, Institute of Social Sciences, Izmir, Turkey.

Cepni, S. (2010). *Introduction to research and project studies* (Revised copy). Trabzon: Celepler Pressing.

Cohen, L. and Manian, L. (1994). *Research methods in education*. London: Routledge.

Cushing, T. J. (2003). *Philosophical concepts in physics-1.* Istanbul: Sabanci University Publications.

Eisenkraft, A. (2003). Expandingthe 5E model. *Science Teacher*, *70*(6), 56-59.

Ejigu, M. A. (2014). *An investigation into physics students' depictions of the basic concepts of quantum mechanics*, (Unpublished Doctoral Dissertation). University of South Africa, South Africa.

Eryilmaz, O. (2014). *Comparison of the learning status of high school modern physics subjects taught in line with two different teaching programs* (Unpublished Doctoral Dissertation). Hacettepe University, Ankara, Turkey.

Eryilmaz, O., & Sen, A. I. (2010). *Determination of concepts of 12th grade students of secondary education by concept maps relating modern physics*. IX. National Science and Mathematics Education Congress, Book of Abstracts, 36, Izmir.

Fletcher, J. (1997). *How students learn quantum mechanics* (Unpublished Master Thesis). University of Sydney, Australia.

Fletcher, P., & Johnson, I. (1999). Quantum mechanics: Exploring conceptual change. Paper present at the annual meeting of National Association for Research in Science Teaching. Retrieved March 22, 2010, from: https://jrm.phys.ksu.edu/papers/narst/QM_papers.pdf#page=22.

Hewitt-Taylor J. (2001). Use of the constant comparative analysis in qualitative research. *Art & Science Research Methods, 15*, 39–42.

Kothari, C. R. (2004). *Research methodogy methods and techniques* (Second Edition). New Delhi: New age International Publishers.

Mashadi, A., & Woolnough, B. (1999). Insights into students' understanding of quantum physics: visualizing quantum entities. *European Journal of Physics, 20*(6), 511-516.

Mcevoy, P. J., & Zarate, O. (2010). *Quantum theory* (N. Catli, Trans.). Istanbul: NTV Publications.

Ireson, G. (1999). A multivariate analysis of undergraduate physics students' conceptions of quantum phenomena. *Europen Journal of Physics*, *20*(3), 193-199.

Muller, R., & Wiesner, H. (1999). Students' conceptions of quantum physics. *Paper present at the annual meeting of National Association for Research in Science Teaching*. Retrieved September 15, 2010, from: https://jrm.phys.ksu.edu/papers/narst/QM_papers.pdf#page=22.

Olsen, R. V. (2001). Introduction quantum mechanics in the upper secondary school: A study in Norway. *International Journal of Science Education, 24*(6), 565-574.

Patton M. Q. (2014). *Qualitative research and evaluation methods* (M. Butun, S.B. Demir, Trans.). Ankara: Pegem Academy.

Sackes, M. (2010). *The role of cognitive, metacognitive, and motivational variables in conceptual change: preservice early childhood teachers' conceptual understanding of the cause of lunar phases* (Unpublished Doctoral Dissertation). *Graduate Program in Education, The Ohio State University,* The Ohio State, USA.

Steinberg, R. Wittman, M. C., Bao, L., & Redisch, E.F. (1999). The influence of student understanding of classical physics when learning quantum mechanics. *Paper present at the annual meeting of National Association for Research in Science Teaching*. Retrieved September 15, 2010, from: https://jrm.phys.ksu.edu/papers/narst/QM_papers.pdf#page=22.

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Preservice elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching, 39*(7), 633–655.

Trundle K., Atwood R., & Christopher J. (2006). Fourth grade elementary students' conceptions of standards based lunar concepts. *International Journal of Science Education*, *29*(5), 595-616.

Ucar, S. (2007). *Using inquiry-based instruction with web-based data archives to facilitate conceptual change about tides among preservice teachers* (Unpublished Doctoral Dissertation). Ohio State University, The Ohio State, USA.

Yalcin, O., & Emrahoglu, N. (2017). Examining the high school students' transfer levels of modern physics topics to daily life. *Pegem Education and Training Journal, 7(1),* 115-158.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.