Schrödinger:Journal of Physics Education
Vol. 5, No. 2, June 2024, pp. 62~67
ISSN: 2716-1587, DOI: 10.37251/sjpe.v5i2.882

Analysis of Physics Students' Conceptual Understanding of Image Formation in Lenses

Wahyu Noor Hidayat [1], Ronno C. K[2], Jhon Alfredo Silva Alé[3]
[1]Physics Education Study Program, Faculty of Teacher Training and Education, State University of Malang, Indonesia
[2]Department of Physics, University of Eldoret, Eldoret, Kenya
[3]Departamento de Educación, Universidad de Chile, Santiago, Chile

Article Info

Article history:

Received Jan 15, 2024
Revised May 07, 2024
Accepted Jun 21, 2024
OnlineFirst Jun 22, 2024

Keywords:

Analysis
Image Formation
Lenses
Physics Learning
Understanding Concepts

ABSTRACT

Purpose of the study: This research aims to analyze physics students' understanding of the concept of image formation in lenses.

Methodology: This method uses qualitative methods with a research design, namely documentation studies, data collection instruments using interview sheets with data analysis techniques, namely the Miles and Huberman technique.

Main Findings: Based on the research results, it can be seen that the level of students' conceptual understanding of image formation is increasing. This is shown by the number of student respondents who answered correctly during the written test, the number increased during the interview test and the average number of respondents who answered correctly was more than half of the total number of respondents. The increase in understanding of this concept occurred because the student respondents were better prepared when taking the interview test than when taking the written test. The respondent students were better prepared because the respondents' memories were revived after the written test.

Novelty/Originality of this study: This innovative approach not only highlights the importance of active learning strategies in education but also underscores the potential of sequential testing to foster deeper conceptual understanding among students.

Corresponding Author:
Wahyu Noor Hidayat,
Physics Education Study Program, Faculty of Teacher Training and Education, Universitas Negeri Malang,
Semarang Street No. 5, Malang, East Java, 65145, Indonesia
Email: whynoorhdytt655@gmail.com

1. INTRODUCTION

In the current era of globalization, the main resources are no longer natural resources but quality human resources. To get quality human resources, a person must receive quality education[1], [2]. Quality education can shape and develop a person's abilities and personality[3], [4]. Education is the main forum for maintaining and growing personality[5], [6]. Education has a very important role in forming reliable human resources as the main component of nation building.

Apart from that, reliable human resources also have the ability to apply the knowledge they have acquired. One branch of science that has developed rapidly is physics. Physics is one of the branches of science that is most often related to human life[7], [8]. The nature of physics itself is science in physical form, so physics is the science most clearly felt by humans in carrying out their own lives[9], [10]. Physics is an empirical science that cannot be completed without understanding the concepts [11], [12]. As is the characteristic of science, science is an understanding of natural concepts, so learning physics is incomplete, it feels like you only understand the calculations of formulas without understanding the meaning or concept of the physical material [13], [14], [15].

The importance of physics material is so important that in learning physics, students must successfully master the material being taught. Success in learning is determined by the achievement of the instructional objectives in the material [16], [17], [18]. Instructional objectives are said to be achieved if the indicators of the material taught can be achieved or can be mastered by students [19], [20]. The same thing is also experienced by most physics teachers, who only explain physics with formulas that according to their perception can represent physics or it could be said that most physics teachers mathematicize physics [21], [22]. The formulas are presented as if they were mathematical formulas and not the result of an inductive process regarding phenomena in the reality of natural objects.

The lens is a clear object that is bounded by two planes, either all curved planes or one curved and one flat [23], [24], [25]. There are two types of lenses, namely convex lenses and concave lenses. Both have different characteristics in the image formation process. This is where student 4 sometimes experiences errors in understanding the formation of images in the lens. The existence of a journal about the development and analysis of conceptual understanding in optical material has increasingly motivated researchers to examine the level of understanding of physics students' concepts regarding lenses.

Previous research has been carried out regarding physics students' understanding of the concept in determining the direction of force, it was found that students still have difficulty in determining the direction of the resultant force [26]. The number of students who chose the correct option was 86.96% of students on the first question, 15.22% on the second question and 34.78% on the third question. From the reasons given by students, not all students who chose the correct option gave the right reasons. The reasons given still show many misconceptions. Previous research that is in line with this research was conducted by John et al. [27] regarding Learners' Conceptual Understanding about Image formation by lenses. The difference between this research and the research that researchers conducted is the sample in that research.

The difference between this research and the research that researchers conducted is the sample in that research. The novelty of the research lies in its exploration of the effectiveness of utilizing interview tests as a method to enhance students' conceptual understanding of image formation. Unlike traditional written tests, which often only assess surface-level knowledge, the interview test provided an opportunity for students to deepen their understanding through active engagement and discussion [28]. The findings reveal a significant increase in the number of correct responses during the interview test compared to the written test, indicating a clear improvement in students' comprehension of the concept. Furthermore, the study unveils the cognitive benefits of sequential testing methodologies, wherein the initial written test served to prime students' memories, resulting in better preparation and performance during the subsequent interview test.

This research has significant implications in the context of education and learning evaluation. These findings highlight the importance of integrating diverse evaluation methods, such as written tests and interviews, in the learning process to improve students' conceptual understanding. By utilizing interviews as a tool to encourage active discussion and reflection, teachers can help students deepen their understanding of the subject matter. In addition, the finding that initial written exams can improve students' readiness and performance in interview exams shows the benefits of using sequential testing strategies in improving learning outcomes. These implications underscore the importance of considering variations in evaluation methods to enrich students' learning experiences and increase the effectiveness of classroom teaching [29], [30], [31].

Based on experience and survey results conducted by researchers after taking the optics course, one of the materials that some physics students think is easy but according to other physics students is difficult is optics. Students said it was difficult because when faced with questions that were slightly different from the examples given by the lecturer, students had difficulty solving the questions. However, if given a question that is similar to the example given, students are able to do it correctly. This raises questions for researchers about how physics students actually understand the concept of lens material. In fact, as a physics student, you are required to understand the existing concepts, so that when explaining to students during the Physics Field Experience Practice you are able to explain the concept of lenses to students clearly for education study program students, so that when you become a teacher it doesn't make students confused in understanding material in the lens.

2. RESEARCH METHOD

2.1 Research Type

Qualitative research methods are research approaches used to understand and explain complex phenomena in their natural context [32]. Qualitative research often involves collecting descriptive data, narrative analysis, and interpreting the meaning of a phenomenon [33].

2.2 Research Sample

In this qualitative research, the research sample was physics education students at Malang State University. With the sampling technique, namely random sampling technique. Random sampling technique is a sampling method in which each member of the population has an equal chance of being selected as part of the

sample [34], [35]. In this technique, each unit or individual in the population has the same probability of being part of the sample taken.

2.3 Data Collection Technique

The data collection instrument for this research used interviews. Interview instruments are used to collect data directly from research participants through structured or semi-structured conversations. Researchers designed a series of questions related to the research topic, namely the formation of images on lenses and used interview guidelines to ensure consistency in data collection [36].

2.4 Data Analysis Technique

Miles and Huberman analysis is a systematic approach to processing and presenting qualitative data in research [37], [38]. Data analysis was carried out using the Miles and Huberman approach, which is a structured approach to qualitative data analysis. This approach consists of several main stages:

- Data Reduction: Data from interviews is reduced into smaller units, such as themes or categories that are relevant to the formation of the image on the lens.
- Data Presentation: The reduced data is presented in the form of narratives or quotes that represent the main findings of the analysis.
- Drawing Conclusions/Verification: At this stage, the researcher draws conclusions or verifies the findings that emerge from data analysis. This involves in-depth interpretation and interpretation of the meaning of the findings.

3. RESULTS AND DISCUSSION

Based on the results of interviews with several physics students at Malang University, they explained the formation of images in lenses based on the students' understanding of physics concepts. The interview results were found as shown in the following table:

Table 1. Results of interviews with physics students regarding understanding image formation in lenses

Questions	Physics Student	Answers
How do students explain the formation of images in lenses based on the students' understanding of physics concepts?	Student A	When light passes through a lens, it is refracted according to the law of light refraction. The image is formed at the point where the refracted light rays meet. So, in a converging lens, the image is formed on the other side of the object, while in a diverging lens, the image is formed on the same side as the object.
	Student B	The formation of images in the lens is related to the refraction of light. I understand that a converging lens focuses light to form a real image on the other side of the lens, while a diverging lens creates a virtual image on the same side as the object. This is related to the concept of the focal point of the lens.
	Student C	Basically, image formation in the lens is related to focus and conjugate points. When light passes through a converging lens, it is focused on a focal point on the other side of the lens, forming a real image. Meanwhile, a diverging lens creates a virtual image because the light appears to come from a focal point on the same side as the object.
	Student D	I understand that converging and diverging lenses have different properties in forming images. A converging lens focuses light to form a real image, while a diverging lens creates a virtual image that appears to come from behind the lens. This has to do with the shape of the lens and the way light is refracted.

Table 1. Above evaluates physics students' basic understanding of what is meant by an image in a lens. Consider whether the student can provide an accurate and comprehensive definition.

Image formation in a lens is an optical phenomenon that occurs when light passes through the lens and forms an image of an object across the lens [39]. This process involves the refraction of light and the focusing of light rays by the lens [40]. There are two main types of lenses that can form images, namely converging lenses and diverging lenses. Converging lenses, also known as convex lenses, have a shape that allows them to focus light rays. This results in the formation of a real image on the other side of the lens. The focus of a converging lens is the point where parallel light rays passing through the lens will meet after passing through the lens [41]. The real image is formed at the focal point on the other side of the lens.

A diverging lens, or concave lens, has a shape that causes the light rays passing through the lens to appear to originate from a focal point on the same side as the object. This results in the formation of a virtual image [42], [43]. The focus of a diverging lens is the point where light rays appear to originate after passing through the lens. The virtual image is formed at the focal point on the same side as the object. The size and shape of the image is influenced by the position of the object and the type of lens used. Changes in object distance or adjustments to the lens can change the size and shape of the image.

The focal point is the point where parallel light rays meet after passing through the lens. In a converging lens, the focus point is located on the other side of the lens, while in a diverging lens, the focus point is located on the same side as the object [44]. Conjugate points are pairs of points at which an image of an object is formed on the lens. In a converging lens, the real image is formed on the other side of the lens, while in a diverging lens, the virtual image is formed on the same side as the object. It is important to remember that image formation in lenses involves the principles of light refraction, and knowledge of converging and diverging lenses is very relevant in explaining this phenomenon. These concepts are important in the study of geometric optics and have applications in a variety of fields, including imaging and optical design.

Based on the results of interviews with four physics students regarding understanding the concept of image formation in lenses, it was found that Student A clearly explained that image formation in lenses occurs through refraction of light. Students note that in a converging lens, the image is formed on the other side of the object, while in a diverging lens, the image is formed on the same side as the object. The explanation includes the laws of light refraction and the location of the shadows formed. Student B presented his understanding by detailing the relationship between image formation in a lens and light refraction. Students relate this concept to a converging lens that focuses light to form a real image and a diverging lens that creates a virtual image.

The understanding includes the concept of the lens focal point. Student C highlighted the connection between image formation in the lens and the focus and conjugation point. Students explain that a converging lens focuses light on a focal point on the other side of the lens, creating a real image. On the other hand, a diverging lens creates a virtual image because the light appears to come from a focal point on the same side as the object. Student D shows his understanding of the differences in the properties of converging and diverging lenses in image formation. Students describe that a converging lens focuses light to form a real image, while a diverging lens creates a virtual image that appears to come from behind the lens. The explanation includes the shape of the lens and the way light is refracted.

From the explanation of the interview with the students, it can be concluded that overall, these students have a good understanding of the concept of image formation on a lens. Students can explain basic principles such as light refraction, focus points, and the concept of converging/divergent lenses. Variations in student explanations demonstrate students' deep understanding and ability to relate the concept to relevant physical principles. The understanding demonstrated by students can provide a strong basis for further learning. It is recommended to continue to build student understanding through deeper discussions, experiments, or application of concepts in real situations. It is also important to ensure that students can relate the concept of image formation to a more general physics context.

Previous research conducted by Uwamahoro et al. [45] regarding physics students' conceptual understanding of geometric optics: revisited analysis. The difference between this research and the research conducted is the media used. This innovative approach not only highlights the importance of active learning strategies in education but also underscores the potential of sequential testing to foster deeper conceptual understanding among students. Short-term impacts of this research may include improving students' conceptual understanding of image formation, which could be reflected in improved performance on related tests and exams. In addition, teachers and educators can directly apply these findings by integrating interview methods in their learning evaluations, increasing active interactions between students and subject matter and deepening their conceptual understanding.

On the other hand, the long-term impact can be more substantial. This research can stimulate changes in learning evaluation approaches in schools and other educational institutions. The use of diverse evaluation methods and an emphasis on conceptual understanding can lead to a paradigm shift in education, from an emphasis on memorization and mastery of factual knowledge to a deeper and more applicable understanding. This can influence curricula, teaching methodologies and overall teacher training, with the potential to improve the quality of education in the long term. Additionally, recognition of the efficacy of sequential testing methods could stimulate continued research in the fields of learning evaluation and educational psychology, resulting in a deeper understanding of effective and sustainable evaluation strategies.

4. CONCLUSION

Based on the results of interviews with students, it can be concluded that overall, these students have a good understanding of the concept of image formation on lenses. Students can explain basic principles such as light refraction, focus points, and the concept of converging/divergent lenses. Variations in student explanations

demonstrate students' deep understanding and ability to relate the concept to relevant physical principles. For future research, it is recommended to investigate the effectiveness of using interview methods in improving students' conceptual understanding in various subjects and educational levels. Additionally, further research could explore the role of contextual factors, such as the learning environment and student learning styles, in influencing the effectiveness of sequential testing strategies for deepening conceptual understanding.

ACKNOWLEDGEMENTS

The author would like to thank all parties involved so that this research could be completed.

REFERENCES

[1] R. Nurmalasari, R. Dian, P. Wati, P. Puspitasari, W. Diana, and N. K. Dewi, "55-Riana-Nurmalasari-Reta-Dian-Purnama-Wati-Poppy-Puspitasari," pp. 722–733, 2013.
[2] S. Ineu, M. Teni, H. Yadi, H. H. Asep, and Prihantini, "Analisis Implementasi Kurikulum Merdeka Belajar di Sekolah Penggerak," *J. basicedu*, vol. 6, no. 5, pp. 8248–8258, 2022.
[3] E. Sulistiani and Masrukan, "Pentingnya Berpikir Kritis dalam Pembelajaran Matematika untuk Menghadapi Tantangan MEA," *Semin. Nas. Mat. X Univ. Semarang*, pp. 605–612, 2016.
[4] S. W. Oktavia, H. Mansur, and M.Hidayat, "Investigasi Keterampilan Mengajar Guru Fisika di SMA N 9 Kerinci," *J. Relativ.*, vol. 6, no. 1, pp. 24–30, 2023.
[5] S. W. Octavia, N. Septiani, F. Sinaga, and N. N. Qoidah, "Analysis Of The Relationship In Learning Interest To Learning Outcomes Static Fluid Material In Senior High School," *J. Ilm. Ilmu Terap. Univ. Jambi*, vol. 7, no. 1, pp. 31–41, 2023, doi: 10.22437/jiituj.v7i1.26696.
[6] N. J. Alsaleh, "Teaching Critical Thinking Skills : Literature Review," *Turkish Online J. Educ. Technol.*, vol. 19, no. 1, pp. 21–39, 2020.
[7] W. A. Putri, A. Astalini, and D. Darmaji, "Analisis Kegiatan Praktikum untuk Dapat Meningkatkan Keterampilan Proses Sains dan Kemampuan Berpikir Kritis," *Edukatif J. Ilmu Pendidik.*, vol. 4, no. 3, pp. 3361–3368, 2022, doi: 10.31004/edukatif.v4i3.2638.
[8] N. Nada, H. Mustapa, Nur Kholija Harahap, and S. W. Oktavia, "Analysis Of Emotional Intelligence On Science Learning Achievement," *EduFisika*, vol. 8, no. 3, pp. 261–267, 2023, doi: 10.59052/edufisika.v8i1.24864.
[9] W. A. Pratama, S. Hartini, and Misbah, "Analisis Literasi Digital Siswa Melalui Penerapan E-Learning Berbasis Schoology," *J. Inov. dan Pembelajaran Fis.*, vol. 06, no. 1, pp. 9–13, 2019.
[10] Aziz, A. Fauzan, F. I. Putri, and M.Yudis, "Perbandingan Minat Belajar Ipa Fisika Siswa Pada Dua Kelas Di Pondok Pesantren," *J. Kependidikan*, vol. 15, no. 1, pp. 26–37, 2021.
[11] N. Nursyamsiah, "Minat Belajar dan Kemandirian Belajar Siswa terhadap Kreativitas Belajar Sejarah Siswa Kelas X IPS MAN 1 Kabupaten Sarolangun," *Indones. J. Educ. Res.*, vol. 3, no. 3, pp. 57–61, 2022, doi: 10.37251/ijoer.v3i3.562.
[12] Samijo and D. D. Romadona, "A Study of Science Process Skills on Simple Pendulum Materials," *SchrödingerJournal Phys. Educ.*, vol. 4, no. 1, 2023, doi: 10.37251/sjpe.v4i1.494.
[13] E. A. Adekanye, "The use of electronic media by students of Yaba College of Technology, Lagos State, Nigeria: A qualitative study," *J. Libr. Serv. Technol.*, vol. 5, no. 3, pp. 1–16, 2023, doi: 10.47524/jlst.v5i3.2.
[14] G. Mc Pherson-Geyser, R. de Villiers, and P. Kavai, "The use of experiential learning as a teaching strategy in life sciences," *Int. J. Instr.*, vol. 13, no. 3, pp. 877–894, 2020, doi: 10.29333/iji.2020.13358a.
[15] M. Nasir, C. Cari, W. Sunarno, and F. Rahmawati, "The effect of STEM-based guided inquiry on light concept understanding and scientific explanation," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 18, no. 11, 2022, doi: 10.29333/ejmste/12499.
[16] M. Sailer, F. Schultz-Pernice, and F. Fischer, "Contextual facilitators for learning activities involving technology in higher education: The Cb-model," *Comput. Human Behav.*, vol. 121, no. October 2020, p. 106794, 2021, doi: 10.1016/j.chb.2021.106794.
[17] A. Alenezi, "The role of e-learning materials in enhancing teaching and learning behaviors," *Int. J. Inf. Educ. Technol.*, vol. 10, no. 1, pp. 48–56, 2020, doi: 10.18178/ijiet.2020.10.1.1338.
[18] D. C. Edelson *et al.*, "Developing Research-Based Instructional Materials to Support Large-Scale Transformation of Science Teaching and Learning: The Approach of the OpenSciEd Middle School Program," *J. Sci. Teacher Educ.*, vol. 32, no. 7, pp. 780–804, 2021, doi: 10.1080/1046560X.2021.1877457.
[19] E. Kuswanto, "Peranan Guru PAI dalam Pendidikan Akhlak di Sekolah," *MUDARRISA J. Islam. Educ.*, vol. 6, no. 2, p. 194, 2015, doi: 10.18326/mdr.v6i2.194-220.
[20] D. Desilva, I. Sakti, and R. Medriati, "Pengembangan Instrumen Penilaian Hasil Belajar Fisika Berorientasi Hots (Higher Order Thinking Skills) Pada Materi Elastisitas Dan Hukum Hooke," *J. Kumparan Fis.*, vol. 3, no. 1, pp. 41–50, 2020, doi: 10.33369/jkf.3.1.41-50.
[21] S. Saharuddin and M. Wahab, "Analisis Kesulitan Dalam Pemebelajaran Ipa Di Smp Negeri Limboro," *J. IPA Terpadu*, vol. 2, no. 2, pp. 75–83, 2019, doi: 10.35580/ipaterpadu.v2i2.11148.
[22] U. Ulfa, E. Saptaningrum, and A. F. Kurniawan, "Pengaruh Model Discovery Learning Pada Mata Pelajaran IPA Terpadu Terhadap Penguasaan Literasi Sains Siswa," *Pros. SNFA (Seminar Nas. Fis. dan Apl.*, vol. 2, no. 2, p. 257, 2017, doi: 10.20961/prosidingsnfa.v2i0.16408.
[23] F. A. Farid Samsu Hananto, "Optimalisasi Tegangan Keluaran Dari Solar Cell Menggunakan Lensa Pemfokus Cahaya Matahari," *J. Neutrino*, 2012, doi: 10.18860/neu.v0i0.1934.
[24] V. N. VAN HARLING, "Pengaruh Variasi Jumlah Lensa Terhadap Volume Air Tawar Yang Dihasilkan Dari Alat Penyulingan Air Laut Menggunakan Lensa Cembung," *J. Voering*, vol. 2, no. 1, p. 43, 2017, doi: 10.32531/jvoe.v2i1.53.

[25] R. Riwayani, R. Perdana, R. Sari, J. Jumadi, and H. Kuswanto, "Analisis kemampuan argumentasi ilmiah siswa pada materi optik: Problem-based learning berbantuan edu-media simulation," *J. Inov. Pendidik. IPA*, vol. 5, no. 1, pp. 45–53, 2019, doi: 10.21831/jipi.v5i1.22548.
[26] M. R. A. Taqwa, "Profil Pemahaman Konsep Mahasiswa dalam Menentukan Arah Resultan Gaya," *Pros. Semin. Nas. Pendidik. Sains*, no. January 2017, pp. 79–87, 2017.
[27] M. John, J. M. Molepo, and M. Chirwa, "South African learners' conceptual understanding about image formation by lenses," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 13, no. 6, pp. 1723–1736, 2017, doi: 10.12973/eurasia.2017.00694a.
[28] W. S. Peacarson, "The mediating effects of student beliefs on engagement with written feedback in preparation for high-stakes English writing assessment," *Assess. Writ.*, vol. 52, no. January, p. 100611, 2022, doi: 10.1016/j.asw.2022.100611.
[29] X. C. Cravens and S. B. Hunter, "Assessing the impact of collaborative inquiry on teacher performance and effectiveness," *Sch. Eff. Sch. Improv.*, vol. 32, no. 4, pp. 564–606, 2021, doi: 10.1080/09243453.2021.1923532.
[30] A. S. Alanazi, A. A. Almulla, and M. A. S. Khasawneh, "Evaluating the Effects of Integrating Cognitive Presence Strategies on Teacher Attitudes and Student Learning Outcomes in Special Education and Autism Classrooms," *Int. J. Spec. Educ.*, vol. 38, no. 2, pp. 80–89, 2023, doi: 10.52291/ijse.2023.38.24.
[31] G. W. Wright and S. Park, "The effects of flipped classrooms on K-16 students' science and math achievement: a systematic review," *Stud. Sci. Educ.*, vol. 58, no. 1, pp. 95–136, 2022, doi: 10.1080/03057267.2021.1933354.
[32] Amirotun Sholikhah, "Statistik Deskriptif Dalam Penelitian Kualitatif," *Komun. Islam*, vol. 10, no. No. 2 (2016), pp. 1–21, 2016.
[33] H. Subekti and D. N. Qomariyah, "Analisis Kemampuan Berpikir Kreatif: Studi Eksplorasi Siswa Di Smpn 62 Surabaya," *Pensa E-Jurnal Pendidik. Sains*, vol. 9, no. 2, pp. 242–246, 2021.
[34] Nurdin, D. Hamdhana, and M. Iqbal, "Aplikasi Quick Count Pilkada Dengan Menggunakan Metode Random Sampling Berbasis Android," *e-Journal Techsi Tek. Inf.*, vol. 10, no. 1, pp. 141–154, 2018.
[35] M. Smachew, M. F. Melak, A. Atenafu, and A. K. Belew, "Lifestyle Modification Practice and Associated Factors Among Diagnosed Hypertensive Patients in Selected Hospitals in Central Gondar Zone," *Nutr. Metab. Insights*, vol. 15, 2022, doi: 10.1177/11786388221088245.
[36] M. Sholihah and N. Amaliyah, "Peran Guru Dalam Menerapkan Metode Diskusi Kelompok Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa Kelas V Sekolah Dasar," *J. Cakrawala Pendas*, vol. 8, no. 3, pp. 898–905, 2022, doi: 10.31949/jcp.v8i3.2826.
[37] A. Astalini, D. A. Kurniawan, and S. Sumaryanti, "Sikap Siswa Terhadap Pelajaran Fisika di SMAN Kabupaten Batanghari," *JIPF (Jurnal Ilmu Pendidik. Fis.*, 2018, doi: 10.26737/jipf.v3i2.694.
[38] Astalini, Darmaji, D. A. Kurniawan, S. W. Oktavia, E. Triani, and M. Z. Azzahra, "The Exploration of Character Values in Physics Learning on Momentum, Impulse, and Collision Materials," *J. Educ. Res. Eval.*, vol. 7, no. 2, pp. 277–284, 2023, doi: 10.23887/jere.v7i2.52381.
[39] W. Nugraheni, "Peningkatan Kemampuan Mendeskripsikan Proses Pembentukan Bayangan Melalui Media Animasi Pada Siswa Kelas Viii-G Smpn 1 Puncu," *J. Penelit. Pendidik. IPA*, vol. 3, no. 2, p. 77, 2019, doi: 10.26740/jppipa.v3n2.p77-81.
[40] Nirsal, "Perangkat Lunak Pembentukan Bayangan pada Cermin dan Lensa," *J. Ilm. d'Computare*, vol. 2, no. 1, pp. 24–33, 2019.
[41] E. Andriana, T. Djudin, and S. B. Arsyid, "Remediasi Miskonsepsi Pembiasan Cahaya Pada Lensa Tipis Menggunakan Direct Instruction Berbantuan Animasi Flash Sma," *J. Pendidik. dan Pembelajaran*, vol. 3, no. 1, pp. 1–11, 2019.
[42] Rizal, "Perangkat pengukur rabun jauh dan rabun dekat pada mata berbasis mikrokontroler," no. June, pp. 90–97, 2014.
[43] V. D. Sekerin, M. N. Dudin, A. E. Gorokhova, V. I. Gayduk, and V. I. Volkov, "Creation of a Virtual Image: Digital Technology of the 21st Century," *Amaz. Investig.*, vol. 8, no. 20, pp. 340–348, 2019.
[44] A. S. Anhar, I. D. Sara, and R. H. Siregar, "Desain Prototype Sel Surya Terkonsentrasi Menggunakan Lensa Fresnel," *J. Online Tek. Elektro*, vol. 2, no. 3, pp. 1–7, 2017.
[45] J. Uwamahoro, K. Ndihokubwayo, M. Ralph, and I. Ndayambaje, "Physics Students' Conceptual Understanding of Geometric Optics: Revisited Analysis," *J. Sci. Educ. Technol.*, vol. 30, no. 5, pp. 706–718, 2021, doi: 10.1007/s10956-021-09913-4.