Available online at www.sciencedirect.com

ScienceDirect

Procedia Social and Behavioral Sciences 15 (2011) 1372–1375

Procedia Social and Behavioral Sciences

WCES-2011

What are the students' mental models about the "spin" and "photon" concepts in modern physics?

Özgür Özcan [a] *

[a]Hacettepe University, Department of Secondary Science and Mathematics Education Beytepe, Ankara, 06800, Turkey

Abstract

Modern physics includes special learning difficulties and unusual conceptions. Because of this reason, it has been regarded as one of the most difficult subject to learn for both students and teachers. The present study aims to determine the mental models which can be drawn from students' reasoning about photon and spin concepts. In this study, semi-structured interviews were conducted with 25 pre-service physics teachers to determine their mental models about photon and spin concepts. The participants of this study consist of 15 female and 10 male students and they ranged from 22 to 24 years of age. All of the interviews were performed one to one by the researcher in class environment. As research findings we summarized students' responses to these concepts under three mental models.

Keywords: Modern physcis, quantum physcis, mental models, pre-service phycics teachers;

1. Introduction

Modern physics includes special learning difficulties and unusual conceptions. Because of this reason, it has been regarded as one of the most difficult subject to learn for both students and teachers (Bao&Redish, 2002; Johnston, Crawford & Fletcher, 1998). Learning difficulties, the weak level of the understanding of quantum mechanics and misconceptions related to this domain have been studied quite widely (Fischer & Lichtfeld, 1992; Müler & Wiesner, 1999). According to the constructivist model the learning is an active and target- oriented process. Thus, the previous knowledge of the students what kind of the information is true and how to interpret it affects fundamentally to the learning process. Also the previous knowledge of the students related to the physical concepts is not in agreement with the scientific knowledge and it leads to the learning difficulties (Duit, 1995; Treagust, Duit & Nieswandt, 2000). The difficulties usually emerge from the problem of mental representations constructed by students in their interactions with the world (Gentner 1983; Greca and Moreira, 2000; Johnson-Laird, 1983). These previous knowledge and ideas are contradictory to scientific facts which are known misconceptions or alternative ideas. This type of studies introduce the 'mental model' term in science education (Çepni & Keleş, 2006). In this study, semi-structured interviews were conducted with 25 pre-service physics teachers to determine their mental

* Özgür Özcan. Tel.: +90-312-2978615; fax: +90-312-2978600.
E-mail address: ozcano@hacettepe.edu.tr.

1877–0428
doi:10.1016/j.sbspro.2011.03.295

models about photon and spin concepts. As research findings we summarized students' responses to these concepts under three mental models.

The present study aims to determine the mental models which can be drawn from students' reasoning about photon and spin concepts.

2. Method

2.1. Participants

In this study, purposeful sampling method was used. The use of purposeful sampling method enables a thorough study of the richly informative situations, thus, the questions which this study focuses on would be better enlightened (Patton, 2002). So, 25 pre-service physics teachers, who have completed modern physics and quantum physics classes in which photon and spin concepts were explained in detail, were selected. The participants consist of 15 female and 10 male students and they ranged from 22 to 24 years of age.

2.2. Data Collection and Analysis

The qualitative data used in the study was gathered with the help of the interviews done with the students. All of the interviews were performed one to one by the researcher in class environment. In order to prevent data loss, the interviews were recorded by a tape recorder. The average time of interviews was 15-20 minutes.

Data gathered via interviews were analyzed according to content analysis method, which is one of the qualitative research methods (Strauss & Corbin, 1990). Having evaluated the explanations made by the students in relation to the concepts of photon and spin, categories were formed. Three different mental models were determined in relation to the concept of photon. In determining these models, the following criteria were taken into consideration:

Wave model (WM): This model includes the wave properties of the photon.
Example: Photon is an electromagnetic wave and it travels in waves.
Particle model (PM): This model includes the particle properties of the photon.
Example: Photon is a particle which has quantized energy values.
Wave-particle model (WPM): Photon is either waves or particles depending on the experiment or the observation.
Example: Photon sometimes behaves like a particle and sometimes like a wave.

At the end of the explanations made on the concept of spin, three categories were constituted, namely, "complete understanding," "incomplete understanding," and "misunderstanding." According to these constituted categories, mental models of students related to the concept of spin were determined as "the quantum model" and "the classical model." In order to secure qualitative research reliability, these analyses were repeated two months later. The reliability coefficient between these two analyses was determined as 0.95.

3. Results

In this part, data gathered via interviews were qualitatively analyzed, and the mental models of students related to the concepts of photon and spin were given in Table 1 and Table 2, respectively.

3.1. Students' mental models related to the concept of photon.

In this study, three scientific models were used to determine the mental models of students in relation to the concept of photon. These models and the descriptions of students related to the concept of photon were given in Table 1. According to this table, 15 of the pre-service physics teachers used the wave model to explain the photon.

On the other hand, six of the pre-service physics teachers used the particle model while four of them used the wave-particle model.

Table 1. Pre-service physics teachers' models of photon concept identified from interview responses

Scientific Model	Description	No. of Students
Wave model	Photon is wave. Photons can move in waves.	15
Particle model	Photon is a particle and it has quantized energy values. Photons are particles with definite energy. Photon is a particle but it has some wave properties.	6
Wave-particle model	Photon is a particle but it has some wave properties at the same time. Photons consist of two parts; a wave part and particle part. Some experiments in physics can be explained by a wave model and other by a particle model of photon.	4

According to the table, a great number of the students explained the concept of photon by using the wave model. The reason for this is that in textbooks and in classes, the concept of photon is often explained by highlighting its wave quality. An excerpt from the interviews done with the students explicitly puts forth this fact:

Researcher (R): What is photon? Could you explain it?

Student 3 (S3): Photon is an electromagnetic wave. I mean, it has wave quality because a photon is a particle without a mass.

According to the interview excerpt taken from the done with S3, photon is a wave. In other words, photon always behaves like a wave, and because it does not have a mass, it does not behave like a particle.

3.2. Students' mental models on the concept of spin

The comprehension levels of the pre- service physics teachers in relation to the concept of spin and the models corresponding to these levels were provided in Table 2.

Table 2. Pre-service physics teachers' mental models of spin concept and understanding level

Scientific Model	Understanding level	Description	No. of Students
Quantum model	Complete understanding	Spin is a intrinsic property of particles.	6
Classical model	Misunderstanding	Spin is the rotation of the particles around their own axis.	14
Without any model	Incomplete understanding	Spin is a one of the quantum numbers.	5

The categories which reflect the mental models of students in relation to the concept of spin and which are also coded as the "scientific model" were determined as "the quantum model," "the classical model," and "without any model." Only six of the participants used the quantum model to explain the concept of spin. Fourteen out of 25 pre-service physics teachers, on the other hand, tried to explain the concept of spin by likening it to an object's turning around its own axis. Some of the excerpts from the interviews done with the students are as follows:

S5: Spin is the turning direction of particles such as electrons and photons.

S7: It is the spinning movement of the electrons which are around an atom's nucleus.

S11: Spin is a movement which stems from turning of particle around its own axis.

As can be seen from the excerpts, most of the students tried to explain the concept of spin by associating it to an object which is turning around its own axis. This analogy which was used to make the mental visualization easier was taken as a real situation by the students. Therefore, it caused a misunderstanding in relation to the concept of spin. Trying to understand the world of subatomic particles by using analogies usually causes misunderstandings, and it leads to one to perceive a non-real situation as real. To think of the concept of spin as atoms' or electrons'

turning around their own axis evidently helps comprehension. However, thinking of them as more than analogies would hinder meaningful learning, and it would cause wrong models to form in the minds.

4. Discussion and Conclusion

In this study, which mental models pre-service physics teachers use when explaining related to the concepts of spin and photon, which have an important place in modern physics, was determined. As a result, students used three mental models when explaining the concepts of photon and spin. A large part of the students explained the concept of photon by using the wave model. The biggest reason for their use of the wave model in their explanation can be the fact that experiments which highlighting the wave nature of light are taught in more detail compared to the experiments which support the particle nature of light.

Another important finding gathered as a result of this study was the mental models of students in relation to the concept of spin. It was seen that students have different descriptions related to this concept which is one of the most important concepts of modern physics and quantum physics. At the end of the analysis of the gathered data, it was determined that many students have alternative concepts related to the concept of spin. Fourteen out of 25 participants accept the concept of spin as a magnitude of turning object around its own axis. There was no research related to this concept in previous studies, so the alternative concepts determined in this study are likely to provide a resource for studies suppose to be done in the future. Studies with large participants of student groups would put forth the mental models of students in relation to these concepts, the alternative concepts, and learning difficulties in more detail.

References

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

Çepni, S. & Keleş, E. (2006). Turkish Students' Conceptions About The Simple Electric Circuits. *International Journal of Science and Mathematics Education*, 4(2), 269-291.

Duit, R. (1995). Vorstellungen und Lernen von Physik und Chemie – Zu den Ursachen vieler Lernschwierigkeiten, *Plus Lucis,* 2, 11–18.

Fischler, H. & Lichtfeldt, M. (1992). Modern physics and students' conceptions. *Inernational 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 Modelling. *Instructional Journal Science Education*, 22, 1-11.

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

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

Müller, R. and Wiesner, H. (1999). Students' conceptions of quantum physics. Presented at NARST 99. Retrieved 25October 2010 at http://web.phys.ksu.edu/papers/narst/qm_papers.pdf.

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

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

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