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Literature Review of Factors Contributing to Students' Misconceptions in Light and Optical Instruments

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ABSTRACT

This study aimed to explore the factors that contribute to students' misconceptions in light and optical instruments concept. Misconceptions impede the students' conceptual understanding of science learning. Misconceptions are considered to have occurred if the students' understanding of a concept differs from what is understood by the scientific community. An analysis of the literature reveals that everyday experiences, language used, teachers and textbooks are the main factors contributing to students' misconceptions of light and optical instruments in science learning. By analyzing these factors, it would make sense to minimize the contributing factors that might help promote the students to achieve conceptual understanding in light and optical instruments concept.

Keywords: literature review, misconceptions, light and optical instruments, science learning

INTRODUCTION

Science learning seeks an understanding of natural phenomena by means establishing fundamental knowledge. Structure of students' knowledge is essential to the conceptual understanding of learning science (Tobin et al., 1994). Before being involved in formal learning, students bring certain concepts that they have acquired through interaction with the environment related to scientific phenomena. With that experience, they develop alternative concepts about the science phenomena in their mind, which are not always correct. The concept that is irrelevant with scientific concepts is called a misconception (Hammer, 1996). Previous studies have found that students acquire misconceptions before and during their school years (Arnaudin & Mintzes, 1985). In the process of learning, students will try to connect the new knowledge to their cognitive structures. If the students have misconceptions, these will interfere with their learning and they will difficult to connect new knowledge with their existing knowledge. Because of this condition, students will difficult to achieve conceptual understanding in a learning process.

A conceptual understanding of science has been the main concern of the researchers in the science education field. Many factors affect the understanding of students in educational settings. One of the major factors that affect students' understanding is misconceptions. Misconceptions have occurred if the students' understanding of a concept differs from the scientific concept. Misconceptions are stable cognitive structures to change, affect students' conceptual understanding, and must be overcome so that students learn scientific concepts effectively (Hammer, 1996). Misconceptions also considered one of the most important obstacles against meaningful learning (Kutluay, 2005).

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Several studies have explored students' conceptual understanding of light, vision and optics phenomena (Galili & Hazan, 2000; Langley et al., 1997). Finding from previous research stated that the topic of light and optical instruments to be obscure and difficult (Galili & Hazan, 2000). Furthermore, studies show that students have learning difficulties with lenses in geometric optics (Galili, Bendall, & Goldberg, 1993; Galili, 1996; Galili & Hazan, 2000; Goldberg & McDermott, 1987). The light and optical instruments is one of the concepts in science learning that difficult for students. The concept of "light" in science is one of the concepts in which everyone has an understanding from the daily life experience or the language used to begin from the childhood (Gürel & Eryilmaz, 2013). Light is a complex and difficult concept that lends itself to misconceptions among the teachers and the students (Ling, 2017). Furthermore, a light concept is one concept in which many students have prevalent misconceptions (Yalcin et al., 2009). A review of the literature on this concept have shown various difficulties in dealing with abstract concepts in the learning process. Because of the difficulties, students tend to develop misconceptions about light and optical instruments (Kutluay, 2005).

Studies related to the students' misconceptions have been conducted all over the world, including in Indonesia. In the educational research studies, not only identification of misconceptions in light and optical instruments is important, but also the identification of possible factors that contribute to these misconceptions. The purpose of this paper is to review some studies related to the research documents to investigate the factors that contribute to students' misconceptions, particularly in light and optical instruments concept. If some factors contributing to misconceptions in this concept are revealed, it can help students to improve their understanding. Therefore, very important to investigate the contributing factors of students' misconceptions in light and optical instruments concept. Thus, the major purpose of this study is to analyze the factors contributing to students' misconceptions in light and optical instruments, particularly the example in the Indonesian context.

This research aimed to investigate the factors that can contribute to students' misconceptions of light and optical instruments concept. It should also provide information about possible sources and causes of misconceptions on this topic that might be interesting and useful for science teachers and educators. The following specific research question is: "What are the factors that can contribute to students' misconceptions of light and optical instruments concept?"

METHODS

This study is a review of the literature. This review includes published research addressing the contributing factors of misconceptions in science learning. To investigate this review, we carried out a database search articles (ERIC, Scopus, and google scholar) that related to the factors contributing to students' misconceptions in science education field. In this article, we first define the definition of misconceptions. Second, we determine the factors contributing to students' misconceptions. In order to determine the factors contributing to students' misconception in light and optical instruments concept, several numbers from previous research are analyzed carefully. Third, we analyze the reasons why each factor can contribute to students' misconceptions. Fourthly, analyzing the way how to eliminate or prevent misconception. Finally, a conclusion is presented in this article.

RESULTS AND DISCUSSION

What is "Misconceptions"?

The primary goal of science education is teaching for conceptual understanding (NSTA, 2015). Conceptual understanding has been traditionally one of the primary goals for science studies, at all levels of formal education. Several studies have been conducted to investigate the students' conceptual understanding of science learning (Alao & Guthrie, 1999; Konicek-Moran & Keeley, 2015; Nieswandt, 2007; Puk & Stibbards, 2011). Students must be taught to develop a conceptual understanding that is aligned with the conceptual understanding accepted by the scientific community (Ausubel, 1963). The literature also indicates that various terms have been used to illustrate these ideas with contradicting with the scientific community. These ideas are known variously as misconceptions (Dykstra et al., 1992), alternative conceptions (Driver & Easley, 1978; Wandersee et al., 1994), naive conceptions (Champagne et al., 1983), and preconceptions (Ausubel, 1963). Analysis of the differences these terms indicates the existence of a subtle distinction in the use of these terms (Wandersee et al., 1994). Hence, similar to various other previous studies, the term "misconceptions" will be used in this study.

Table 1. Summary of factors contributing to students' misconceptions

Author(s)	Factors contributing to misconceptions			
	Everyday experiences	Language used	Teacher	Textbooks
Osborne et al., 1983		√		
Abraham et al., 1992	√	√		
Smith et al., 1994	√			
Bahar, 2003		√		
Boz, 2006		√		
Devetak et al., 2007				√
Tyson et al., 1999		√		
Kaltacky & Erylmaz, 2010	√		√	√
Suniati et al., 2013	√			√
Gudyanga & Madambi, 2014			√	√
Satilmiş, 2014			√	
Widarti et al., 2016	√			√
Erman, 2017		√	√	√

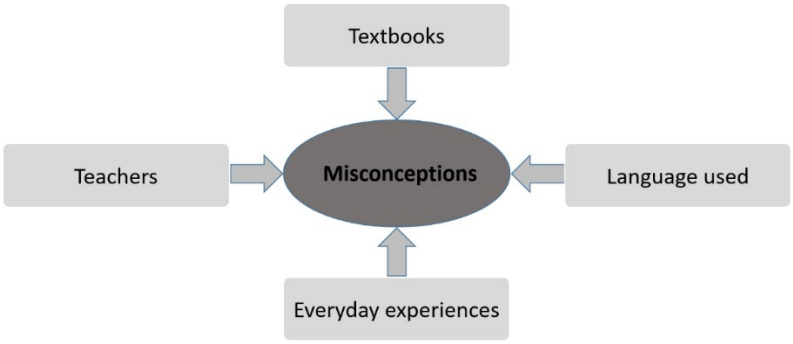

Figure 1. Factors contributing to students' misconceptions in science learning

Misconceptions are deemed to have occurred if the students' understanding of a concept differs from what is understood by the scientific community (Nakhleh, 1992). Besides, misconceptions are a stable cognitive structure that affects students' understanding of scientific concepts (Taşlıdere, 2013). Misconceptions can occur in students' understanding of scientific concepts as well as in their organization of scientific knowledge (Thompson & Logue, 2006). Misconceptions are sturdy and resistant, so they are difficult to replace with new, true understandings; they consistently influence the effectiveness of further learning (Ozmen, 2004; Taber, 2009).

Meaningful and successful learning of science occurs when the misconceptions that students bring to the classroom are corrected (Bilgin, 2006). Therefore, after students' misconceptions were identified, the instructor or teacher can help the students to achieve the understanding of scientific concepts. Helping students to develop a meaningful conceptual understanding of how the concept can be used in their daily lives is an aim of science education.

Factors Contributing to Students' Misconceptions in Science Learning

Misconceptions are developed by students from various resources. Misconceptions contrast with scientific concepts, and most authors frequently refer to some factors such as influence from everyday life experiences (Abraham et al., 1992; Kaltakci & Eryilmaz, 2010; Smith et al., 1994; Suniati et al., 2013; Widarti et al., 2016), teachers (Erman, 2017; Gudyanga & Madambi, 2014; Kaltakci & Eryilmaz, 2010; Satilmiş, 2014), reference book or textbooks (Devetak, Vogrine, & Glazar, 2007; Erman, 2017; Gudyanga & Madambi, 2014; Kaltakci & Eryilmaz, 2010; Widarti et al., 2016) and confusion of everyday language used as factors contribute to misconceptions (Abraham et al., 1992; Bahar, 2003; Boz, 2006; Erman, 2017; Osborne et al., 1983; Suniati et al., 2013; Tyson, Treagust & Bucat, 1999). The Summary of studies the factors contribute to misconceptions in science learning can be seen in **Table 1**.

Based on **Table 1** four major factors contribute to students' misconceptions in science learning, namely everyday experiences, language used, teacher and textbooks. These factors are shown in **Figure 1**.

Analyzing Factors Contributing to Students' Misconceptions in Light and Optical Instruments Concepts

Although light and optical instruments is an everyday phenomenon that students observe, numerous researcher have reported that students often showed learning difficulties and held the unscientific understanding of this concept. According to Ling (2017), light and optical instruments is a complex concept that lends itself to misconceptions among teachers and students. A review of the literature on this concept have shown various difficulties in dealing with abstract concepts in the learning process. Because of these difficulties, students tend to develop misconceptions about light and optical instruments.

With careful study of previous literature, main possible factors that contribute to students' misconceptions of light and optical instruments concept are discussed in this section.

Everyday experiences

Students interactions with the environment in daily life experiences confuse the students (Agnes et al., 2015; Smith et al., 1994). The close relation of light and optical instruments concept to the everyday experiences of students may be a source of misconceptions on this topic (Kaltakci & Eryilmaz, 2010). Students get familiar with their environment, and they spend a lot of time outside of school. They have their explanations of meanings of things in the world around them. Mainly, such explanations do not match with scientific meaning. Students understanding of the science concept based on the interaction with the surrounding environment and embedded with the daily life experience.

In an everyday sense "light" can be defined as an area that is illuminated, e.g., we need more light in here, or is it light outside yet? Therefore, students understanding light as being a general quality of a particular location, which conflicts with the scientific idea of light as a form of energy that travels from one place to another (Allen, 2014). In light and optical instruments concept, students in Indonesia provide an example of the properties of light based on their daily experiences. One misconception has found from previous research is "light is an electromagnetic wave and has infinite speed." Based on this misconception, students think that light is an electromagnetic wave and has infinite speed because they taught that the sun is shining every second. The fact is light needs around 8 minutes 20 seconds to reach on the earth from the sun.

Language used

Students faced difficulties when the scientific words were used in everyday language. The language used by individuals may be responsible for students' misconceptions (Boz, 2006; Osborne et al., 1983). Many words in light and optical instruments are difficult for students, for instance "light'. Students commonly speak that light is something that makes vision possible. However, in science, the definition of light is electromagnetic radiation of any wavelength that travels in a vacuum with a speed of 299,792,458 meters per second; specifically: such radiation that is visible to the human eye.

Students also have the misconceptions that color is a property of the object rather than light. In daily language saying "the table is red" instead of "the table is reflecting red light" may be considered as the source of misconceptions (Kaltakci & Eryilmaz, 2010). The factors that impede understanding of this concept are: the light concept is abstract for the students, and the characteristic of light (its speed, wavelength, color, etc.) are beyond the perception of student's senses. Furthermore, many terms in the light concept are difficult for students, for instance, reflection, refraction, and dispersion. In Indonesia, the misconception found from previous research is convex mirror can make an image larger than the object (Agnes et al., 2015). Students think that the characteristic of magnification image of convex mirror similar with the convex lens. Many difficult and complex words in light and optical instruments concept provided in Indonesian textbooks, such as real image, virtual image, magnification, etc. Due to the difficulty and complexity of light and optical instruments concept, students have developed misconceptions about this concept. **Table 2** provides the summary of difficult words of light and optical instruments concept.

Table 2. Difficult words in light and optical instruments concept (MoEC, 2017)

Subtopic		Difficult words
1.	The properties of light	Reflection, refraction, electromagnetic wave
2.	The formation of images in mirrors and lenses	Focal length, convergent, divergent
3.	The formation of images in optical instruments	Real image, virtual image, magnification
4.	The structures and function of human eyes	Cornea, eye lens, pupil, iris, punctum proximum, punctum remotum
5.	Eye disorders and the solutions for each disorder	Myopia, presbyopia, hypermetropia

Table 3. The reasons why teachers propagate misconceptions

Why teachers propagate misconceptions?		Studies
1.	Teachers inability to communicate effectively with students	Gudyanga & Madambi, 2014
2.	Teachers fail to connect a various concept	Ibnu, 1989
3.	Teachers fail to appropriately present abstract concept, either by visualization to help students understand the material	Treagust et al., 2003
4.	Teachers also have misconceptions	Gudyanga & Madambi, 2014
5.	Teachers inability to implement various teaching methods	Gudyanga & Madambi, 2014; Taber 2003

Teachers

Science learning is enacted in classrooms mainly through the interactions between teachers-students, students-students, students-materials, and teachers-materials. In the science classroom, the teacher is perceived to be the dominant figure to provide the direction for learning. Thus, the roles played by science teachers are necessary for shaping students' experiences of science learning and sometimes teachers are propagating misconceptions to students.

Previous research in Indonesia founds several misconceptions from science teachers. For instance, teachers think that the property of an image formed by a plane mirror is real (Saputri & Nurussaniah, 2015). The correct concept is the property of an image formed by a plane mirror is virtual because teachers think that the eyes can see the images. The fact, virtual images are images that are formed in locations where light does not reach. Another example is teachers think that the angle of incidence formed between the incident ray with the mirror surface (Saputri & Nurussaniah, 2015). The correct concept is the angle of incidence formed between the incident ray and normal line.

Teachers propagate misconceptions because of their inability to communicate effectively with students (Gudyanga & Madambi, 2014). In some cases, teachers may be unaware of student's difficulties and fail to take appropriate methods in presenting specific ideas to students (Kaltakci & Eryilmaz, 2010). Furthermore, Satilmiş (2014) stated that students had misconceptions due to ineffective teaching method especially when the teachers followed the traditional method. Teacher fails to present abstract concepts appropriately, either by visualization or analogy to help students understand the concepts (Treagust et al., 2003). The reasons why teachers propagate misconceptions can be seen in **Table 3**.

Teachers' misconceptions are also one reason for students' misconceptions (Gudyanga & Madambi, 2014). It means that there is the possibility of the teachers transferring their misconceptions to the students since they are the main source of instruction. During their training when teachers learn abstract concepts without clear understanding, they end up disseminating their misconceptions to their students. Therefore, science teachers must have a clear conceptual understanding of the science concept in each learning activities.

Textbooks

Textbooks is a tool used in the teaching-learning process and a guide for teachers and students. Textbooks have an important role in students' construction of conceptual understanding. However, textbooks may also serve as a cause of misconceptions (Devetak, Vogrine, & Glazar, 2007; Gudyanga & Madambi, 2014). The unclear figure in the textbook is one of the reason misconceptions at the submicroscopic level (Devetak, Vogrine, & Glazar, 2007). Similarly, textbooks do not always provide complete and correct information or explanations (Gudyanga & Madambi, 2014). Finally, textbooks present the information in the symbol which is difficult to understand (Gabel, 1998; Nyachwana & Wood, 2014). The reasons why textbooks can cause misconceptions can be seen in **Table 4**.

Table 4. The reasons why textbooks cause misconceptions

Why textbooks cause misconceptions?	Studies
1. Textbooks are using confusing language	Devetak, Vogrine, & Glazar, 2007; Gudyanga & Madambi, 2014
2. Textbooks are presenting oversimplified materials and misleading information	Gilbert, 2003; Taber 2003
3. Textbooks are presenting information or ideas which difficult for students	Gilbert, 2003; Taber 2003
4. Textbooks are using symbols that are difficult to interpret	Gabel, 1998; Nyachwana & Wood, 2014
5. Textbooks are using terms that are unfamiliar to students	Taber, 2003

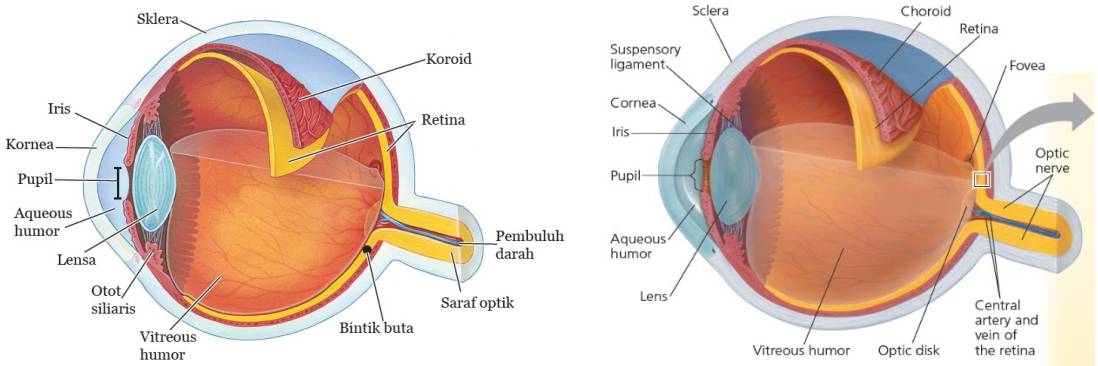

Figure 2. **(a)** Parts of human eye (MoEC, 2017) and **(b)** Parts of human eye (Campbell et al., 2017)

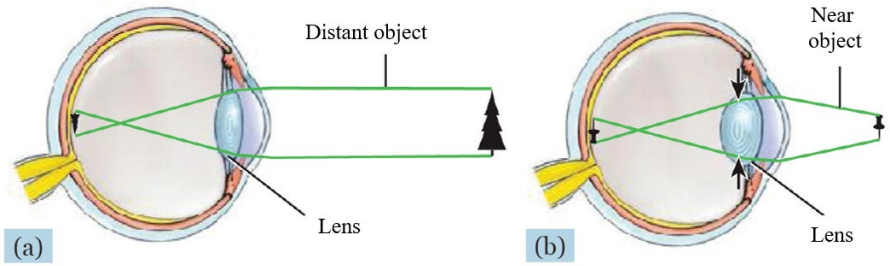

Figure 3. Accommodation of human eye (MoEC, 2017)

In Indonesia, most of the science textbooks are provided by the MoEC (Ministry of Education and Culture). These textbooks are perhaps the only learning materials available and used in most Indonesian Schools. In light and optical instruments concept, there is some unclear figure that is presented in the textbooks. For instance, in the parts of the human eye, the Indonesian textbooks represent the unclear image of the pupil and aqueous humor (**Figure 2**). Meanwhile, in a biology book by Campbell (2017), pupil and aqueous humor are shown by clear picture (**Figure 2**).

Students in Indonesia are difficult to explain the process of the eye's accommodation. Eye's accommodation is the ability of the eye to change its focus from distant to near objects. This process is achieved by the lens changing its shape (Campbell, 2017). The process of the eye's accommodation is too abstract for students and tends to cause the misconceptions. This misconception occurs because the textbooks provide static illustration related to the function of the human eye (**Figure 3**).

Based on science textbooks, the plan mirror reflects 100% of the light will reflect the light that shines on it (**Figure 3**). In fact, no mirror reflects 100% of the light that shines on it. Good mirrors reflect 95% of the light that is incident on them. The remaining light 5% is absorbed and converted to heat (Pompea et al., 2007). The accurate information, illustration, and clarity of the contents in the textbooks are important in the learning process. Therefore, textbooks should be reviewed by experts and should be carefully chosen in order to facilitate students' learning and to prevent the misconceptions. Furthermore, textbooks can help students to understand the science concept particularly light and optical instruments concept.

Remediation of Misconceptions

Past studies on improving conceptual understanding of science suggest that the first step towards an effective teaching and learning process is to identify the misconceptions and employ effective teaching strategies to remediate the misconceptions (Çepni et al., 2006; Çibik et al., 2008). To promote meaningful learning, teaching strategies must be found to eliminate misconceptions. One strategy being the use of appropriate is teaching method. Research related to misconceptions had shown that traditional teaching strategies are not effective for overcoming students misconceptions (Jimoyiannis & Komis, 2001; Saul & Redish, 1999). The process of correcting students' misconceptions depends on not only the delivery of new knowledge but also the gradual of integration of new concepts related to students' existing conceptual structures (Vosniadou, 2002). New instructional methods must be developed to support students in actively constructing and adapting their knowledge (de Jong & Van Joolingen, 1998).

Posner et al. (1982) stated that conceptual change develops through cognitive conflict and comprises four conditions before students can replace their existing misconceptions: (1) Students must become dissatisfied with their existing knowledge so that accommodating new ones may be easier, (2) The new concept must be intelligible so that students able to understand the concepts and make sense to them, (3) The new concepts must be plausible so that students must emerge to have the capacity to solve the problems and be consistent with past experiences, and (4) The new concepts must be fruitful, it means that the new concept should have the capacity to solve the problems or predict phenomena more easily than the existing concept.

Overcoming misconceptions require teaching strategies which provide chances for students to reveal their pre-concepts and dissatisfaction with their concepts. Several teaching strategies have been tried to overcome students' misconceptions, and some results of such trials have revealed significant effectiveness in dealing with students' misconceptions.

From the previous research on students' misconceptions in science learning, we found most strategies for overcoming students misconceptions. These strategies focused on repairing and changing misconceptions when they have already been formed or identified. The strategies are most frequently adopted are: using computer simulation (Chen et al., 2013; Moosa, 2015; Ramnarain & Moosa, 2017), utilizing concept cartoon (Yong & Kee, 2017), using constructivist-based approach (Awan, 2013; Ling, 2017), using drawing analysis (Dikmenly, 2010), using inquiry-based learning (Ray & Beardsley, 2008; Heng & Karpudewan, 2017), using cooperative learning approach (Bilgin & Geban, 2006; Manolas & Leal, 2011), using analogy activity (Çalik et al., 2009), and using learning cycle approach in the classroom (Osman, 2017).

CONCLUSION

In conclusion, several factors are contributing to students' misconceptions in light and optical instruments concept in Indonesia. Factors that can contribute to students' misconceptions are students' everyday experiences, language used, teachers and textbooks. By analyzing sources of these misconceptions, it would make sense to minimize the contributing factors that might help promote the students to achieve conceptual understanding, particularly in light and optical instruments concept.

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No potential conflict of interest was reported by the authors.

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REFERENCES

Abraham, M. R., Grzybowski, E. B., Renner, J. W., & Marek, E. A. (1992). Understandings and misunderstandings of eighth graders of five chemistry concepts found in textbooks. *Journal of research in science teaching*, *29*(2), 105-120. https://doi.org/10.1002/tea.3660290203

Agnes, D., Kaniawati, I., & Danawan, A. (2015). Analisis Deskriptif Tes Tiga Tingkat Materi Optika Geometri dan Alat Optik [Descriptive Analysis Three-Tier Test Geometry Optics and Optical Instruments]. *Prosiding Simposium Nasional Inovasi dan Pembelajaran Sains*, 597-600.

Awan, A. S. (2013). Comparison between Traditional Text-book Method and Constructivist Approach in Teaching the Concept'Solution'. *Journal of Research & Reflections in Education*, *7*(1), 41-51

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: A cross-age study. *Science Education*, *69*(5), 721-733. https://doi.org/10.1002/sce.3730690513

Alao, S., & Guthrie, J.T. (1999). Predicting conceptual understanding with cognitive and motivational variables. *The Journal of Educational Research*, *92*, 243–254. https://doi.org/10.1080/00220679909597602

Allen, M. (2014). *Misconceptions in primary science*. UK: McGraw-Hill Education.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York, NY: Grune& Straton.

Bahar, M. (2003). Misconceptions in biology education and conceptual change strategies. *Educational Sciences: Theory & Practice*, *3*(1), 55-64.

Bilgin, I. (2006). Promoting pre-service elementary students' understanding of chemical equilibrium through discussions in small groups. *International Journal of Science and Mathematics Education*, *4*(3), 467-484. https://doi.org/10.1007/s10763-005-9015-6

Bilgin, I., & Geban, Ö. (2006). The effect of cooperative learning approach based on conceptual change condition on students' understanding of chemical equilibrium concepts. *Journal of Science Education and Technology*, *15*(1), 31-46. https://doi.org/10.1007/s10956-006-0354-z

Boz, Y. (2006). Turkish pupils' conceptions of the particulate nature of matter. *Journal of Science Education and Technology*, *15*(2), 203. https://doi.org/10.1007/s10956-006-9003-9

Campbell N. A., Reece J. B., Urry L. A., Cain M. L., Wasserman S. A., & Minorsky P. V. (2017). *Biology 11th ed*. Jakarta. Penerbit Erlangga.

Çalik, M., Ayas, A., & Coll, R. K. (2009). Investigating the Effectiveness of an Analogy Activity in Improving Students' Conceptual Change for Solution Chemistry Concepts. *International journal of science and mathematics education*, *7*(4), 651-676. https://doi.org/10.1007/s10763-008-9136-9

Çepni, S., Taş, E., & Köse, S. (2006). The effects of computer-assisted material on students' cognitive levels, misconceptions and attitudes towards science. *Computers & Education*, *46*(2), 192-205. https://doi.org/10.1016/j.compedu.2004.07.008

Champagne, A. B., Klopfer, L. E., & Gunstone, R. F. (1983). Naive knowledge and science learning. *Research in Science & Technological Education*, *1*(2), 173-183. https://doi.org/10.1080/0263514830010205

Chen, Y. L., Pan, P. R., Sung, Y. T., & Chang, K. E. (2013). Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. *Journal of Educational Technology & Society*, *16*(2), 212-227.

Çibik, A., Diken, E. H., & Darçin, E. S. (2008). The effect of group works and demonstrative experiments based on conceptual change approach: Photosynthesis and respiration. *Asia-Pacific Forum on Science Learning & Teaching*, *9*(2), 1-22.

De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, *68*(2), 179–201. https://doi.org/10.3102/00346543068002179

Devetak, I., Vogrine, J., & Glazar, S. A. (2007). Assessing 16-year-old students' understanding of aqueous solution at submicroscopic level. *Research in Science Education*, *39*, 157–179. https://doi.org/10.1007/s11165-007-9077-2

Dikmenli, M. (2010). Misconceptions of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essays*, *5*(2), 235-247.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, *5*, 61-84. https://doi.org/10.1080/03057267808559857

Dykstra, D. I., Boyle, C. F., & Monarch, I. A. (1992). Studying conceptual change in learning physics. *Science Education*, *76*(6), 615-652. https://doi.org/10.1002/sce.3730760605

Erman, E. (2017). Factors contributing to students' misconceptions in learning covalent bonds. *Journal of Research in Science Teaching*, *54*(4), 520-537. https://doi.org/10.1002/tea.21375

Gabel, D. (1998). The complexity of chemistry and implications for teaching. *International handbook of science education*, *1*, 233-248. https://doi.org/10.1007/978-94-011-4940-2_15

Galili, I., Bendall, S., & Goldberg, F. (1993). The effects of prior knowledge and instruction on understanding image formation. *Journal of research in science teaching*, *30*(3), 271-301. https://doi.org/10.1002/tea.3660300305

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education*, *22*(1), 57-88. https://doi.org/10.1080/095006900290000

Goldberg, F. M., & McDermott, L. C. (1987). An investigation of student understanding of the real image formed by a converging lens or concave mirror. *American Journal of Physics*, *55*(2), 108-119. https://doi.org/10.1119/1.15254

Gudyanga, E., & Madambi, T. (2014). Pedagogics of chemical bonding in Chemistry; perspectives and potential for progress: The case of Zimbabwe secondary education. *International Journal of Secondary Education*, *2*(1), 11-19. https://doi.org/10.11648/j.ijsedu.20140201.13

Gürel, D. K., & Eryilmaz, A. (2013). A content analysis of physics textbooks as a probable source of misconceptions in geometric optics. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *28*(2), 234-245.

Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research. *American Journal of Physics*, *64*(10), 1316-1325. https://doi.org/10.1119/1.18376

Heng, C. K., & Karpudewan, M. (2017). Facilitating Primary School Students' Understanding of Water Cycle through Guided Inquiry-Based Learning. In *Overcoming Students' Misconceptions in Science* (pp. 29-49). Springer, Singapore. https://doi.org/10.1007/978-981-10-3437-4_3

Jimoyiannis, A., & Komis, V. (2001). Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion. *Computers & education*, *36*(2), 183-204. https://doi.org/10.1016/S0360-1315(00)00059-2

Kaltakci, D., & Eryilmaz, A. (2010). Sources of Optics Misconceptions. In G. Çakmakçı & M. F. TaĞar (Eds.), *Contemporary Science Education Research: Learning and Assessment* (pp.13-16). Ankara, Turkey: Pegem Akademi.

Konicek-Moran, R., & Keeley, P. (2015). *Teaching for conceptual understanding in science*. NSTA Press, National Science Teachers Association.

Kutluay, Y. (2005). *Diagnosis of eleventh grade students' misconceptions about geometric optic by a three-tier test* (Unpublished master thesis), Middle East Technical University, Ankara.

Langley, D., Ronen, M., & Eylon, B. S. (1997). Light propagation and visual patterns: Preinstruction learners' conceptions. *Journal of Research in Science Teaching*, *34*(4), 399-424. https://doi.org/10.1002/(SICI)1098-2736(199704)34:4<399::AID-TEA8>3.0.CO;2-M

Ling, T. W. (2017). Fostering Understanding and Reducing Misconceptions about Image Formation by a Plane Mirror Using Constructivist-Based Hands-on Activities. In *Overcoming Students' Misconceptions in Science* (pp. 203-222). Springer Singapore. https://doi.org/10.1007/978-981-10-3437-4_11

Manolas, E., & Leal Filho, W. (2011). The use of cooperative learning in dispelling student misconceptions on climate change. *Journal of Baltic Science Education*, *10*(3), 168-182.

MoEC (Ministry of Education and Culture). (2017). Ilmu Pengetahuan Alam untuk SMP/MTs Kelas 8 [*Science for Grade 8 Junior High School*]. Jakarta: Kementerian Pendidikan dan Kebudayaan.

Moosa, S. (2015). *The use of simulations in supporting grade 10 learners from under-performing Dinaledi schools in Soweto to eliminate their misconceptions on simple electric circuits* (Doctoral dissertation). University of Johannesburg, South Africa.

Nakhleh, M. B. (1992). Why some students do not learn chemistry: Chemical misconceptions. *Journal of chemical education*, *69*(3), 191-196. https://doi.org/10.1021/ed069p191

Nieswandt, M. (2007). Student Affect and Conceptual Understanding in Learning Chemistry. *Journal of Research in Science Teaching*, *44*(7), 908–937. https://doi.org/10.1002/tea.20169

National Science Teacher Association. (2015). *Teaching For Conceptual Understanding*. USA: David Beacom, Publisher.

Osborne, R. J., Bell, B. F., & Gilbert, J. K. (1983). Science teaching and children's views of the world. *European Journal of Science Education*, *5*(1), 1-14. https://doi.org/10.1080/0140528830050101

Osman, K. (2017). Addressing Secondary School Students' Misconceptions about Simple Current Circuits Using the Learning Cycle Approach. In *Overcoming Students' Misconceptions in Science* (pp. 223-242). Springer, Singapore. https://doi.org/10.1007/978-981-10-3437-4_12

Ozmen, H. (2004). Some student misconception in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology*, *13*, 147–159. https://doi.org/10.1023/B:JOST.0000031255.92943.6d

Pompea, S. M., Dokter, E. F., Walker, C. E., & Sparks, R. T. (2007). Using misconceptions research in the design of optics instructional materials and teacher professional development programs. In *Education and Training in Optics and Photonics*. Optical Society of America. https://doi.org/10.1364/ETOP.2007.EMC2

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Puk, T., & Stibbards, A. (2011). Growth in Ecological Concept Development and Conceptual Understanding in Teacher Education: The Discerning Teacher. *International Journal of Environmental and Science Education*, *6*(3), 191-211.

Ramnarain, U., & Moosa, S. (2017). The Use of Simulations in Correcting Electricity Misconceptions of Grade 10 South African Physical Sciences Learners. *International Journal of Innovation in Science and Mathematics Education*, *25*(5), 1-20.

Ray, A. M., & Beardsley, P. M. (2008). Overcoming student misconceptions about photosynthesis: A model- and inquiry-based approach using aquatic plants. *Science Activities: Classroom Projects and Curriculum Ideas*, *45*(1), 13-22. https://doi.org/10.3200/SATS.45.1.13-22

Saputri, D. F., & Nurussaniah, N. (2015). Penyebab Miskonsepsi Pada Optika Geometris [Causes of Misconceptions in Geometric Optics]. *Prosiding Seminar Nasional Fisika (E-journal)*, *4*, 33-36.

Satilmiş, Y. (2014). Misconceptions about Periodicity in Secondary Chemistry Education: The Case of Kazakhstan. *International Online Journal of Primary Education*, *3*(2), 53-58.

Saul, J., & Redish, E. F. (1999). *A comparison of pre and post FCI results for innovative and traditional introductory calculus-based physics classes*. APS Southeastern Section Meeting Abstract.

Smith III, J. P., Disessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The journal of the learning sciences*, *3*(2), 115-163. https://doi.org/10.1207/s15327809jls0302_1

Suniati, N. M. S., Sadia, I. W., & Suhandana, G. A. (2013). Pengaruh Implementasi Pembelajaran Kontekstual Berbantuan Multimedia Interaktif Tehadap Penurunan Miskonsepsi (Studi Kuasi Eksperimen Dalam Pembelajaran Cahaya Dan Alat Optik Di SMP Negeri 2 Amlapura) [Effect of Implementation of Assisted Contextual Learning Interactive Multimedia towards Misconceptions (Quasi Study Experiment in Light and Optical Instrument in SMP Negeri 2 Amlapura)]. *Jurnal Administrasi Pendidikan Indonesia*, *4*(1).

Taber, K. S. (2009). *Progressing science education: Constructing the scientific research programme into the contingent nature of learning science* (Vol. 37). Springer Science & Business Media.

Taşlıdere, E. (2013). Effect of conceptual change oriented instruction on students' conceptual understanding and decreasing their misconceptions in DC electric circuits. *Creative Education*, *4*(4), 273-282. https://doi.org/10.4236/ce.2013.44041

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994): Research on instructional strategies for teaching science. *Handbook of research on science teaching and learning*, *45*, 93.

Thompson, F., & Logue, S. (2006). An exploration of common student misconceptions in science. *International Education Journal*, *7*(4), 553-559.

Treagust, D., Chittleborough, G., & Mamiala, T. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, *25*(11), 1353-1368. https://doi.org/10.1080/0950069032000070306

Tyson, L., Treagust, D. F., & Bucat, R. B. (1999). The complexity of teaching and learning chemical equilibrium. *Journal of Chemical Education*, *76*(4), 554-558. https://doi.org/10.1021/ed076p554

Vosniadou, S. (2002). On the nature of naïve physics. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 61-76). Dordrecht, the Netherlands: Kluwer. https://doi.org/10.1007/0-306-47637-1_3

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. *Handbook of research on science teaching and learning* (pp. 177-210). New York: Macmilan.

Widarti, H. R., Permanasari, A., & Mulyani, S. (2016). Student misconception on redox titration (a challenge on the course implementation through cognitive dissonance based on the multiple representations). *Jurnal Pendidikan IPA Indonesia*, *5*(1), 56-62.

Yalcin, M., Altun, S., Turgut, U., & Aggül, F. (2009). First year Turkish science undergraduates' understandings and misconceptions of light. *Science & Education*, *18*(8), 1083-1093. https://doi.org/10.1007/s11191-008-9157-3

Yong, C. L., & Kee, C. Z. (2017). Utilizing concept cartoons to diagnose and remediate misconceptions related to photosynthesis among primary school students. In *Overcoming Students' Misconceptions in Science* (pp. 9-27). Springer, Singapore. https://doi.org/10.1007/978-981-10-3437-4_2