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Student' Conceptual Difficulties about Electron Transitions in Bohr and Quantum Models

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Abstract

This study aims to describe students' basic concepts in understanding spectral phenomena and students' conceptual difficulties regarding the electron transition of the Bohr and quantum atomic models. The subjects of this research are 37 Physics Education students, Tadulako University. The participants consisted of 2 students in high, medium and low categories based on the results of the basic concept understanding test. This research shows that 1). Understanding the basic concepts of students are low includes atomic models, spectrum series, line and absorption spectra, as well as energy levels diagrams of hydrogen atomic; 2). Students experience conceptual difficulties in describing electrons in a stationary state, excitation, and spectroscopic notation. In addition, medium and low category students have difficulty analyzing energy level diagrams and spectrum ranges, as well as mathematical difficulties in determining the energy and wavelength electromagnetic in radition and absorbs.

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Introduction

The college education curriculum, especially physics education, requires prospective physics teacher students to take modern physics courses. Generally, modern physics courses are taught in the second or third year. Modern physics exists to answer microscopic phenomena that classical mechanics cannot answer. Modern physics is a part of physics that studies the behavior of matter and energy at the atomic scale and subatomic particles or waves.

Student failure in modern physics courses is due to student preconception, namely negative perceptions of modern physics material. One of the negative perceptions of students is conceptual difficulties. The reasons students experience conceptual difficulties are that laboratory practicums are rarely carried out, lack of visualization of modern physics in everyday life, ordinary teaching methods and do not consider the level of student readiness (Aksakalli, et al., 2016).

Students' conceptual understanding of electron transitions of Bohr atomic model is quite low (Ivanjek et al., 2015; McKagan et al., 2008). The results of the research by Ivanjek et al. showed that only half of the students were right about the emission spectrum lines. Students did not understand that spectral lines are the result of electron transitions from two different energy levels. While graduate and teaching undergraduate assistants, no one answered correctly. In line with the research of Savall et al. (2016) showed that only a few high school students and physics teachers with master's degrees and more than ten years of teaching experience could answer correctly about atomic emissions.

The concept of the absorption spectrum of Bohr atomic model also difficult to be understood by students and teachers. Students of high school can not be answered correctly (Savall, et al., 2016). In line energy level, many students assume that the base state of lowest energy is 0 eV (Ivanjek, et al. , 2015) and physics teachers think the same (Savall, et al., 2016).

Kiray (2016) states that the Bohr atomic model is the atomic model that many students prefer compared to other atomic models because it is concrete and easier to understand. The tendency of students to understand the concept of orbitals in the Bohr atomic model has a bad impact on students' understanding of the modern or quantum atomic model (electron cloud model).

Korhasan & Wang (2016) show that students have a misunderstanding about the atomic spectrum with a coherent organization in the form of elements of basic knowledge about spectral phenomena including atomic structure (matter), the properties of light and how photons and electrons interact. In line with the research of Tsaparlis & Papaphotis (2009). It was found that students were still confused about whether electrons were waves or particles. It is difficult to describe the electron orbitals of the hydrogen atom.

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Based on the explains of several studies above, the difficulties regarding electron transition in students, college students and physics teachers has been investigated. Bohr's atomic model theory became a key concept in previous research. Therefore, the research to be carried out is to investigate students's conceptual understanding of the concept of electron transition of quantum atomic model and students' basic concepts. In addition, the research will to invertigate students' conceptual difficulties including verbal, diagram, mathematical, and pictorial when students analyze the phenomenon of electron transition in the quantum and Bohr atomic model.

This article will explain students' conceptual understanding and conceptual difficulties of concepts' quantum and Bohr atomic model.

Materials and Method

This research is a qualitative descriptive study. The subjects in this study were prospective physics teacher students at the Physics Education Study Program, Faculty of Teacher Training and Education, Tadulako University with 37 student respondents who had taken Basic Chemistry and Modern Physics courses. Furthermore, the participants in this study were six students who were willing to be interviewed, consisting of two students each in the high category (P1 and P2), the medium category (P3 and P4), and the low category (P5 and P6).

The research instrument that will be used in this research:

(1) a test of basic concept understanding. This research instrument aims to describe the students' initial understanding. This basic concept understanding test consists of 17 essay questions covering the understanding of the concept of the nature of electrons as quantum (particle-wave), the nature of light as a dualism of particles and waves, atomic concepts and atomic models, emission-absorption spectrum series, and the level energy diagram of the hydrogen atom.

(2) a test of conceptual understanding of electron transitions. This research instrument consists of 3 essay questions covering the material of electron transition based on the Bohr and quantum atomic models. The transition of electrons when there is emission and absorption. Including difficulties in interpreting diagrams, mathematical, verbal, and pictures.

Data analysis techniques in this study according to Sugiyono (2014) include:

(1) reducing data. The data reduction activity begins with correcting the results of student work from tests of understanding basic concepts and tests of conceptual understanding of electron transitions, scoring tests based on scoring criteria, and classifying students' level of conceptual understanding. The level of conceptual understanding used refers to Table 1.

(2) presenting data, test results data namely understanding basic concepts and conceptual understanding of electron transitions are presented in the form of tables containing percentages of conceptual levels of understanding, namely sound understanding (SU), partial understanding (PU), misconception (MC), no understanding (NU) and no response (NR).

(3) verification and drawing conclusions, verification is done by interviewing participants in depth on the answers that have been given. Conclusions can be drawn or obtained by comparing the results of student test answers and interview results.

Table 1. Scoring criteria and level of conceptual understanding.

Code	Level of Understanding	Score	Scoring Criteria
SU	Sound Understanding (Abraham, et al, 1994)	4	A response that includes all validated components, an answer that includes all aspects of a valid answer (a scientifically accepted concept).
PU	Partial Undersanding (Nakibolgu & Nakiboglu, 2016)	3	Responses that contain part of a scientifically accepted concept, answers that cover only one or part of the aspects of a valid answer.
MC	Misconception (Samsudin, et al, 2017)	2	Responses that contradict scientific theory.
NU	Not Understanding (Saglam, et al., 2010)	1	Irrelevant or unclear (vague) responses, repetition of questions or answers.
NR	Not Response (Costu, et al, 2010)	0	Blank response, answered "I don't know/understand".

Results and Discussion

Results in this study used a basic concept undersanding test were processed and presented in table 2.

Table 2. Percentage of students at the level of conceptual understanding of the basic concepts of students in understanding spectral phenomena.

Basic Concepts	Level of Understanding (%)				
	SU	PU	MC	NU	NR
Electrons behave as waves	0	70	19	6	5
Electrons behave as particles	0	81	8	3	8
Electrons do not simultaneously behave as particles and waves	3	24	51	3	19
Light is wave	16	81	3	0	0

Basic Concepts	Level of Understanding (%)				
	SU	PU	MC	NU	NR
Light is a particle	8	73	3	5	11
Dalton atomic model	3	43	49	0	5
Thomson atomic model	3	35	54	3	5
Rutherford atomic model	0	40	38	0	22
Bohr atomic model	5	57	22	0	16
de Broglie atomic model	0	8	43	3	46
Schrodinger atomic model	3	11	27	8	51
Electron transition of Lyman series	0	14	35	16	35
Electron transition of Barmer series	0	11	27	11	51
Electron transition of Paschen series	0	8	27	11	54
Line spectrum	0	13	38	0	49
Absorption spectrum	0	3	51	0	46
The energy level diagram of hyrogen atom	0	11	8	5	76

Based on Table above, 19 % of students had misconceptions. Low category students P5 and P6 had misconceptions about electrons acting as particles and waves. Student P5 stated that electrons do not behave as waves because the vibrations in the waves do not contain particles. Olsen (2002) state that students have misconceptions that electrons are particles that move like transverse waves. Meanwhile, according to P6 students, electrons behave as waves in terms of moving charges into electric waves that can be observed on an oscilloscope.

Low category students had a misconception of the behavior of light as a wave-particle. Light behaves as a wave because light can propagate to Earth (P5) in a medium or without a medium (P6). Student P6 knew that light behaves as a particle because light has particle-wave dualism (Olsen, 2002). However, Student P6 did not know that why light is a particle. Student P5 found the wrong thing that light is a particle of carbon dioxide in the air.

In Table 2, as many as 49% students had misconception of Dalton atomic concept. Student P5 and thought that the Dalton atomic model contained electrons and positrons. This is in line with the research by Sutomo & Fathurrahman (2019) which found that more than half of the research subjects or students did not understand and experienced misconceptions about Dalton atomic model.

Less than half of students (54%) had misconceptions of Thomson atomic model. Students in the high, medium, and low categories experienced misconceptions about Thomson atomic model. P1 and P3 assume that the raisins scattered in the cake are protons. Similarly, the student P2 assumed that the raisins were charged with positrons. Student P4 described Thomson atom model with electrons (-) and protons (+) scattered in a solid sphere. In contrast to P6 assumes that in Thomson atom model, electrons revolve around a positron. Students P5 did not respond. This is in line with the research conducted by Sutomo & Fathurrahman (2019) which found that half of the research subjects or students did not understand the concept, including experiencing misconceptions about Thomson atomic model.

Students P4 and P6 had misconceptions about Rutherford atomic model. Student P4 assumes that in Rutherford's model a positive atom (positron) is centered and surrounded by neutrons. P6 explained that in Rutherford atom model there is a force that affects two charges.

In Table 2, 57% of students partial understanding of Bohr atomic model. Students in the P1, P2 and P3 categories can understand the Bohr atomic model. However, only P1 students can drew a Bohr's model of the atom with a positive nuclear charge and surrounded by negatively charged electrons. In contrast, student P2 explained electrons around the atomic nucleus and drew the Bohr atomic model with a neutral charge around the atomic nucleus, including students P3 did not draw the Bohr atom model, only partially understood it. This is in line with Kiray (2016) which states that students understand more and can drew the Bohr atom model. Students P4, P5, and P6 did not respond.

Students P1, P2, and P3 experienced misconceptions about the movement of electrons according to de Broglie. The three students did not know that electrons move like stationary waves, not the movement of planets in the solar system. Student P1 assume that the de Broglie atomic model is the probability of the movement of electrons moving freely and approaching this atom. Student P2 explained correctly about electron transition by emission and absorption. P3 students assume that electrons move randomly in the atomic nucleus. Students P4, P5 and P6 did not respond.

Only 3% of students sound understanding of quantum atomic model. Students did not understand the quantum atomic model (Schrodinger), including high category students. Students P1 and P3 only rewritten the 'atomic model according to Schrodinger', while students P2, P4, P5, and P6 did not respond.

The P3 middle category students have misconceptions about spectrum series. Student P3 uses an incorrect equation in determining the wavelength of the Lyman, Balmer, and Paschen series. Student P4, P5 and P6 did not respond to the spectrum series.

Based on Tabel 2, 38% students had misconception of line spectrum concept. P4 and P6

students had misconceptions about the emission and absorption spectrum phenomena. The P4 student thought that the emission spectra were formed due to the emission of monochromatic light, while the absorption spectrum was caused by the emission of polychromatic light. P6 students think that the spectral phenomena occur due to differences in heat energy, without considering electron transitions. Sunyono, et al. (2014) stated that they cannot interpret the energy of electrons when transitioning from one energy level to another, students also do not understand that energy will be absorbed or emitted when electrons transition. Student P3 and P5 did not respond.

Difficulty of Conceptual Understanding

The results of the conceptual understanding of electron transition tests are processed and presented in percentage levels of understanding in table 3.

Table 3. Percentage of students at the level of conceptual understanding of students about the electron transition of the Bohr and quantum atomic models.

Concept of Electron Transition	Level of Understanding (%)				
	SU	PU	MC	NU	NR
Emission spectrum phenomena in the Bohr atomic model	0	30	24	43	3
Absorption spectrum phenomena in the atomic model Bohr	0	5	41	16	38
Emission spectrum phenomena in the quantum atomic model	0	5	0	30	65

Based on Table above, only 30% students had partial understanding of concept of emission spectrum phenomena in the Bohr atomic model. Students in the high, medium, and low categories experienced verbal difficulties in describing electron in a stationary state (Postulate I). P1 students had the misconception that in atoms the electrons would move constantly around the atomic nucleus with the binding energy of the nucleus so that the electrons would not out of orbit, and emit energy. Students P2 did not understand, but P1 and P4 understood enough when asked about electrons not emitting energy in a stationary state. Students P3, P5, and P6 did not understand electron in a stationary state. This is in line with the research of Savall, et al. (2016) stated that some students had difficulty in explaining the stationary state or the quantization of energy in atoms.

Students P4, P5 and P6 had a misconception of electron transition and had difficulties regarding the energy level diagram of the Hydrogen atom. Student P4 assumes that electrons will move (emit) and absorb energy from a higher excitation energy level (above) to n = 3 or E = -1.51 eV. Student P5 assumes that the electron will move from the ground state n = 1, to n = 2, and ends at n = 3 or the excited state E = -1.51 eV. Student P6 has difficulty and does not understand energy level diagrams, P6 depicts electron transitions with straight down arrows and does not understand transitioning electrons ending in a basic energy state. This is in line with the research of Ivanjek et al. (2015) stated that students had difficulties regarding the phenomenon of hydrogen atom emission. Students assume that the electron transition always involves a basic energy state and uses an inaccurate model.

Students P4, P5 and P6 did not understand the amount of energy emitted by electrons and had mathematical difficulties. Students P4 and P5 calculated the amount of energy by subtracting between the initial energy and the final energy, but experienced arithmetic operations errors. Students P4 and P5 ignore the negative sign (-) when calculating the energy. This is in line with the research of Savall et al. (2016) stated that students have difficulty in determining the amount of energy conservation in electrons of emission and absorption, and did not look to the (negative) sign indicating the energy of each energy level of the hydrogen atom. P6 students only guessed the amount of energy emitted.

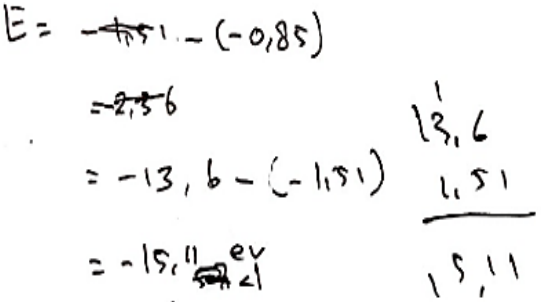


Figure 1. Student's mathematical difficulty in determining the amount of energy emitted

Medium and low category students did not understand that electrons that experience emission will occur a line spectrum (emission) according to its wavelength. Students have difficulty in analyzing the spectrum to be observed. Students P4 and P5 assumed that an absorption spectrum would be observed. Students P3 and P6 can determine that the spectrum to be observed is a line spectrum. However, students P3, including P4, P5 and P6 did not know the correct emission spectrum ranges based on the final energy level of the transition electron and its wavelength. Students P3, P4, P5 and P6 did not understand that every line in the observed spectrum represents a transition of electrons between two different energy levels. This is in line with the research of Ivanjek, et al. (2015) stated that students have difficulty in analyzing the

spectrum of the visible line with the line for each state of the energy level. Students assume that the number of observed spectral lines is the number of energy level lines.

Emission spectrum phenomena in the quantum atomic model

Based on Table 3, only 5% of students had partial understanding of concept of absorption phenomena in the Bohr atomic model. Students can see that when electrons transition from a certain energy state to a higher energy level, they absorb energy. Students in the high, medium and low categories know that when an energy of 2.55 eV is irradiated on an electron that is in an excited state at n = 2, the energy will be absorbed so that the electron moves to a higher energy level. However, students P1, P3, P5 and P6 did not understand and had verbal difficulties, students could not describe that an energy of 2.55 eV would be absorbed causing electrons to transition from n = 2 to n = 4. This is in line with Savall et al. (2016) showed that students assumed that photon energy would always be absorbed into a high energy state, regardless of the conservation energy at each energy level of the hydrogen atom.

Students P1, P3, P5 and P6 did not understand and had difficulty analyzing energy level diagrams. Students ignore the energy conservation of 2.55 eV so that an electron transition can occur from n = 2 to n = 4 (Savall et al., 2016). Students P3 and P6 do not understand that the absorbed energy of 2.55 eV causes electrons to transition to n = 4. While students P1 and P5 understand it well enough but the calculation results are not correct. So that the P1 and P5 students took the calculated values that were close to the absorbed energy. Students P3 and P5 assume that electrons cannot move directly from n = 2 to n = 4, but must first transition to n = 3 then to n = 4.

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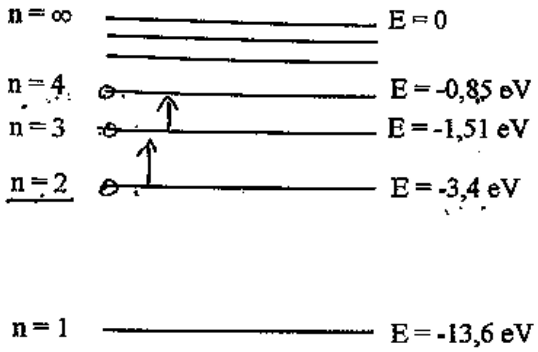


Figure 2. Student's difficulty on energy level diagram

Students simply understand that electrons transition from n = 2 to n = 4 produces an absorption spectrum, characterized by the disappearance of lines (dark in color) in the visible light spectrum. However, students have difficulty in analyzing which range of the spectrum appears when the electrons are transitioning. Students P1, P3, P4, P5, and P6 did not know the wavelength range of each spectrum, even though they already knew the wavelength. Only P2 students can understand that electron transitions are in the visible light spectrum (Balmer series), but are wrong about the wavelength range of each color.

Researcher : Based on the electron transitions you have made on the energy level diagram, calculating the energy and electromagnetic wavelengths, what will you observe?

Suppose the electron is transitioned by giving rise to a spectrum in visible light, which of these spectra is the emission spectrum (line)?, Why?



(picture 1) *(picture 2)*

What are the possible lines (emissions) in the spectrum in terms of the electron transitions in the previous energy level diagram?

P3 : The transition of electrons from n=3 to n=2 with a wavelength of 656 nm is in the infrared because the wavelength is higher than and n=2 to n=1 with a wavelength of 121 nm which means it is in the ultraviolet. Figure 2 (line spectrum). Three lines might appear because if you look at the energy level diagram there are lines from n=3 to n=2, then to n=1.

P4 :…, Figure 1 (absorption spectrum), black lines indicate the energy level. I will see two lines (line diagram of energy levels from n=4 to n=3). The wavelength of 18.78 nm is in the infrared.

P5 :…, picture 1 (absorption spectrum), 3 black lines will appear as seen from the lines of the energy level diagram from n=1 to n=2, then to n=3. The wavelength of 82 nm is in the ultraviolet spectrum..

P6 :…, picture 2 (line spectrum), it looks like the spectral lines have different colors due to different energy levels. A blue line will appear.

Emission spectrum phenomena in the quantum atomic model

Based on Table 3, only 5% of students had partial understanding of concept of phenomenon in the quantum atomic model. Students did not understand and have verbal difficulties in describing the conditions for electrons to be able to transition, namely meeting the rule l = ±1 (spectroscopic notation). Students P1, P2, and P3 stated that an electron transition can occur from 3p to 2s. P2 students think that a transition from 3p to 2s can occur because they are in different orbit, while according to P2 students this is due to a smaller value (number). Students P4, P5, and P6 stated that electron transitions cannot occur because they are not in the same orbit. This is contrary to the research of Savall, et al. (2016) show that some students can understand that electrons when transitioning in a quantum atomic model from one orbit to another must meet the selection rules, with angular momentum values of +1 or -1.

Students P1, P2, and P3 can understand the energy level diagram when electrons experience emission from 3p to 2s. However, students did not understand the electron transition when it is influenced by an external magnetic field. Students P4, P5, and P6 assumed that electron transitions could not occur, so students could not make diagrams of their energy levels.

Students P1, P2, and P3 can understand that electrons transitioning from 3s to 2s will emit electromagnetic waves. Students can also calculate (mathematically) the amount of energy and its wavelength. However, students cannot understand the amount of energy emitted by electrons transition under the influence of an external magnetic field.

It is sufficient for students to understand that electrons transition from 3p to 2s can emit electromagnetic waves in the form of a single line spectrum. However, students have difficulty in analyzing the range of the line spectrum with the emitted wavelength. Students P1 and P3 assume that they are in the infrared spectrum. Only, P2 students can understand that one emission spectrum in the visible light spectrum is red. Students P4, P5, and P6 did not respond.

Students do not understand and have difficulty with the emission spectrum when electrons transition under the influence of an external magnetic field. The six students could not give a scientific response. Students have difficulty with the concept of the fine structure of the spectrum (Zeeman effect) on the correction of hydrogen atomic energy for strong and weak fields (Keebaugh et al., 2018).

Conclusion

Students' conceptual understanding of the basic concepts of spectral phenomena is in the low category. Some students only understand part of the concept and experience misconceptions. The basic concepts include atomic models, spectrum series, line and absorption spectra, and energy level diagrams.

Students have difficulties with verbal, diagrammatic, mathematical, and drawing on the electron transition of the Bohr and quantum atomic models. Students have verbal difficulties in describing electrons in a stationary state, and in excitation, as well as, the rules of spectroscopic notation as a condition for electrons to be able to transition in a quantum model. Medium and low category students had difficulty mathematically determining the amount of energy and wavelength, difficulty analyzing the energy level diagram of transitioning electrons by emission and absorption, and having difficulty drawing images in determining the lines on the emission and absorption spectrum, as well as the range of the spectrum (electromagnetic waves). Students also experience the same difficulty regarding electron transitions in the quantum atom model that is affected and without an external magnetic field.

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