# EFFECTIVENESS OF FLIP-BOOK OPTIC DEVICES BASED ON PROBLEM BASED LEARNING ASSISTED WITH VIRTUAL LABORATORY SIMULATION TO IMPROVE HIGH SCHOOL STUDENTS' VISUAL REPRESENTATION

## LA EFECTIVIDAD DE DISPOSITIVOS ÓPTICOS FLIP-BOOK BASADOS EN EL APRENDIZAJE EN BASE A PROBLEMAS ASISTIDO CON SIMULACIÓN DE LABORATORIO VIRTUAL PARA MEJORAR LA REPRESENTACIÓN VISUAL DE LOS ESTUDIANTES DE SECUNDARIA

R. Sebastian[a,b†], H. Kuswanto[a], J. Jumadi[a,c], N. P. Putri-Haspari[a]

a) Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta. Jl. Colombo No. 1, Sleman, Yogyakarta, 55281, Indonesia. riosebastian.2022@student.uny.ac.id
b) Department of Physics Education, Universitas Sarjanawiyata Tamansiswa, Jl. Batikan UH.III/1043, Yogyakarta 55167, Indonesia.
c) Department of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta. Jl. Colombo No. 1, Sleman, Yogyakarta, 55281, Indonesia
† corresponding author

Recibido 20/09/2023; Aceptado 20/11/2023

Optical devices are a complex material, most of the concepts are related to abstraction and visualization such as the formation of shadows and light trails, so that a good visual representation is needed to achieve this material competence. Visual representation in physics learning is important, but some teachers still find it difficult to instill this ability due to media constraints. Therefore, this study uses PBL-based flip-book media assisted by virtual laboratory simulations to overcome this problem. This study aims to determine the effectiveness of PBL-based flip-books assisted by Virtual Laboratory Simulation in improving students' visual representation skills on optical instrument material. The method used is quantitative with quasi-experimental methods, pretest and posttest through instruments based on visual representation indicators. The experiment was conducted in grade 11 of senior high school's student. The results of this study indicate that the use of PBL-based flip-books assisted by Virtual Simulation has a positive effect on students' visual representation abilities. This is shown in the acquisition of the N-Gain value of 0.828 in the high category. This study concludes that the use of PBL-based flip-books assisted by virtual lab simulations improves students' visual representation abilities.

Los dispositivos ópticos son un material complejo, la mayoría de los conceptos están relacionados con la abstracción y la visualización como la formación de sombras y estelas de luz, por lo es necesaria una buena representación visual para lograr competencia en este material. La representación visual en el aprendizaje de la física es importante, pero a algunos profesores todavía les resulta difícil inculcar esta habilidad debido a las limitaciones de los medios. Por lo tanto, este estudio utiliza medios de libro animado basados en PBL asistidos por simulaciones de laboratorio virtual para superar este problema. Este estudio tiene como objetivo determinar la efectividad de los flip-books basados en ABP asistidos por la simulación de laboratorio virtual para mejorar las habilidades de representación visual de los estudiantes en el material de instrumentos ópticos. El método utilizado es cuantitativo con métodos cuasi-experimentales, pretest y postest a través de instrumentos basados en indicadores de representación visual. El experimento se llevó a cabo en el grado 11 de la escuela secundaria. Los resultados de este estudio indican que el uso de flipbooks basados en ABP asistidos por Simulación Virtual tiene un efecto positivo en las habilidades de representación visual de los estudiantes. Esto se muestra en la adquisición del valor de N-Gain de 0,828 en la categoría alta. Este estudio concluye que el uso de flip-books basados en ABP asistidos por simulaciones de laboratorio virtual mejora las habilidades de representación visual de los estudiantes.

PACS: Computer as educational aids (la computación como ayuda educativa), 01.50.H-; optical devices (dispositivos óticos), 42.79.-e; physics education (educación física), 01.40.-d; teaching methods (métodos de enseñanza), 01.40.gb; visual perception (percepción visual), 42.66.Si.

## I. INTRODUCTION

In learning physics, students cannot be separated from the abstraction and analysis of an image case or demonstration to understand the concepts and principles of physics. Visual representation as one of the representation abilities used to understand physics learning through an image, diagram, or graph that is presented in the case of physics problems. Visual representation is an ability to understand an image, diagram, table and graph [1]. Visual representations consist of notational representations that attempt to reduce reality in a particular way and non-notational representations that provide a view of the various complex meanings of reality. [2]. However, some of these representations need to be interpreted from one form to another so that this ability can be applied easily to solve multi-representational problems [3]. Visual representation for students plays an important role in creating information, understanding abstract text retention and communicating scientific phenomenon data for problem solving in the learning process [4, 5]. In physics learning, the importance of developing visual representations can foster science process and problem solving skills in students' scientific method processes [6, 7]. However, visual representation is a complex ability and consists of many components at different levels, so that students face difficulties in replicating the visuals they have in mind [8–10].

Difficulties in visualizing often arise in physics learning, because the material is abstract and complex, one of which is optical instrument material [11, 12]. Optical instrument material is a difficult topic in basic physics, because it involves complex abstractions and concepts that make it difficult for students to understand and misconceptions are often found [13, 14]. Most of the problems with this optical instrument material come from the problem of visual representations of students [15, 16]. This is supported by the research of Özdemir which states that the level of conceptual understanding of optometrists regarding optical materials and light is still low, which indicates that there are still misconceptions and difficulties in describing optical cases precisely [17]. In addition, the use of textbooks which are commonly used in schools does not support students in developing optical instrument material activities directly and tends to be low in inquiry [18]. Therefore, learning optical devices requires a medium that can help students visualize while directing students in building abstract and complex concepts, one of which is a Flip-book assisted by virtual laboratory simulations.

The use of flip-books in the learning process is an innovative learning media in the technological era that can facilitate the fulfillment of student teaching materials. Flip-book is an electronic book device that is equipped with multimedia such as sound images, animations and videos interactively which aims to make it easier for students to access in real time [19, 20]. Basically, flip-book technology is an animation that is designed from a pile of paper that resembles a thick book on each page and is abstracted as an animated process [21]. The use of Flip-books has several advantages which include making it easy for students to access them, interactive displays, environmentally friendly because they save paper use, are not easily damaged, more affordable prices and have multimedia [19, 22]. This is supported by research by Suyasa and Aswanti who developed flip-book media that can help improve student cognitive learning outcomes and critical thinking skills [23, 24]. Therefore, the presentation of instructional media in the form of flip-books is of interest to students so that they can be motivated and easily accept concepts presented through multimedia such as pictures, sound or videos. Even to support physics experiments, you can add a virtual laboratory link into the flip-book.

Most of the physics learning in schools is still difficult to do practicum because there are several constraints both infrastructure and time factors. While practicum is important for students to develop abstraction skills and abilities. However, this can be overcome in the current technological era, namely using a virtual laboratory. A virtual laboratory is a software that is used to carry out practical simulations of influences, investigations or phenomena in learning without explaining verbally via virtual [25]. Virtual laboratories can help students make observations and discover a concept effectively and practically [26]. The use of virtual laboratories can visualize physical phenomena and their concepts with animation and simulate concepts related to students' daily lives so as to develop students' mastery of abstraction, motivation, learning interest and understanding of concepts [27,28]. Practicum activities through a virtual laboratory have a positive impact on scientific skills, and visual representation of students [29, 30]. The advantages of a virtual laboratory include providing safety, security because it does not interact with real tools and materials that are at risk, makes it easier for students to practice repeatedly, provides easy access in conducting practicums, and minimizes the cost of procuring practicum materials [31, 32]. In previous research, Abdjul stated that the development and implementation of virtual laboratory-assisted learning obtained very good responses from students and had a significant increase in learning outcomes after the learning process [33]. Furthermore, it is supported by Husnaini's research results which state that learning using virtual laboratories can have a positive impact on students' multiple representations, one of which is visual representation [34]. Therefore, the use of virtual laboratories can be applied in learning physics on abstract and complex material so that it can improve students' visual representation skills. However, the expected visual representation in physics learning must be able to solve a problem so that a learning model is needed, namely Problem Based Learning (PBL).

Problem-based learning is a learning model that presents a problem to motivate students to understand concepts, so that it emphasizes solving students' real problems in collaboration or active group discussion under the direction of the teacher [35–37]. An indication of the success of the Problem Based Learning model is in encouraging students to be more active in applying all information, finding problems, and planning solutions in creative and innovative ways [38, 39]. The impact of applying the problem based learning model is that students can have skills in communicating, solving problems, critical thinking, and learning independently [40, 41]. In addition, the problem-based learning model combined with TPACK (Technology, Pedagogy and Content Knowledge) has a positive impact on learning outcomes and learning activities which are characterized by students who are enthusiastic and enthusiastic about participating in the learning process [42]. This is supported by Fidan and Prahani's research. By applying the problem based learning model in learning technology media, students can improve achievement, solve problems and have a positive attitude towards physics [43,44]. Therefore, the Problem Based Learning model can support this research to direct students' visual representation abilities that can solve problems in physics concepts.

Therefore, in this study the implementation of Flip-book learning media will be carried out on optical instrument material using the Problem Based Learning model with the help of virtual laboratory simulations so that learning is more interactive, and provides easy visualization to students on the abstract concept of optical devices. In addition, this research was conducted to have a positive impact on students' visual representation abilities in learning physics, one of which is optical instrument material. Based on several existing exigencies, this study aims to determine the effectiveness of PBL-based flip-books assisted by Virual Laboratory Simulation in improving students' visual representation skills on optical instrument material.

## II. METHOD

This research is a quasi-experimental research that uses a one group pretest-posttest research design. The research was conducted in March-April 2023 at State Senior High School 4 Yogyakarta. The sample used in this research was 61 students from grade 11 who were taken from two classes from 5 classes majoring in MIPA. The research sampling technique uses a cluster sampling technique. Derived from the word cluster which means natural grouping of people, this technique involves taking a random cluster sample from the population with all members from each cluster selected so that each cluster has the same probability of being selected [45]. Research data collection was carried out using test instruments in the form of descriptions with visual representation indicators including: (1) understanding of visual information; (2) processing information into cognitive structures; (3) externalization of information as a visual model [46]. The test instrument is used to measure the increase in students' visual representation abilities from the impact of using Flip-Book Optical Tools Based on Problem Based Learning Assisted by Virtual Laboratory Simulation. In the description test instrument, visual representation indicators have been validated by experts so that it is feasible to be used to measure visual representation abilities. The visual representation ability test instrument in this study has detailed question indicators which can be shown in appendix. Meanwhile, in research data analysis technique using inferential analysis to determine the impact of using flip-book, through the acquisition of students' pretest and posttest scores so that the N-Gain test equation can be determined as shown in eq. 1.

$$N - gain = \frac{\bar{X}_{PostTest} - \bar{X}_{PreTest}}{max.value - \bar{X}_{PreTest}} \tag{1}$$

The categorization of the N-Gain test scores was carried out with reference to the categories of Hake which are shown in Table 1.

Table 1. Categories of N-Gain Test Values ??

| N-Gain Value | Criteria |
|---|---|
| 0.00<g<0.30 | Low |
| 0.30<g<0.70 | Moderate |
| 0.70<g<1.00 | High |

Based on Table 1, the N-Gain value refers to the category of impact on visual representation ability from using Flip-books which consists of three categories including high, medium, and low. Before the N-Gain test was carried out, there was an analysis of the prerequisite tests for normality and homogeneity using the SPSS 22.0 number processing software.

## III. RESULTS AND DISCUSSION

### *III.1. Flip-Book of Problem Based Learning Optical Devices Assisted by Virtual Laboratory Simulation*

In this study, testing the effectiveness of using Flip-books on optical instrument materials using the Problem Based Learning (PBL) learning model with the help of virtual lab simulations. The flip-book product in this study can be accessed using the link https://heyzine.com/flip-book/7ba49ea339.html. The flip-book design was designed using the Canva application to create attractive and innovative template designs. The flip-book is integrated through the heyzine flip-book in html form that is easy for students to access and creates a flip effect on physics flip-books so that students are not bored and are motivated in learning physics on optical instruments. This is also supported by research by Sunaryo & Qumillaila that the flip-book design using Canva has a media expert's assessment in the very proper category and can increase students' interest in learning and high order thinking skills, [48, 49]. Initial appearance of the cover from the optical instrument physics flip-book can be seen in Fig. 1.

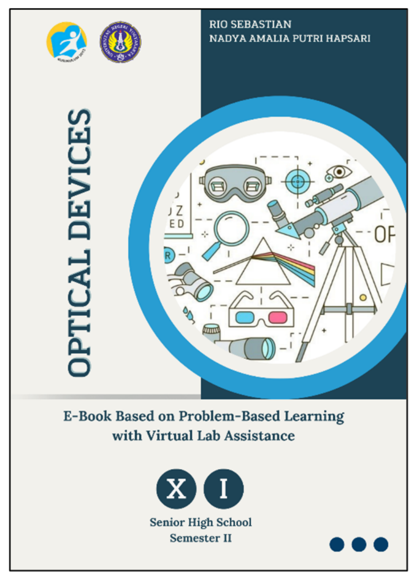


Figure 1. View of the Flip-Book cover.

Based on Fig. 1, shows the initial display menu on the Flip-book in the heyzine flip-book integration, where there are zoom, fullscreen and speaker icons as well as the book page turning icon. The zoom icon has functions to zoom in and zoom out, the fullscreen icon to enter full screen mode on our device and the speaker icon to make sound settings in the flip-book.

The optical device physics flip-book is embedded with a student appreciative video as a trigger for problems in the material to be studied because it is adapted to the syntax of the Problem Based Learning model. The apperception video in the flip-book is also followed by questions that can be answered via the Google form link related to the problems in the video. Multimedia elements using videos in learning help students become interested in understanding the material so they are more active and concentrated in the learning process [50,51]. In previous studies, the use of flip-books with interactive videos, animation, and audio has legibility and validity criteria that are appropriate for use in learning which can create an interesting and active learning atmosphere [52]. The themes of the problem appreciation videos in the flip-book include eyes, glasses, cameras, lenses, microscopes, binoculars, and periscopes. One of the apperception video displays can be shown in Fig. 2.


Figure 2. Apperception and Question Video Display.

Based on Fig. 2, to start a video, you can click the start icon on the video and there is a menu icon and speaker icon. The menu icon is for making video settings such as fullscreen mode, speeding up or slowing down the video. Meanwhile, on the speaker icon to adjust the sound. In the column section of the question answer sheet, you can click on it which is directly connected to the Google form link to answer questions.

In the physics flip-book, optical devices to support practicum activities in learning are using a virtual lab simulation whose link is embedded in the flip-book so that it can be easily accessed by students via smartphone devices. The virtual lab simulation used is vascak.cz, a virtual laboratory originating from the Czech Republic which can be accessed in general, both for use from secondary to higher education in science [53]. The appearance of one of the virtual lab simulations in the flip-book can be shown in Fig. 3.

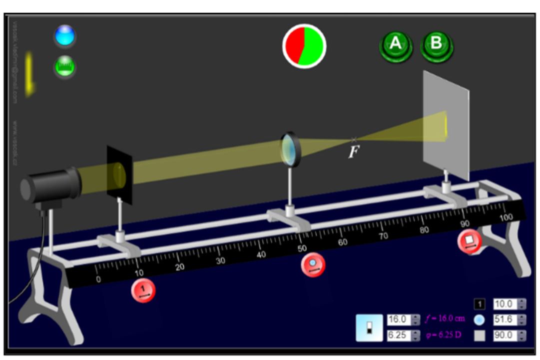


Figure 3. Display of a Virtual Laboratory Simulation in a Flip-book.

Based on Fig. 3, students can freely explore and manage variables in a virtual laboratory simulation by utilizing the available icons. Through the virtual laboratory, students can carry out and experience virtual physics practicum so that students can easily and practically understand the concepts of optical devices. The use of virtual laboratories allows students to carry out experiments like facing real laboratory equipment so that it is more practical, efficiency, satisfaction, playfulness and affordable [54]. In addition, through virtual practicum, it makes it easy for students to build concepts and inquiry performance, because it can facilitate complex visualization [34]. The virtual laboratory simulations used in the flip-book include: eye accommodation, eye defects, negative glasses, positive glasses, bifocal glasses, loops, microscopes, Newtonian telescopes, Keplerian telescopes and Galerian telescopes. Virtual laboratory simulations are intended to support student learning in order to better understand the concept of optical instrument material contextually.

### III.2. *Prerequisite & N-Gain Test of Visual Representation Ability Assessment*

The results of this study are in the form of measuring pretest and posttest scores using a description test instrument with visual representation indicators. The distribution of students' pretest and posttest data values can be shown using the scatter plot in Fig. 4.

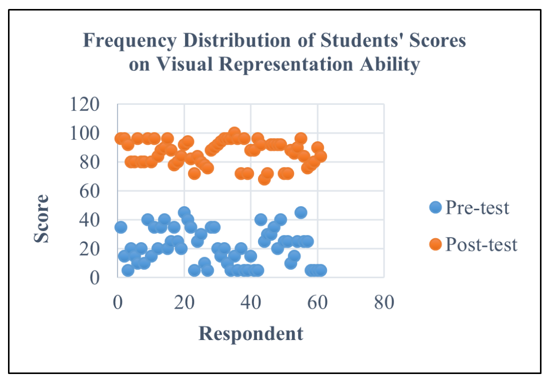


Figure 4. Distribution of Student Scores on the Pretest and Posttest.

Based on Fig. 4, it is shown that the pretest scores and posttest scores for each student experienced a significant increase. This is supported by the research of Abdjul that the use of virtual laboratory-assisted flip-books has a positive impact on student learning activities with a significant increase [33]. In the visual representation measurement data before being analyzed using the N-Gain value, prerequisite tests are first carried out which consist of normality and homogeneity tests. In the normality test, it functions to ensure that the data on student scores obtained is normally distributed through the Shapiro-Wilk test which states that the normal data requirements are sig. $> 0.05$ [55, 56]. The results of the normality test of the measurement data for the visual representation of each indicator can be shown in Table 2.

In Table 2, it shows that all 61 students' pretest and posttest scores for each visual representation indicator have a normal distribution because they have a significance value that exceeds 0.05 in the Shapiro-Wilk method. Meanwhile, in testing the homogeneity of the data, student scores were tested using the Levene's Test which was used to determine the similarity of the variants of the pretest and posttest data. In Levene's homogeneity test, data is considered homogeneous if the significance value is more than 0.05 (sig. > 0.05). The results of the analysis of the homogeneity of the data on student scores are shown in Table 3 which presents the Levene' test for each indicator of visual representation ability.

Table 2. Data Normality Test Results for Each Visual Representation Indicator

| Visual Representation Indicator | Shapiro-wilks | | | | N |
|---|---|---|---|---|---|
| | Pre-test | | Post-test | | |
| | Stat. | Sig. | Stat. | Sig. | |
| Understanding Visual Information | 0.983 | 0.557 | 0.985 | 0.649 | 61 |
| Process information into cognitive structures | 0.990 | 0.888 | 0.989 | 0.846 | |
| Externalization of information as a visual model | 0.977 | 0.297 | 0.980 | 0.398 | |

Table 3. Data Homogeneity Test Results for Each Visual Representation Indicator

| Visual Representation Indicator | Levene's Test | | N |
|---|---|---|---|
| | Statistic | Sig. | |
| Understanding Visual Information | 1.581 | 0.211 | 61 |
| Process information into cognitive structures | 2.548 | 0.113 | |
| Externalization of information as a visual model | 2.376 | 0.126 | |

In Table 3 it can be seen that the significance value of the three visual representation indicator data has a value of more than 0.05 so that it can be stated that the pretest and posttest value data for measuring students' visual representation abilities are homogeneous. After the visual representation measurement values have been tested for normality and homogeneity, an analysis of the N-Gain value test data is performed to determine the level of effectiveness of the use of Problem-Based Learning Optical Equipment-Based Flip-Books Assisted by Virtual Laboratory Simulation in improving students' visual representation skills. The results of obtaining the N-Gain value from the visual representation measurement data can be shown in Table 4.

In Table 4, the visual representation of each indicator can be visualized in a graph to facilitate the interpretation of the results of the N-Gain score shown in Fig. 5.

Based on the interpretation of Table 4 and Fig. 5, it can be seen that the information externalization indicator as a visual model has the highest N-Gain score in the high category, while the lowest N-Gain score is in the medium category indicator of processing information into cognitive structures. The indicator of information externalization as a visual model is an indicator of visual representation ability which is characterized by students being able to receive information stimulus in the form of pictures or diagrams and then being able to rewrite the visual model according to their own understanding in the form of pictures, verbal or diagrams. This is because the use of virtual laboratory simulations on flip-books can stimulate students to form concepts independently and contextually. Supported by the research of Arista & Kuswanto microscopic and macroscopic phenomena can be visualized through a virtual laboratory so students can clearly observe them [27]. This is also in line with the research of Gunawan that virtual laboratories can visualize physics concepts so that they are easy to understand [29]. In addition, integrating flip-books using graphics in the form of a virtual laboratory provides effectiveness in students' visual representation abilities [2].

Table 4. Results of N-Gain Values for Each Visual Representation Indicator

| Visual Representation Indicator | Pre-test Mean | Post-test mean | N-Gain Score | Criteria |
|---|---|---|---|---|
| Understanding Visual Information | 30 | 84 | 0.773 | High |
| Process information into cognitive structures | 30 | 68 | 0.546 | Moderate |
| Externalization of information as a visual model | 28 | 91 | 0.882 | High |

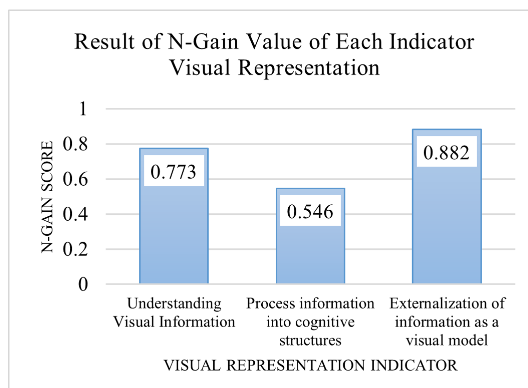


Figure 5. Result of N-Gain Value for Each Visual Representation Indicator.

In the indicator of processing information into cognitive structure, the N-Gain value is the lowest compared to other visual representation indicators where this indicator is marked in students being able to process information obtained from an image, diagram, or graph into an analysis and interpretation of problem solving. This is because in the presentation of flip-books assisted by virtual lab simulations, it does not present enough practice questions and examples of various questions related to visual representation abilities, and emphasizes more on virtual laboratory simulation activities. Overall the N-Gain score indicators obtained in this study based on measurements through visual representation ability test instruments can be shown in Table 5.

Table 5. Results of the Overall N-Gain Value of the Visual Representation Ability Indicator

| Test Phase | Pre-test mean | Post-test Mean |
|---|---|---|
| Mean | 21 | 86 |
| N | 61 | |
| N-Gain | 0.828 | |
| Category | High | |

Based on Table 5, it can be stated that the impact of using the Flip-Book on Optical Devices Based on Problem Based Learning Assisted by Virtual Laboratory Simulation in improving students' visual representation abilities is classified as in the high category, therefore the use of the flip-book is a recommendation as a physics learning medium applicable in a school environment. This is supported by previous research that the use of virtual laboratory-assisted flip-books can assist teachers in simulating and explaining abstract concepts that cannot be explained verbally so that students' visual representation abilities develop [33, 57]. In addition, learning using flip-books assisted by a virtual laboratory can help students' independent learning processes, learning motivation, conceptual understanding, and creative thinking [27,58,59]. Therefore, the use of problem-based learning-based flip-books assisted by virtual laboratory simulations can be a good and appropriate learning medium for use in physics learning, especially to improve visual representation skills.

## IV. CONCLUSION

Based on the results of the study, the use of Flip-Book media for Problem-Based Learning with the Assistance of Virtual Laboratory Simulation has a positive impact on students' visual representation abilities with an N-Gain value of 0.828 which is included in the high category. Each indicator of visual representation ability appears in the use of a flip-book with the indicator having the highest N-Gain value on the information externalization indicator as a visual model with the high category and the lowest N-Gain value on the indicator processing information into cognitive structure with the medium category.

## V. ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to Universitas Negeri Yogyakarta (UNY) for providing the opportunity to conduct this research. The support and resources provided by UNY have been invaluable in the successful completion of this study. The authors would also like to extend their heartfelt appreciation to the LPDP (Lembaga Pengelola Dana Pendidikan/ The Indonesia Endowment Funds for Education) for funding this research. The financial support from LPDP has greatly contributed to the progress and accomplishment of this study. Furthermore, the authors would like to acknowledge the guidance and support received from their supervisors and colleagues throughout the research process. Their valuable insights and feedback have been instrumental in shaping the direction and quality of this study. Lastly, the authors would like to express their deepest gratitude to all the participants who willingly participated in this research. Their cooperation and involvement have been essential in gathering the necessary data for analysis.

## REFERENCIAS

[1] M. Evagorou, S. Erduran, and T. Mäntylä, Int. J. STEM Educ. **2**, 1 (2015).
[2] B. Wei, C. Wang, and L. Tan, Phys. Rev. Phys. Educ. Res. **18**, 20138 (2022).
[3] B. Mainali, Int. J. Educ. Math. Sci. Technol. **9**, 1 (2021).
[4] L. Pauwels, Soc. Semiot. **33**, 426 (2023).
[5] N. D. LaDue, J. C. Libarkin, and S. R. Thomas, J. Sci. Educ. Technol. **24**, 818 (2015).
[6] B. Priemer et al., Res. Sci. Technol. Educ. **38**, 105 (2020).
[7] H. Matovu et al., Stud. Sci. Educ. **59**, 205 (2023).
[8] B. Eilam and J. K. Gilbert, Science teachers' use of visual representations (Springer International Publishing, New York, 2014).
[9] L. E. Mnguni, Springerplus **3**, 1 (2014).
[10] F. Y. Yang and H. Y. Wang, Comput. Educ. **193**, 104659 (2023).
[11] S. Cai, C. Liu, T. Wang, E. Liu, and J. C. Liang, Br. J. Educ. Technol. **52**, 235 (2021).
[12] E. İbili, M. Çat, D. Resnyansky, S. Şahin, and M. Billinghurst, Int. J. Math. Educ. Sci. Technol. **51**, 224 (2020).
[13] A. Widiyatmoko and K. Shimizu, Int. J. Environ. Sci. Educ. **13**, 853 (2018).
[14] E. Aregehagn, A. Lykknes, D. A. Getahun, and M. I. M. Febri, Educ. Sci. **13**, 445 (2023).
[15] H. -S. Wang, S. Chen, and M.-H. Yen, Am. J. Phys. **86**, 777 (2018).
[16] L. Xu, V. Prain, and C. Speldewinde, Int. J. Sci. Educ. **43**, 844 (2021).
[17] E. Özdemir, M. Coramik, and H. Ürek, Int. J. Educ. Math. Sci. Technol. **8**, 53 (2020).
[18] S. Gumilar and A. Ismail, Res. Sci. Technol. Educ. **41**, 614 (2023).
[19] D. Maynastiti, V. Serevina, and I. Sugihartono, J. Phys. Conf. Ser. **1481**, 012076 (2020).
[20] E. Mnkandla and A. Minnaar, Int. Rev. Res. Open Distance Learn. **18**, 227 (2017).
[21] Y. Asri and Y. Fitriani, AIP Conf. Proc. **1867**, 2017.
[22] A. Mardikaningsih and P. Kurniasari, Taman Vokasi **6**, 215 (2018).
[23] P. W. A. Suyasa, D. G. H. Divayana, and M. R. Kristiantari, J. Phys. Conf. Ser. **1810**, (2021).
[24] N. H. Aswanti and W. Isnaeni, Res. Eval. Educ. **9**, 37 (2023).

[25] S. M. Reeves and K. J. Crippen, J. Sci. Educ. Technol. **30**, 16 (2021).
[26] T. Hardianti, and S. Fitriana, Int. J. Instr. **15**, 101 (2022).
[27] F. S. Arista and H. Kuswanto, Int. J. Instr. **11**, 1 (2018).
[28] W. Tarng, C. L. Liu, C. Y. Lee, C. M. Lin, and Y. C. Lu, Comput. Appl. Eng. Educ. **27**, 472 (2019).
[29] G. Gunawan, N. Nisrina, N. M. Y. Suranti, L. Herayanti, and R. Rahmatiah, J. Phys. Conf. Ser. **1108** (2018).
[30] R. Taibu, L. Mataka, and V. Shekoyan, Int. J. Educ. Math. Sci. Technol. **9**, 353 (2021).
[31] M. Masril, H. Hidayati, and Y. Darvina, IOP Conf. Ser. Mater. Sci. Eng. **335**, 012069 (2018).
[32] K. A. A. Gamage, D. I. Wijesuriya, S. Y. Ekanayake, A. E. W. Rennie, C. G. Lambert, and N. Gunawardhana, Educ. Sci. **10**, 1 (2020).
[33] T. Abdjul, N. E. Ntobuo, and C. Payu, J. Pendidik. Fis. Indones. **15**, 97 (2019).
[34] S. J. Husnaini and S. Chen, Phys. Rev. Phys. Educ. Res. **15**, 10119 (2019).
[35] J. A. A. do Amaral and F. Fregni, Int. J. Instr. **14**, 1 (2021).
[36] R. Ramadhani, R. Umam, A. Abdurrahman, and M. Syazali, J. Educ. Gift. Young Sci. **7**, 137 (2019).
[37] H. Tadjer, Y. Lafifi, H. Seridi-Bouchelaghem, and S. Gülseçen, Interact. Learn. Environ. **30**, 1879 (2022).
[38] R. Capone, P. De Caterina, and G. A. G. Mazza, Blended learning, flipped classroom and virtual environment: challenges and opportunities for the 21st century students, EDULEARN17 Conference, 2017.
[39] R. Widyatiningtyas, Y. S. Kusumah, U. Sumarmo, and J. Sabandar, J. Math. Educ. **6**, 30 (2015).
[40] P. Panwong and K. Kemavuthanon, Wirel. Pers. Commun. **76**, 603 (2014).
[41] W. Y. Silviariza, Sumarmi, and B. Handoyo, Int. J. Instr. **14**, 133 (2021).
[42] S. Tanjung, Baharuddin, D. Ampera, Farihah, and I. Jahidin, Int. J. Educ. Math. Sci. Technol. **10**, 740 (2022).
[43] M. Fidan and M. Tuncel, Comput. Educ. **142**, 103635 (2019).
[44] B. K. Prahanı, H. V. Saphıra, F. C. Wıbowo, Mısbah, and N. F. Sulaeman, J. Turkish Sci. Educ. **19**, 1096 (2022).
[45] P. Sedgwick, BMJ **348**, 1 (2014).
[46] R. E. Mayer, *Multimedia Learning* (Cambrigde Unviresity Press, New York, 2009).
[47] R. R. Hake, Am. J. Phys. **66**, 64 (1998).
[48] S. Sunaryo, A. Kushermawati, and M. Delina, Int. J. Innov. Creat. Chang. **11**, 444 (2020).
[49] Qumillaila, A. P. Lestari, Y. Kuboki, and F. Hasim, Developing an E-Flipbook on Environmental Education to Promote Digital Literacy among Elementary School Students and Teachers in Rural Areas in Indonesia, 2022 International Conference on ICT for Smart Society (ICISS), 2022.
[50] A. N. S. I. Septiani, T. Rejekiningsih, Triyanto, and Rusnaini, Eur. J. Educ. Res. **9**, 1267 (2020).
[51] M. Hanif, Int. J. Instr. **13**, 247 (2020).
[52] Setiyani, S. B. Waluya, Y. L. Sukestiyarno, and A. N. Cahyono, Int. J. Interact. Mob. Technol. **16**, 116 (2022).
[53] H. Roziboyevich, "The use of information technology in teaching exact and natural sciences, Eurasian Sci. Her. **14**, 72 (2022).
[54] R. Estriegana, J. A. Medina-Merodio, and R. Barchino, Comput. Educ. **135**, 1 (2019).
[55] E. González-Estrada and W. Cosmes, J. Stat. Comput. Simul. **89**, 3258 (2019).
[56] Q. Iqbal, Glob. Bus. Rev. **21**, 377 (2020).
[57] S. Hurtado-Bermúdez and A. Romero-Abrio, Interact. Learn. Environ. **31**, 1126 (2023).
[58] I. Ladamay, F. N. Kumala, R. H. Susanti, N. Ulfatin, B. B. Wiyono, and S. Rahayu, IOP Conf. Ser. Mater. Sci. Eng. **1098**, 032028 (2021).
[59] R. Oktarina, A. -, M. G. -, F. -, M. Muskhir, and H. Effendi, J. Educ. Technol. **5**, 159 (2021).

Table 6. Indicators of test instruments in measuring visual representation abilities

| Visual Representation Indicator | Number Item | Test instrument indicator |
|---|---|---|
| Understanding Visual Information | 2 | Presented a diagram of rays in the eye by people with eye defects. Students can identify eye defects and the correct glasses to use based on the diagram. |
| | 3 | Presented a diagram of rays in the eye by people with eye defects. Students can determine the right glasses for people with eye defects based on the case diagram. |
| | 7 | Presented an image of camera parts along with the path of light in capturing images, students can abstract the function of camera parts such as the function of parts of the eye. |
| Process information into cognitive structures | 4 | Presented is a diagram of a convex lens in forming rays and shadow. Students can determine the distance of a shadow in this case if they know the focus and distance of the image. |
| | 5 | Presented a graph of the relationship between the distance of the object and the distance of the image in magnifying glass lens. Students can determine the lens focus value based on the graph. |
| Externalization of information as a visual model | 1 | Presented an image of the anatomy of the eye. Students can describe the process of light traveling through the eye to form an image. |
| | 6 | Presented a case narrative of the use of magnifying glasses in everyday life. Students describe a diagram of the rays and shadows produced by a magnifying glass when it is shifted a certain distance. |