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The importance of diagrams representation in physics learning

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Abstract. The research objective is to identify the use of diagrams representations in various cases of the physics system and identify questions that cannot be answered and whose answers are wrong in the topics of mechanics, optics and electricity. The study was conducted on 40 physics students who have taken introductory physics courses. The research instrument is in the form of questions that only require drawing answers. The findings of the study were only 9.84% who answered correctly, 32.18% of students answered incorrectly, and there were 57.98% who did not work or did not answer. It has been found that 49.3% of students did not answer correctly in mechanics, 10% in optics, and 40.7% in electricity. Furthermore, the number of students who did not work or did not answer found 16.1% in mechanics, 42.4% in optics, and 41.4% in electricity. Pedagogically, the implication of the results of this study is to be very important in physics education, namely to condition the balance of physics understanding not only in mathematical mastery but also in mastering the use of diagrams representations. Understanding the correct diagram will increase meaningful physics learning, especially in finding solutions to solve physics problems correctly.

1. Introduction

Physics is knowledge that studies the real world that requires mathematics as a tool to explain both tangible and abstract phenomena. Therefore, in the physics learning process the use of pictures and symbols will greatly help learners to understand abstract concepts, as written by Opfermann Schmeck and Mayer [1-2]. Much research shows that multiple representations can have immense benefits for students' learning [3-9]. Optics is one branch of physics that must require pictures in explaining the concept of the propagation of light waves. Experience as a lecturer in physics shows that many students cannot apply the propagation of light waves using Snellius law, especially the propagation of light in the lens of the spherical surface. By using images the learners will be able to solve the problem, and thus the representation of images and symbols will complement the real and abstract physical concepts for example relating to the use of vectors, as written by Bahtaji and Olympiou [10-11]. Based on several points of view mentioned above, it is important to conduct studies to identify the use of diagrams representations in various cases of physics systems and identify questions that cannot be answered and wrong answers in topics of mechanics, optics and electricity.

2. Conceptual Framework

In general, everyone is easier to understand the explanation if given with pictures and symbols. In his dissertations Airey (2009) said that the semiotic resources that together constitute a disciplinary discourse include not only the words, symbols, gestures, diagrams, formulas, etc. used by a discipline; but also the artefacts, pieces of apparatus, measuring devices, etc. and the actions, practices and methods residing within the discipline [12]. Ainsworth quoted Lohse et al and Cox as saying that the type of representation (e.g., histogram, equation, table, line graph, narrative text, picture) is identified 11 major clusters: graphs, numerical and graphical tables, time charts, cartograms, icons, pictures, networks, structure diagrams, process diagrams and map clusters [13]. And then Airey and Linder (2017) explained that the critical constellations of semiotic resources is described in idealized hypothetical representation of a physics concept using a hexagon as shown in Figure 1.

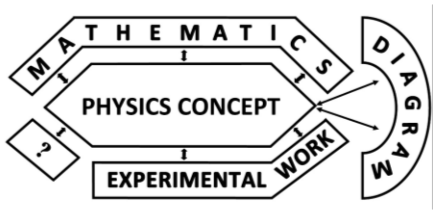

Figure 1. Visual semiotic resources of hypothetical representation of a physics concept

This study focused on the use of representation in the fields of mechanics, optics and electricity. In the field of classical mechanics, Newton's laws play a central role, which is the basis for the development of further science and technology. As written by Nieminen that the concept of force is central to physics education from primary school to university. In order to successfully apply the concept of force in physics, students must understand Newton's laws and related kinematics, such as position, velocity and acceleration [14]. The author's experience shows that many students do not understand the concepts of vectors and forces. The concept of force must be explained comprehensively from all aspects. From ontological aspect, force is the property of an interaction between two objects; from conceptual aspects, interaction between two objects implies that they exert forces on each other - interaction always creates a pair of forces [6]. Indeed, the concept of optics requires deepening in physics learning, as written by Muller and Schnotz about "Representational Competence, Understanding of Experiments, Phenomena and Basic Concept in Geometrical Optics: A Representational Approach" [15]. The following related to the electricity field can be explained that, there was a wide range of views among the teachers about the difficulties of both the concepts of DC electricity and the teaching of these concepts, and about the nature of physics knowledge [16]. Student understanding of electrical phenomena was examined within a phenomenological perspective in order to best describe (1) the students' experiences of electrical phenomena and (2) the relationship between each student and the content knowledge across time [17]. Apparently there is a difficulty in understanding students about the concept of electricity. Many students' difficulties in understanding the behaviour of a simple electric circuit are reported in the literature.

3. Methods

The research began with preparation of instruments, and then continued with making test specifications. Test materials include the fields of mechanics, optics and electricity. The research material is in the form of questions that must be answered by students with only pictures. The number of questions is 21 questions. the test is carried out within 30 minutes. The questions used in the study have been tested for validity. Participants involved in this study were 40 physics students, and participants who had passed the introductory physics course. Test materials are shown in Table 1. Participants' worksheets are examined one by one. Participant's answer data is processed and analyzed, and the results are shown in Figure 2 and Figure 3.

Table 1. Tests for diagrams representation in physics course

Part of physics	The identification of representation
Mechanics	Drawing force vectors in cases, such as free fall, blocking horizontal and

	inclined surfaces, stairs leaning against walls above rough horizontal floors and pulleys
Optics	The combination pictorial of wave diagrams and ray diagrams in the process of reflection and refraction on the flat boundaries, spherical boundaries and thick lenses with different indexes of refraction
Electricity	Drawing force vectors such as in interaction between charges (positive and negative), lines of force in uniform electric field, motion of a charged particle in a uniform electric field, lines of force in bar magnet, interaction of compass and current-carrying wire, force on electric charge moving in a magnetic field, lines of force in current-carrying wire, force between parallel wires.

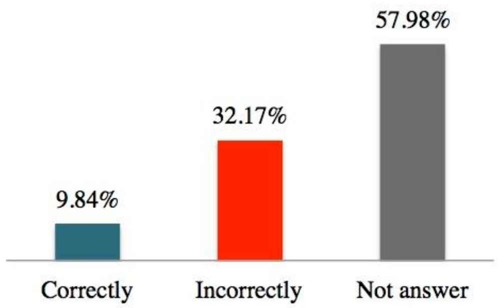

Figure 2. Participants' answers correctly, incorrectly and not answer regarding diagrams of representation

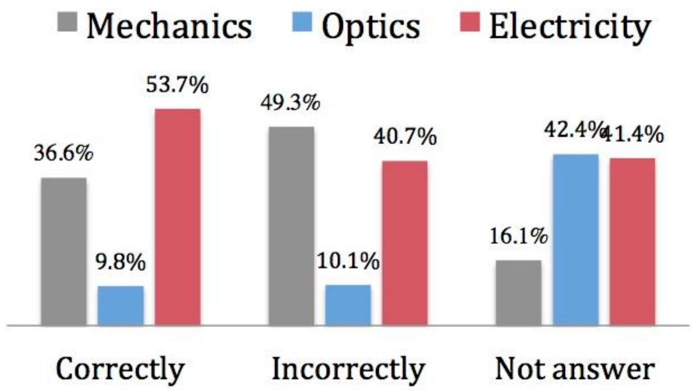

Figure 3. Participants' answers regarding diagrams of representation

4. Discussion

Based on data and Figure 2 and Figure 3, identification of the most difficult physics concepts related to diagram representation is shown, as in Table 2.

Table 2. The most difficult of physics concept related diagrams representation

Identification of the most incorrectly	Identification of that were not answered
Ladder leaned against wall no friction and rough horizontal floor	Draws a plane (flat) wavefront diagram that moves towards the reflection plane and the reflected plane wavefront
Draws a ray diagram moves towards spherical (convex and concave) mirror and reflected ray	Draws a plane wavefront diagram (in medium n_1) that moves towards the boundary plane with

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diagrams	different refractive indexes and the refraction of plane wavefront (in medium n_2)
Draws a ray diagram that moves towards convex and concave direction between two optical materials with a different refractive index ($n_1 < n_2$), and a refraction ray diagram	Draws a ray diagram that moves towards convex and concave direction between two optical materials with a different refractive index ($n_1 > n_2$), and a refraction ray diagram
Particles of positive charge move perpendicular to the magnetic field	Draws a ray diagram that moves towards thick converging and diverging lenses with a different refractive index ($n_1 > n_2$ and $n_1 < n_2$), and a refraction ray diagram
Force between parallel current wires (same and opposite current direction)	

The identification shown in Table 2 above, gives an indication of the mastery of physics concepts by students that are not intact, not deep and not comprehensive. For example, ladder leaned against wall and on the horizontal floor. Students do not understand correctly about the use of forces as a vector. Several studies have shown that students encounter difficulties when presented with simple familiar or academic static equilibrium cases in mechanics [18]. Physics problems will be answered correctly when using the correct vector pictures. Physics, being both descriptive and predictive in nature, makes it difficult for students to understand. The descriptive part of physics involves conceptual understanding that is used in problem solving–the predictive aspect of physics [19]. The explanation in Table 2 reveals that students do not fully understand the process of propagating light waves through the medium boundary plane, especially the curved boundary plane. Students cannot draw waves front of light with the help of light rays. Science education studies have revealed that students often have misconceptions about how nature works, but what happens to misconceptions after a conceptual change remains poorly understood [20]. The above phenomenon is seen specifically in the optics, Table 2 shows important findings about students' difficulties in drawing representation diagrams. Many students answer incorrectly and cannot answer the pictures of the process of light propagation because they do not understand the concept of waves front of light and light rays. In abstract article of Tural (2015) said, geometric optics is one of the difficult topics for students within physics discipline and in other part of article he said students may have difficulty understanding the function of the lenses in a refracting telescope [21]. According to Table 2, for electricity the difficulty of understanding the concepts of physics is related to forces in a magnetic field. Almost all students cannot make a path diagram and force on charged particles when entering the perpendicular region of the magnetic field. Ozdemir E (2018) in his research said that the conceptual understanding of electromagnetism, the vector algebra and spatial cognition effect the usage of the RHR- Right-Hand Rules [22]. Therefore, the use of vector representations in the fields of electricity and magnetism is very important, especially the representation of vectors is represented in 3 dimensions.

Implication

The role of vector diagrams is very important in mechanics and electricity. Mastery of representation diagrams becomes very important in geometric optics. The laws of physics will be explained correctly when using the correct pictures representation. To help students better understand organizational graphics (which are quite abstract and therefore challenging), have students consider two diagrams: a pictorial diagram that is organized according to the system's natural structure and an organizational diagram that is arranged semantically [23]. Mastery of complete representation diagrams will be the first step to reconstructing a complete understanding to solve physics problems in a systematic and comprehensive manner. Didactically, it is very important to write a physics textbook that is rich in pictures representation, which combines physics concepts and observations through laboratory practices and physics research activities.

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