Investigation of Mental Models of Turkish Pre-Service Physics Students for the Concept of "Spin"

Özgür ÖZCAN*

Suggested Citation:

Özcan, Ö. (2013). Investigation of mental models of Turkish pre-service physics students for the concept of "spin". *Egitim Arastirmalari-Eurasian Journal of Educational Research*, 52, 21-36.

Abstract

Problem Statement: Difficulties in the learning process usually emerge from the problem of mental representations constructed by students in their interactions with the world. This previous knowledge and these ideas are in contradiction with scientific facts, and are known as misconceptions or alternative ideas. Thus, an analysis of the mental models can provide very valuable information in understanding students' ideas and learning processes.

Purpose of Study: The present study aims to determine pre-service physics teachers' understanding of and difficulties with spin concept via mental models, which can be drawn from students' reasoning both at introductory and advanced levels.

Methods: In determining the participants, a purposeful sampling method was used so that the questions the study focuses on would be better illuminated. The qualitative data used in the study was gathered via interviews with the students. All of the interviews were conducted one on one by the researcher in the class environment.

Findings and Results: The data gathered through interviews were analyzed both qualitatively and quantitatively, and the mental models formed by students about the concept of spin were determined. The categories codified as "mental models" reflect the mental models of students concerning the concept of spin and were categorized as "quantum model," "classical model," and "without any model."

* Assoc. Prof. Dr., Hacettepe University, Faculty of Education, Ankara-Turkey, ozcano@hacettepe.edu.tr

Conclusions and Recommendations: As a result of this examination, it was seen that the students' models related to the concept of atom and the models related to the concept of spin show similarities. One of the main reasons for the occurrence of such similar thought processes was that students from both groups attribute classical meanings to these concepts (spin and atom). It was not by chance that students who know of the classical atom model (Bohr's atom model) also consider the concept of spin as the rotation of an object around its own axis. This case signifies to what extent their ideas about the structure of an atom is influenced by the atom models they learned in modern physics classes during their high school years. Therefore, it is necessary that the quantum model of atom is emphasized through modern atom theories and through the concept of probability, especially at the high school level, because the concept of probability is an important gateway that facilitates the transition from Bohr's atom model to the quantum atom model.

Keywords: mental models, modern physics, spin concept, Turkish pre-service physics students

Introduction

Modern physics includes special learning difficulties and unusual conceptions. Therefore, it is regarded as one of the most difficult subjects to learn for both students and teachers (Bao & Redish, 2002; Johnston, Crawford & Fletcher, 1998; Singh, 2001; Strnad, 1981; Styer, 1996). Learning difficulties, a weak level of comprehension of modern / quantum physics, and misconceptions related to this domain have been studied quite widely (Çataloğlu, 2002; Fischler & Lichtfeld, 1992; Ireson, 2000; Müller & Wiesner, 2002; Niedderer & Bethge, 1995; Şen, 2002; Özcan, Didiş & Taşar, 2009). According to the constructivist model, learning is an active and target – oriented process. Thus, previous knowledge of the students as to what kind of information is true and how to interpret it fundamentally affects the learning process. Also, previous knowledge of students related to physical concepts is not in agreement with scientific knowledge and leads to learning difficulties (Duit, 1995; Treagust, Duit & Nieswandt, 2000).

Difficulties usually emerge from the problem of mental representations constructed by students in their interactions with the world (Gentner, 1983; Greca & Moreira, 2000; Johnson-Laird, 1983). This previous knowledge and these ideas are in contradiction with scientific facts, and are known as misconceptions or alternative ideas. These types of studies introduce the term 'mental model' in science education. Therefore, Greca and Moreiro (2001) defined mental models as follows:

> Mental models are an internal representation, which acts out as a structural analogue of situations or processes. Its role is to account for the individuals' reasoning both when they try to understand discourse and when they try to explain and predict the physical world behavior. (p.108)

In other words, mental models are internal representations that act as the analogical structures of situations or processes. According to Greca and Moreira (2001), comprehension of a scientific theory necessitates the construction of mental models. Norman (1983), alternatively, points out that there is a simple and linear relationship between the conceptual model and the mental model. Thus, an analysis of the mental models can provide us with very valuable information in understanding students' feelings and learning processes (Park, 2006). If we want to teach students the concepts and qualities of the world that is composed of sub-atomic particles, we should avoid drawings and concepts based on classical physics laws that would make them construct wrong mental models or make comprehension difficult (Fischler & Lichtfeldt, 1992). Fischler and Lichtfeldt's approach to this can be summarized as follows:

1. Reference to classical physics should be avoided.
2. Bohr's model of the hydrogen atom should be avoided.
3. The teaching should focus on the properties of electrons.
4. The statistical interpretation of observed phenomena should be used, and dualistic descriptions avoided.
5. Heisenberg's uncertainty principle should be introduced at an early stage. (Fischler & Lichtfeldt, 1992, pp. 183-4).

A new teaching method has been developed based on the above-mentioned points by Fischler and Lichtfeldt (1992). It has been determined that students understand the concepts better with this new method. However, there are also several researchers completely opposed to this idea. Budde, Niedderer, Scott and Leach (2002a) claim that because Born's probability model does not correspond to the classical ideas they have constructed, the new model would not work. More importantly, they argue that this new teaching would trigger learning difficulties.

During the literature search on this subject there has been no indication or mention of student learning or learning difficulties related to the concept of spin. The present study aims to (a) determine pre-service physics teachers' understanding of and difficulties with the concept of spin via mental models that can be drawn from students' reasoning both at introductory and advanced levels, and (b) add to literature concerning students' misunderstanding of the concept of spin in quantum physics.

Method

Research Design

The survey method was used in the current study. Since the measurements were taken from groups at two different academic levels, this study is a cross – sectional study. Cross – sectional studies can be thought of as providing a 'snapshot' of a population at a particular point in time (Cohen, Manion & Morrison, 2007). In order to determine the mental models, semi-structured interviews were conducted with 24 introductory level students and with 25 advanced level students. As research findings, we summarized the students' responses to the concept of spin under three mental models according to the content analysis of the data gathered from the interviews.

Participants

The participants of this study consisted of students from two different academic levels: introductory level (IL) and advanced level (AL). All of these students came from different high schools that applied a common curriculum. In determining the participants, a purposeful sampling method was used so that the questions the study focused on would be better illuminated (Patton, 2002). To this end, 25 advanced level students, who successfully completed modern and quantum physics classes in which the concept of spin was comprehensively covered, were chosen for participation. All students in the advanced level group were those who had taken all of the modern physics, quantum physics, and statistical physics classes at the university level. The participants in this group consisted of 16 female and 9 male students between the ages of 21-24. Students in the introductory level had taken none of the modern physics, quantum physics, or statistical physics classes at the university level. Participants in this group consisted of 15 female and 9 male students between the ages of 17-19. All of the students in the introductory level had taken the modern physics class offered at the high school their senior year in which the Bohr atomic model was taught.

Data Collection and Analysis

The qualitative data used in the study was gathered via the interviews with the students. All of the interviews were conducted one on one by the researcher in the class environment. In order to prevent data loss, the interviews were recorded by an audio recorder. The average interview lasted 10-15 minutes. During the interviews, special attention was paid to make sure that the questions were clear and comprehensible, and the students were given enough time to answer the questions. Moreover, a pen and paper were provided for the students who wanted to draw.

Four tasks were established in order to study the students' ideas about the concept of spin (provided in Appendix). Since the study was conducted through interviews, in order to make the interviews more comprehensive, in some cases some of the questions were asked in various different forms without changing the content. In order to ensure the internal validity of the interview questions, two physics education researchers examined them and considered their appropriateness for grade level and the research aims.

Data gathered through the interviews were analyzed via the content analysis method, which is one of the qualitative research methods (Strauss & Corbin, 1990). By assessing the students' explanations of the concept of spin, categories were made. A series of coding procedures were developed in order to analyze the explanations made by the students. These codes are:

1. Classical Model: Explanations in which there are examples and drawings related to classical physics, given in order to explain the concept of spin.

   Example: Spin is the rotation of the particles around their own axis.

2. Quantum Model: Explanations in which there are drawings related to quantum physics and that use concepts of quantum physics in order to explain the concept of spin.

   Example: Spin is an intrinsic property of sub-atomic particles, or is a quantity that stems from the internal symmetry of particles.

3. Without any Model: Explanations that use concepts unrelated to the concepts of spin.

   Example: Spin is the charge of the electron or one of the quantum numbers.

By way of analyzing the explanations made by the students about the concept of spin, three different categories were formed, "complete understanding," "misunderstanding," and "no understanding." These understanding levels were taken into consideration as an element of the mental models. Taking these elements into consideration, the mental models of students were determined as "quantum model," "classical model," and without any model" according to the aforementioned coding rules. In order to prove qualitative research reliability, another physics education researcher was also asked to do the coding. A replication of the coding was done by this researcher and the agreement between results was over 90%.

Results

In this section, data gathered through interviews were analyzed both qualitatively and quantitatively, and the mental models formed by students about the concept of spin are given in Table 1. Moreover, English equivalents of Turkish words in the drawings made by the students during the interviews are given in parentheses. The categories codified as "mental models" that reflect the mental models of students about the concept of spin were determined as "quantum model," "classical model," and "without any model."

Students' Mental Models about the Concept of Spin

The comprehension levels of pre-service physics teachers who participated in the study and the models corresponding to their comprehension levels are given in Table 1. As can be seen in Table 1, all of the introductory level students have misunderstandings about the concept of spin.

Table 1

Pre-Service Physics Teachers' Mental Models of the Concept of Spin and Their Level of Comprehension

			Students(N)	
Mental Model	***Understanding level***	***Description***	N_{IL}	N_{AL}
Classical model	Misunderstanding	Spin is the rotation of the particles around their own axis.	18	6
Quantum model	Complete understanding	Spin is an intrinsic property of particles.	-	16
Without any model	No understanding	Spin is one of the quantum numbers.	4	1

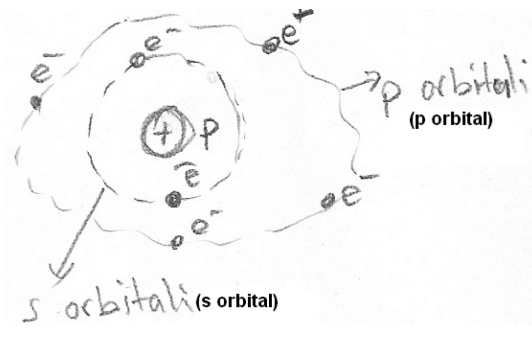
IL: Introductory level students, AL: Advanced level students

Classical model. The model they mentally created about the concept of spin was completely unscientific, and it merely consisted of explanations based on classical ideas. Almost all of the introductory level students (18 students out of 24) visualized the concept of spin as a "rotating" object. In all the drawings they made and the explanations they gave, they interpreted spin as a magnitude that is a result of the rotation of the electrons (or particles) around their own axis (Figure 2). Below are three examples of answers given by introductory level students:

Spin is the turning direction of particles such as electrons. It either gets the value of ½ or - ½. (five students)

It is the spinning movement of the electrons that are around an atom's nucleus. (nine students)

Spin is a movement that stems from the turning of a particle around its own axis like a circular motion. (four students)



(N_{IL}=16, N_{AL}= 2)

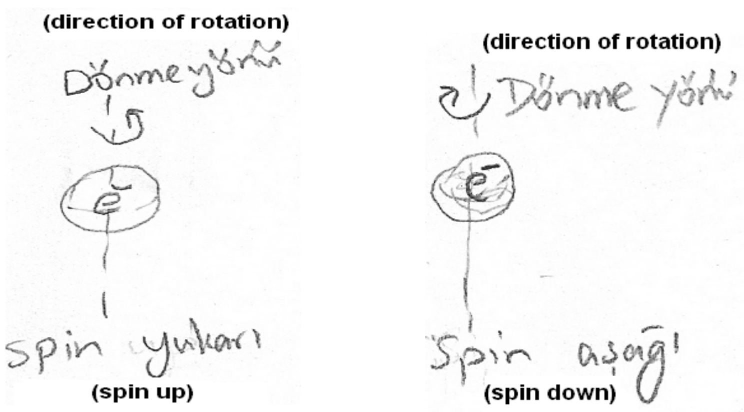
Figure 1. Diagrammatic descriptions of atomic structure drawn by introductory and advanced level students

Six of the advanced level students had a misunderstanding about the concept of spin. Moreover, these six students indicated that spin is a number without unit. Noteworthy expressions drawn from the interviews made by these students are as follows:

> *Spin is the orientation movement of the electron on the axis. It can be thought of as the orientation of the vector in positive and negative directions. It becomes a positive for the upward orientation, and it becomes a negative for the downward orientation. (four students)*

> *An electron turns around both its own axis and the atom. Spin results from its movement around its axis. (two students)*

The atom model in the minds of the students who define the concept of spin as the turning movement of the electrons around their own axis is the atom model given in Figure 1. During the interview, a question related to the atom model was deliberately asked by the researcher. The aim in asking this question was to understand whether or not the mental models of students who define spin as a turning movement was indeed a classical atomic model. The atomic model drawn by 16 out of 18 students who have a classical model for the concept of spin was similar to the atomic model provided in Figure 1. Moreover, all of the introductory level students indicated that the spin value of an electron is a dimensionless number and that it cannot have a unit.



(N_{IL}=18, N_{AL}= 6)

Figure 2. Drawings of introductory and advanced level students for the concept of spin

Quantum model. The explanations given by 16 advanced level students were codified as "quantum model," because all of these students defined the concept of spin as a magnitude stemming from the intrinsic property of the matter. It was observed that the quantum model was dominant in the drawings and the atomic model of students who indicated that the concept of spin has no correspondence in classical physics (Figure 3 and 4). There is a consistent correlation between the atomic models of these students and their explanations about the concept of spin. Almost all of the advanced level students used "quantum theory" for explaining the atomic structure in their drawings. As can be seen in Figures 3 and 4, advanced level students explained the s and p orbitals by using the concept of probability in their drawings. These students easily stated that spin cannot be a quantity related to the movement of rotation since they thought that orbitals represent a volume of space where electrons are most likely to be found. Therefore, they defined spin as "a magnitude stemming from the intrinsic property of the matter" and as something that cannot be found in classical physics. Advanced levels students, who have a different atomic structure in their minds than that of the introductory level students, were therefore able to develop a scientific model related to the concept of spin. Some examples from the explanations made by advanced level students are given below:

> *Spin is a magnitude that cannot be explained by classical physics laws and stems from the intrinsic property of the matter. (five students)*
>
> *They [Spin] are the orientation within the magnetic field. Spin orientations are either in the opposite direction to the magnetic field or are the same. As far as I know, these orientations are not like those in classical physics, it is like symmetry. (nine students)*

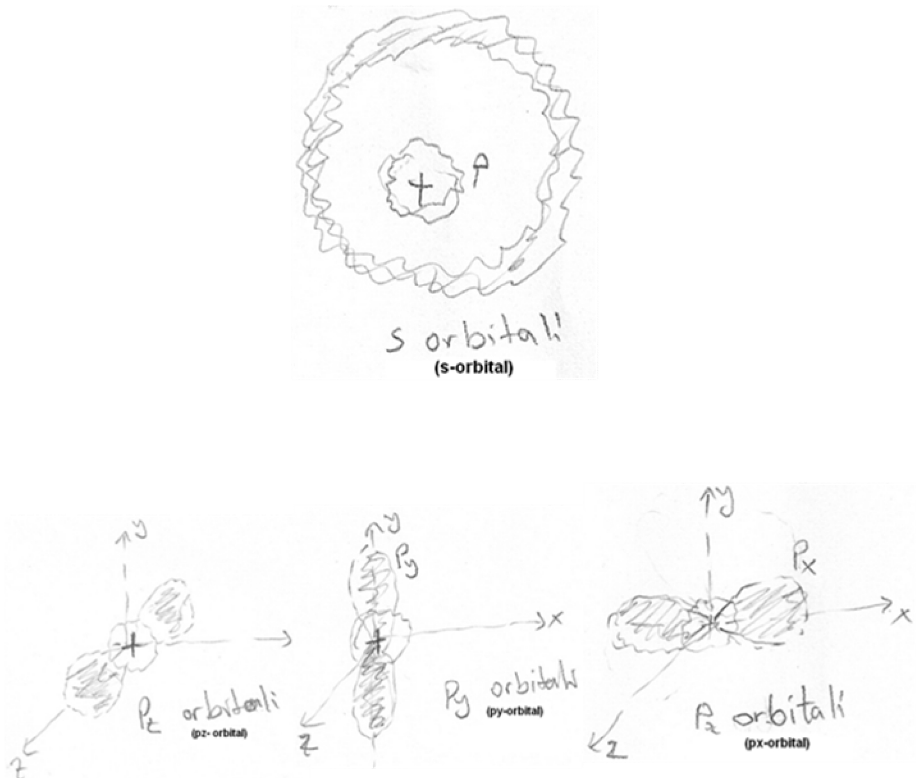


Figure 3. Advanced level students' atomic structure with s and p orbitals

As can be seen in Table 1, none of the students at the introductory level could provide a scientific explanation to the concept of spin. Eight out of sixteen advanced level students stated that the unit of spin is the Planck constant, and eight stated that it is a dimensionless magnitude.

Without any model. As a result of the gathered data, all explanations that were not related to the concept of spin were collected under this model. Four introductory level students and one advanced level student were in this group. Some of the explanations made by the students are given below:

> *Spin refers to dimension. In classical physics, it correspondence to the x and y coordinates. (one introductory level student)*
>
> *Spin is the incident of an electron losing its energy in time and falling on the core. This incident is known as spin, and therefore, we cannot talk about a unit. (three introductory level students)*
>
> *Spin is one of the quantum numbers of the electron. It is signified by "s," and is dimensionless. (one advanced level student)*

As can be seen in the examples above, during the interviews students gave incomprehensible examples and explanations related to the concept of spin. Indeed, students indicated that they found the modern physics class interesting, but that since they did not have the chance to observe and process these magnitudes it was difficult for them to learn.

Discussion and Conclusion

In this study, the mental models pre-service teachers use while making explanations about the concept of spin, which has a highly important place in modern physics, were determined. As a result, students used three mental models while explaining the concept of spin. Most of the students tried to explain the concept of spin by likening it to the rotation of an object around its own axis. As a result of the analysis of the obtained data, it was seen that both groups (introductory level and advanced level) have different explanations for the concept of spin which is one of the most important concepts of modern and quantum physics. Almost all of the students at the introductory level (18 out of 24 students) consider the concept of spin as a quantity that result from the rotation of particles (electrons) around their own axis. This analogy, which is used in order to easily visualize the concept of spin in our minds, was perceived as a real incident by most of the introductory level students. Thus, it caused many misunderstandings. Trying to understand the world of subatomic particles by way of analogies usually leads conceptual confusion of students or it may cause them develop alternative concepts. This may lead them to perceive non-scientific knowledge or things that clash with scientific knowledge as real. Evidently, most of the introductory level students in this study chose to explain the concept of spin by attributing a classical meaning to it, such as trying to explain it by the rotation of an object around its own axis. Indeed, thinking of the concept of spin as a rotation of the electrons or atoms around their own axis would make it easy to understand. However, if we make an attribution to this situation beyond analogy it would hinder meaningful learning and lead to incorrect models in the students' minds.

The reasons for these incorrect mental models found in the results of the study may originate from a variety of sources, such as students' preconceptions learned in high school or textbooks written on this subject. In some of the textbooks written by Turkish and foreign authors, the concept of spin has been defined by such expressions as "a kind of internal angular momentum" (Bernstein, Fishbane & Gasiorowicz, 2000), "angular momentum" (Feynman, 1965), and "the rotation of the electron around its own axis" (Aygün & Zengin, 1998). Because the first two of these expressions are about the magnitude that is revealed from the rotation of an object in classical physics, using them to explain spin may be misleading for students and may trigger the formation of incorrect models. The expression used by Aygün and Zengin (1998) is completely incorrect, and is an expression that contradicts the special theory of relativity (Barnett, Mühry & Quinn, 2000; Dereli & Vercin, 1999) because the angular momentum in classical physics is equal to the sum of the angular momentums of all particles constructing the solid body with respect to the rotation axis. Such an analogy for the concept of spin cannot be made. The rotation speed of the electron would exceed the speed of light if we imagine the electron as a "ball" or a "cloud" of electrical charge that rotates around the atomic nucleus. Even if we assume that the whole charge is located in a thin ring around the 'equator', the angular momentum would be far too low to explain the experimentally observed spin of the electron.

These contradictory expressions in the textbooks cause dilemmas and confusion about the concepts in students' minds. Under the light of the suggestions made by educators who have noticed this problem, some improvements were made in the textbooks of The Turkish Ministry of National Education (2008). With the changes in the high school curriculum, modern atom theory has been expanded in the 11th graders' physics program, and the clear, comprehensible, and scientific expressions related to the concept of spin were thoroughly examined.

In order to clear the doubts of these students, educators should be very careful when teaching this concept, and they should be careful with each expression they use related to this concept. While explaining this concept, educators should especially avoid using such concepts as "spin angular momentum" and "rotation." Should they use "rotation," students might continue perceiving the concept of spin as a magnitude resulting from the rotation of the electron around its own axis. A possible explanation for this behavior of the electron can be the concept of "magnetic moments." Thus, expressions such as "in the direction of the magnetic field" or "in the opposite direction to the magnetic field" may prevent the formation of the idea of "rotation" in students' minds, and thus a meaningful learning may take place.

Conclusion

The results of the current study may not present absolute or generalizable results. However, the result of this study about the concept of spin includes some examples that may pave the way for future studies, and it may be helpful for teachers/educators in teaching the concept of spin both in the high school (introductory level) level and in advanced level courses. With this study, mental models created both by introductory level and advanced level students related to the concept of spin were put forth. In order to highlight the root of these models, the atomic structure in the students' minds from both groups were also examined. As a result of this examination, it was seen that the students' models related to the concept of atom and models related to the concept of spin show similarities. One of the main reasons for the occurrence of such similar thought processes was that students from both groups attribute classical meanings to these concepts (spin and atom). It was not by chance that students who have a classical atom model (Bohr's atom model) also consider the concept of spin as the rotation of an object around its own axis. This case signifies to what extent their ideas about the structure of an atom is influenced by the atom models they learned in modern physics classes during their high school years. Therefore, it is necessary that the quantum model of an atom is emphasized through modern atom theories and through the concept of probability, especially at the high school level, because the concept of probability is an important gateway that facilitates the transition from Bohr's atom model to the quantum atom model (Park & Light, 2009). The concept of probability has a function that would get rid of the obstacle in front of students' understanding of the atomic structure.

This study provides some evidence of the pre-service physics teachers' understanding of the spin concept in quantum physics and the models that they used in explaining the concept. Thus, the models and expressions determined in this study about the concept of spin are such that they can be a source for further studies. Studies that include a wide number of participants would put forth the mental models of students, the alternative concepts, and the learning difficulties in a more comprehensive way. Moreover, whether or not students have similar or different mental models about the concept of spin may be researched with studies done in other countries that have different education systems. Researches of this nature would provide researchers the opportunity to compare the results on an international scale.

Appendix

1. What can you say about your conceptions of spin?
   Explain:
2. Try to draw your mental image of the concept of spin?
   Explain:
3. Does spin have a unit like the qualities as velocity, acceleration and mass?
   Explain:
4. Try to draw a picture of an atom. Write down any necessary explanations next to the picture.
   Explain:

References

Aygün, E., & Zengin, M. (1998). *Kuantum Fiziği [Quantum Physics].* Ankara: Barışcan Ofset Ltd. Şti.

Bao, L., & Redish, E. F. (2002). Understanding probabilistic interpretation of physical systems: A prerequisite to learning quantum physics. *American Journal of Physics,* 70(3), 210-217.

Barnett, M. R., Mühry, H., & Quinn, H. R. (2000). *The Charm of Strange Quarks – Mysteriesand Revolutions of Particle Physics*. New York: Springer.

Bernstein, J., Fishbane, P. M., & Gasiorowicz, S. (2000). *Modern Physics*. Prentice-Hall USA.

Budde, M., Niedderer, H., Scott, P., & Leach, J. (2002). "Electronium": a quantum atomic teaching model. *Physics Education*, 37(3), 197-203.

Çataloğlu, E., & Robinett, R. W. (2002). Testing the development of student conceptual and visualization understanding in quantum mechanics through the undergraduate career. *American Journal of Physics,* 70(3), 238-251.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education (6th Edition).* New York: Routledge.

Dereli, T., & Verçin, A. (2000). *Kuantum Mekaniği 2 [Quantum Mechanics 2]*. Ankara: Metu Press.

Duit, R. (1995). Vorstellungen und Lernen von Physik und Chemie. Zu den Ursachen vieler Lernschwierigkeiten. *PLUS LUCIS. Verein zur Förderung des Physikalischen und Chemischen Unterrichts*, 2, 11-18.

Duit, R., & Treagust, D. F. (1995). Students' conceptions and constructivist teaching approaches In B. J. Fraser, & H. J. Walberg (Eds.). *Improving Science Education*. Chicago: The University of Chicago Press, 46–69.

Feynman, R. Leighton, R., & Sands, M. (1963–1965). *The Feynman Lectures on Physics*. ReadingMA: Addison-Wesley.

Fischler, H., & Lichtfeldt, M. (1992). Modern physics and students' conceptions.*International Journal of Science Education,* 14(2), 181-190.

Gentner, D. (1983). Structure-mapping A theoretical framework for analogy. *Cognitive Science,* 7(2), 155-170.

Greca, I. M., & Moreıra, M. A. (2000). Mental Models, Conceptual Models and Modeling. *International Journal of Science Education,* 22(1), 1–11.

Greca, I. M. & Moreira, M. A. (2001). Mental, physical, and Mathematical Models in the Teaching and Learning of Physics. *Science Education,* 86(1), 106–121.

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

Johnson-Laird, P. N. (1983). *Mental Models: Toward a Cognitive Science of Language Inference and Consciousness*. Harvard University Press.

Johnston, I. D., Crawford, K., & Fletcher, P. R. (1998). Student difficulties in learning quantum mechanics. *International Journal of Science Education,* 20(4), 427-446.

Müller, R., & Wiesner, H. (2002). Teaching quantum mechanics on an introductory level. *American Journal of Physics,* 70(3), 200-209.

Niedderer, H., & Bethge, T. (1995). Students' conceptions in quantum physics. Retrieved from http://www.idn.uni-bremen.de/pubs/Niedderer/1995-AJP-TBHN.pdf.

Norman, D. A. (1983). Some observations on mental models, In D. A. Gentner & A .L. Stevens (ed)., *Mental Models:* Lawrence Erlbaum Hillsdale NJ.

Park, E. J. (2006). *Student Perception and Conceptual Development as Represented by Student Mental Models of Atomic Structure*. Published doctoral thesis. The Ohio State University.

Park, E. J., & Light, G. (2009). Identifying Atomic Structure as a Threshold Concept: Student mental models and troublesomeness. *International Journal of Science Education,* 31(2), 233-258.

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. USA: Sage Publication.

Şen, A. I. (2002). Concept Maps as a Research and Evaluation Tool to Asses Conceptual Change in Quantum Physics. *Science Education International*, 13(4), 14–24.

Singh, C. (2001). Student understanding of quantum mechanics. *American Journal of Physics*, 69(8), 885-896.

Strauss, A. L., & Corbin, J. (1990). *Basic of qualitative research: Grounded theory procedures and techniques*. Newbury Park CA: Sage.

Strnad, J. (1981). Quantum physics for beginners. *Physics Education*, 16(2), 88-92.

Styer, D. F. (1996). Common misconceptions regarding quantum mechanics. *American Journal of Physics*, 64(1), 31-34.

Treagust, D., Duit, R., & Nieswandt, M. (2000). Sources of students' difficulties in learning Chemistry. *Educación Química*, 11(2), 228-235.

Turkish Ministry of National Education. (2008). Retrieved on March 20 2011 from http://www.fizikprogrami.com.

Fizik Öğretmeni Adaylarının Spin Kavramına Yönelik Zihinsel Modellerinin Araştırılması

Atıf:

Özcan, Ö. (2013). Investigation of mental models of Turkish pre-service physics students for the concept of "spin". *Egitim Arastirmalari-Eurasian Journal of Educational Research*, 52, 21-36.

Özet

Problem Durumu: Öğrencilere atom altı parçacıklardan oluşan dünyanın özelliklerini ve kavramlarını öğretmek istiyorsak, onların öğrenmelerini zorlaştıracak veya zihinlerinde yanlış modeller oluşturmalarını sağlayacak klasik fizik yasalarını temel olan çizimlerden ve kavramlardan kaçınmamız gerekir. Öğrenciler, günlük yaşantıları yoluyla geliştirmiş oldukları ön kavramlara sahip olarak sınıf ortamına gelirler. Çoğu zaman bilimsel gerçeklerle çelişen bu düşünceler kavram yanılgıları olarak ifade edilir. Öğrencilerin sahip oldukları kavramlar ile derslerde öğrendikleri yeni kavramlar arasında bir bağ oluşturulmalı ve yanlış kavramlarının doğru olanlarla değiştirilmesi öğretim sürecinde desteklenmelidir. Bu nedenle fizik eğitimi araştırmacılarının öğrencilerin yaşadıkları makro çevre ile ilgili sezgisel algılarına

odaklanarak bu algıları tanımlamak ve algıların atom altı parçacıklardan oluşan dünya için geçerlik sınırlarını etraflıca ortaya koymaları önemlidir.

Farklı tipteki öğrenci zorlukları arasında, yapılandırılmış bilişsel kavramlar veya zihinsel model kaynaklı araştırmalar fizik eğitimcilerinin ilgiyle çalıştıkları konulardır. Zihinsel modeller, öğrencilerin değişik bilimsel kavram ve fikirleri betimleme yollarını ortaya koymak için yapılan fizik eğitimi araştırmalarının odak noktasını oluşturmuştur. Atom altı parçacıklardan oluşan mikroskobik dünyanın soyut doğasından dolayı, öğrencilerin atomun yapısıyla ilgili zihinsel modellerin ve anlama düzeylerinin araştırılması fizik eğitimi alanında oldukça önemli bir yere sahiptir. Alan yazında oldukça yoğun çalışılmış olan atomun yapısıyla ilgili araştırmaların aksine bu çalışma da yine atomun yapısı kadar önemli ve önce ki araştırmalarda hiç çalışılmamış bir kavram olan spin kavramı ile ilgili öğrencilerin zihinlerinde oluşturdukları modellerin neler olduğu sorusuna cevap aranmıştır.

Araştırmanın Amacı: Konuyla ilgili yapılan literatür araştırmasında öğrencilerin spin kavramıyla ilgili zihinsel modelleri ve bu kavramla ilgili öğrenme zorluklarına rastlanmamıştır. Bu noktadan hareketle yapılan bu çalışmada amaç (a) üniversite birinci sınıfta eğitim gören fizik öğretmen adayları ile üniversite üçüncü sınıfta eğitim gören fizik öğretmen adaylarının spin kavramına yönelik geliştirdikleri zihinsel modelleri tespit etmek ve bu kavrama yönelik alternatif kavramlarını ortaya koymak ve (b) kuantum fiziğinde önemli bir yere sahip olan bu kavramla ilgili öğrencilerin sahip oldukları yanlış anlamaları alan yazına kazandırmaktır.

Araştırmanın Yöntemi: Öğrencilerin spin kavramına yönelik zihinsel modellerini belirleyebilmek için üniversite birinci sınıfta öğrenim gören 24 ve üniversite üçüncü sınıfta öğrenim gören 25 öğretmen adayı ile yarı yapılandırılmış görüşmeler gerçekleştirilmiştir. Görüşmeler yoluyla toplanan nitel verilerin analizi neticesinde öğretmen adaylarının spin kavramına yönelik zihinsel modelleri üç temel model altında toplanmıştır.

Araştırmanın Bulguları: Yarı yapılandırılmış görüşmeler yoluyla toplanan veriler hem nicel hem de nitel olarak analiz edilmiş ve öğrencilerin spin kavramına yönelik zihinlerinde oluşturdukları modeller tespit edilmiştir. Ayrıca görüşme esnasında öğrenciler tarafından yapılan çizimlerde yer alan Türkçe kelimelerin parantez içinde İngilizce karşılıkları da verilmiştir. Öğrencilerin spin kavramıyla ilgili zihinsel modellerini yansıtan ve 'Zihinsel Model' olarak kodlanan kategoriler 'klasik model', 'kuantum model', ve 'modelsiz' olarak belirlenmiştir.

'Klasik model' olarak kodlanan bu modelde öğrencilerin spin kavramına yönelik zihinlerinde oluşturdukları model tamamen bilimsel modelden uzak ve klasik fikirleri temel alan açıklamalardan ibarettir. Çünkü üniversite birinci sınıf öğrencilerinin büyük çoğunluğu (24 öğrenciden 18'i) spin kavramını zihinlerinde dönen bir cisim olarak canlandırmışlardır. Yaptıkları çizimler ve açıklamaların tamamında, spin'i parçacıkların (elektron) kendi eksenleri etrafında dönmelerinin bir sonucu olarak ortaya çıkan bir büyüklük olarak yorumlamışlardır.

Üçüncü sınıfta bulunan 16 öğrenci tarafından spin kavramı ile ilgili yapılan açıklamalar "kuantum model" olarak kodlanmıştır. Çünkü bu öğrencilerin tamamı spin kavramını maddenin iç simetrisinden (intrinsic property) kaynaklanan bir büyüklük olarak tanımlamışlardır. Spinin klasik fizikte bir karşılığının olmadığını belirten öğrencilerin yaptığı atom modeli çizimlerinde, kuantum atom modelinin baskın olduğu görülmektedir. Bu öğrencilerin zihinlerindeki atom modeli ile spin kavramı hakkında yaptıkları açıklamalar arasında tutarlı bir ilişki vardır. Bu öğrencilerin tamamına yakın kısmı çizimlerinde olasılıkçı düşünce biçiminin etkilerini ortaya koymuşlardır.

Herhangi bir model altında toplanamayan ve 'modelsiz' olarak kodlanan bu kategoride dört birinci sınıf ve bir de üçüncü sınıf öğrencisi bulunmaktadır. Yapılan görüşmeler boyunca öğrenciler spin kavramını anlamsız örnekler ve açıklamalar kullanarak betimlemeye çalışmışlardır. Aslında öğrenciler görüşme sırasında modern fizik dersini ilginç bulduklarını, ancak günlük yaşamda bu büyüklükleri gözlemleme şansları olmadığı için özümsemelerinin ve öğrenmelerinin zor olduğunu belirtmişlerdir.

Sonuç ve Öneriler: Bu araştırma ile hem birinci sınıf hem de üçüncü sınıf fizik öğretmen adaylarının zihinlerinde spin kavramına yönelik oluşturdukları modeller ortaya konmuştur. Spin kavramına yönelik bu modellerin kaynağına ışık tutması açısından her iki gruptan öğrencilerin zihinlerindeki atom modelleri de incelenmiştir. Bu inceleme neticesinde öğrencilerin atom kavramına yönelik modelleri ile spin kavramına yönelik modelleri arasındaki paralellik oldukça ilginçtir. Bu benzer düşünme biçiminin ortaya çıkmasının başlıca nedeni her iki gruptan öğrencilerin iki kavrama da (spin ve atom) klasik anlamlar yüklemeleridir. Öğrencilerin yaptıkları çizimlerde, klasik atom modeli (Bohr atom modeli) fikrine sahip olanların spin kavramını da bir dönme hareketinden ibaret görmeleri tesadüf değildir. Bu durum lisede aldıkları modern fizik dersindeki atom modellerinin öğrencilerin atomun yapısıyla ilgili düşüncelerini önemli ölçüde etkilediğinin bir göstergesidir. Bu nedenle özellikle lise düzeyinde modern atom teorileri ve olasılık kavramı yoluyla atomun kuantum modeline ağırlık verilmesi gerekmektedir. Çünkü Bohr atom modelinden quantum atom modeline geçişi kolaylaştırabilecek önemli bir geçit olasılık kavramıdır. Olasılık kavramı öğrencilerin atomik yapıyı anlamalarının önündeki engeli kaldırabilecek bir işleve sahiptir.

Çalışma sonunda spin kavramıyla ilgili belirlenen modeller ve tanımlamalar bundan sonra yapılacak olan diğer çalışmalara da kaynak oluşturacak niteliktedir. Geniş öğrenci gruplarının katılımıyla yapılacak olan araştırmalar, öğrencilerin bu kavramlarla ilgili zihinlerinde oluşturdukları modelleri, alternatif kavramları ve öğrenme zorluklarını daha etraflıca ortaya koyacaktır. Ayrıca farklı eğitim sistemine sahip başka ülkelerde yapılacak olan spin kavramıyla ilgili araştırmalarla, öğrencilerin zihinlerinde benzer veya farklı modellerin olup olmadığı ve zihinsel modellerdeki değişimler araştırılabilir. Bu bağlamda yapılacak olan araştırmalar hem fizik eğitimi alanına katkı sağlayacak nitelikte olur hem de araştırmacılara sonuçları uluslararası düzeyde karşılaştırma fırsatı verir.

Anahtar Sözcükler: Zihinsel modeller, modern fizik, spin kavramı, fizik öğretmen adayları