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Development of an Arduino Uno-Based Tactile Audio Electrical Circuit KIT To Train Visually Impaired Students' Mathematical Ability in Ohm's Law Experiment

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Tactual Audio Electrical Circuit KIT, Arduino Uno, Experiment, Ohm Law, Visually Impaired Students,

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Abstract

The study aimed to develop an Arduino Uno-based Tactual Audio Electrical Circuit KIT tool and test its implementation in training the mathematical thinking skills of visually impaired students on Ohm's Law material. The problem identified was the difficulty visually impaired students in conducting experiments and performing mathematical calculations on Ohm's Law material. Therefore, it is necessary to develop a KIT Tool utilizing an Arduino Uno to produce sound output in the form of a guide for assembling electrical circuits and electrical measurement results. The research used the 4D model of Research and Development (R&D) method with the steps of Define, Design, Develop, and Disseminate. This research produced a Tactual Audio Electrical Circuit KIT equipped with audio counting aids to facilitate in filling out Student Worksheets (LKS) on Ohm's Law experiments. Expert validation and empirical trials were conducted to ensure the feasibility of KIT in learning. The Arduino Uno-based Tactual Audio Electrical Circuit KIT is effective in helping visually impaired students to understand the concept of Ohm's Law and train their mathematical thinking skills. This research contributes to the development of technology-based inclusive learning media and be an inspiration for teachers in improving the quality of education for visually impaired students. It concluded that the tactual audio electrical circuit KIT received a positive response from the teacher with an average score of 4.22, with the standard "very good." The average score of students' responses to the tool is 4.58, with the category "very good." Thus, the Arduino Uno-based Tactual Audio Electrical Circuit KIT on Ohm's Law Material is feasible for use as a learning medium and train the mathematical abilities of visually impaired students.

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INTRODUCTION

In the 21st century, education plays an important role in preparing young people to face future challenges. Based on data from the United Nations (UN), it is estimated that 150 million children under the age of 18 are disabled. Based on the 2015 Intercensal Population Survey (SUPAS), it was found that 0.85% of the population had total visual impairment or significant visual difficulties. It is estimated that the number of visually impaired individuals in Indonesia currently stands at 3.75 million, which is equivalent to approximately 1.5% of the total population of 250 million (Abdi et al., 2021). Students with special needs, especially the visually impaired, require special treatment in accessing learning (Al-Eidarous et al., 2024). Inclusive education is an increasingly important approach in modern education systems, especially in supporting students with special needs, including visually impaired students. According to Al-Azawei et al. (2023), inclusive education not only provides

access to students with disabilities but also improves the quality of learning for all students. In this context, the development of innovative educational aids becomes very important to support the teaching and learning process, especially in subjects that require understanding of mathematical and scientific concepts (Ketheeswaran & Nawastheen, 2024).

The lack of adequate science practicum facilities in special schools (SLB) hinders the understanding of science material for some students with special needs. Therefore, innovation in the method of delivering science material is crucial so that students with special needs are able to master physics concepts effectively (Maryam et al., 2023). So far, visually impaired students have primarily used Braille and audiobooks for, which have not been utilized to their full potential in supporting their learning. Additional learning media that can stimulate multiple senses are needed to achieve optimal multisensory learning (Shidqi & Budi, 2023). The inability to visualize information makes it difficult for students to understand and apply basic mathematical principles (Abbas et al., 2023). Visually impaired students frequently face difficulties in applying calculation operations, which become the obstacle their learning process(Ahmad et al., 2025).

As for student problems, based on the results of the study (Ookeditse & Garegae, 2024), teachers identified several key areas that need attention, including the development of concepts and problem-solving skills, braille literacy, and the availability of resources and support.

To achieve optimal learning, it needs to have diverse media support. However, the reality shows that the current learning media cannot fully meet the diverse of students' needs. Therefore, teachers need to play an active role in choosing appropriate media to facilitate the learning of each student, especially students with special needs (Sukma et al., 2024). Teachers need to design learning that not only accommodates differences in characteristics, but also develops their potential. The use of appropriate technology is the key to success in teaching science concepts to visually impaired students (Pramata et al., 2023). The use of technology-based aids, such as Arduino, has been proven effective in improving students' understanding. According to research, well-designed teaching aids can increase students' interest and engagement in the learning process and help them understand the material better. Arduino Uno, as an open-source microcontroller board system, allows the integration of various sensors and modules, so it can be used to create interactive and engaging teaching aids (Bulan et al., 2024).

Based on the results of the literature study, visual limitations often make visually impaired students feel afraid and pessimistic in the science learning process. One of the materials that is considered difficult and frightening for visually impaired students is electrical circuits, which are very close to everyday life. On the topic of Ohm's Law, students learn how to calculate the current strength in an electrical circuit. However, the availability of electrical measuring instruments is still limited to use as learning (Yulanto et al., 2022).

The teacher's limited use of learning media, such as Reglette and Braille, and the lack of variety in the delivery of material, lead the students to have a difficulty in developing critical and creative thinking skills. In addition, students have limited understanding of basic concepts, especially in arithmetic operations. Therefore, with the existence of KIT, efforts are needed to improve the quality of mathematics learning for visually impaired students, for example, through maximizing the potential of auditory stimulation (Damayanti et al., 2024). KITs with audio technology provide audible feedback, so that students can understand the concepts of current, voltage, and resistance without relying on visual graphics. In line with research showing that programming tools with audio can assist students with visual impairments in understanding basic concepts without reliance on visual graphics, as described in a study that used Lego blocks and an audio platform to translate instructions into audible output (Utreras & Pontelli, 2020).

In research conducted by Widiyawati et al (2020), the Elclivs (Electricity Circuit Learning KIT for Visual Impairment Student) tool has been developed (media explanation) (lack of audio and manual tools) as a medium for learning electricity for visually impaired students. However, mastery of the electrical circuit material is still found difficulty due to the weak ability of students in mathematical calculations, which can be an obstacle to learning. Students look difficult and confused when dealing with numbers in the form of fractions. The concept of numerator and denominator is quite complicated for them to calculate because they only imagine the rows of numbers. Visually impaired students at SLB A Dria Adi take a long time to understand the concept of Ohm's law, but they are skilled in calculating fractions. On the other hand, visually impaired students at SLB YAAT Klaten are fast in capturing the concepts about Ohm's law, but students have difficulty working on mathematical problems. The difficulty of using fractions for SLB

A YAAT students appears from the pattern of answers to description-type questions. They need to obtain special guidance in terms of mathematical calculations, especially fractions (Widiyawati & Nurwahidah, 2020). Science learning for visually impaired students is a complex challenge since their special needs in understanding abstract concepts. In this context, the use of appropriate learning aids is essential to support their learning process. Currently, a variety of aids are available, such as manual tools to audio technology specifically designed for visually impaired students. Research shows that the integration of technology in learning can improve visually impaired students' understanding and engagement in science and math.

Electrical circuit KIT tools and digital measuring instruments are currently not equipped with an audio-tactual system that allows students with special needs, especially the visually impaired, to conduct independent experiments. The ability of visually impaired students' needs to be trained and developed, which aims to adapt to the advancement of natural science. The physical limitations of visually impaired students are one of the obstacles to doing abstract learning, such as electrical circuits and mathematical calculations. Therefore, learning media is needed to help visually impaired students in learning that requires high-level reasoning, including science and mathematics. Technological advances allow the development of electrical circuit KITs and calculation aids to overcome the limitations of visually impaired students in accessing abstract learning and support mathematical thinking training in experiments for visually impaired students. Presenting graphics in a physically perceived format is an effort to improve the learning experience of visually impaired students. Then, they can more easily understand and learn from complex material. Hearing, Touch, and Hearing-Feeling. According to (Riga & Kouroupetroglou, 2024), this research is important because visually impaired students often rely on memory to recall, unlike their sighted peers who can acquire this information visually. Through the application of audio-tactile graphics, students are not only passively provided with information, but also invited to interact with the educational content directly (Mackowski & Brzoza, 2022).

Based on the background, research is needed with the aim of developing an Arduino Uno-based Tactual Audio Electrical Circuit KIT to train the mathematical thinking skills of visually impaired students in Ohm's Law experiments. It is hoped that the Tactual Audio Electrical Circuit KIT can bridge the gap in the learning process in special and inclusive schools so that visually impaired students can experience a more concrete learning experience.

RESEARCH METHOD

The research used the research and development (R&D) method, which used the 4D research methodology with the steps of Define, Design, Develop, and Disseminate. The research was conducted at SLB ABCD Muhammadiyah Palu City. Moreover, it was conducted in the even semester of the 2024/2025 school year.

The research subjects consisted of two media experts, 4 students, and 1 teacher. The research instruments were a validation questionnaire by media experts, a teacher's response questionnaire and students' response questionnaire.

The results of the expert assessment were calculated using Aiken's variables to test the validity.

The Aiken validity index formula is expressed in the equation:

$$\mathrm{V} = \frac{\sum \mathrm{s}}{n\,(\mathrm{c}-1)}$$

where V is the item validity index; s is the score given by each validator minus the lowest score in the category used (s = r - lo, where r is the score of category selection by the rater, and lo is the lowest score in the scoring category); n is the number of raters; and c is the number of categories that can be selected by the rater (Aiken, 1980). The V index value ranges from 0 to 1. Items are better the closer of 1 because they are more relevant to the indicator.

According to (Arikunto, 2011), the feasibility can be calculated by the formula:

$$\text{Percentage of feasibility} = \frac{\sum gained\ score}{\sum maximum\ score}\ x\ 100$$

Media expert validation results were analysed using Aiken's technique. Meanwhile, the response's questionnaire was analysed by calculating the average score and then converted to qualitative data. There are two categories of data.

1. Quantitative data in the form of assessment scores. Student assessment and validator assessment questionnaire provide quantitative data.
2. Qualitative data or information presented in the form of sentence-by-sentence descriptions. Moreover, it is in the form of product development ideas, suggestions from validators, and notes of product trials. Expert validation sheets, physics teacher response sheets, student response sheets,

and Likert scale data analysis were used in data collection.

The data analysis approach used the following steps:

1. Qualitative Data Analysis Methods.

Qualitative information is in the form of criticism and suggestions for the Arduino Uno-based Tactual Audio Electrical Circuit KIT from validators, including evaluations by media experts and physics teachers at SLB ABCD Muhammadiyah Palu.

2. Quantitative Data Analysis Methods

Expert and student assessments and tests show the usability of the developed teaching aids. Then, the information is used as material to revise each component of the tool that has been developed, and the feasibility of its use. Student teaching aids are assessed through instruments. According to Sugiyono (2020), the average value calculation technique is used to analyse the data from the instrument. The average value is obtained by adding up all the scores obtained from the respondents, then dividing by the number of respondents. It allows researchers to get an overview of the response to each statement item in the research instrument. So, the formula for calculating the average value is:

$$\bar{X} = \frac{\sum x}{n}$$

Description:

$\bar{X}$: Average score in each question item

$\sum x$: Total score of all assessments in each question item

n : Number of question items

The average value is converted into a qualitative scale based on the predetermined assessment criteria table to interpret the assessment data. This table generally consists of a range of scores and corresponding assessment categories, helping researchers in determining the level of quality or effectiveness of the product. Assessment criteria follows the assessment category with the criteria in tables 1 and 2 (Widoyoko, 2012).

Table 1. Scores for answer choices

Description	Score
Very Less	1
Less	2
Simply	3
Good	4
Very good	5

Table 2. Conversion of Scores into Five-Scale Values

Interval	Category
$X > 4{,}2$	Very good
$3{,}4 < X \leq 4{,}2$	Good
$2{,}6 < X \leq 3{,}4$	Simply
$1{,}8 < X \leq 2{,}6$	Less
$X \leq 1{,}8$	Very Less

Table 2 is a reference for the assessment criteria of the validation result on the feasibility of tools by physics teachers and trials on students, which aims to make it easier to provide a value criterion for whether the Arduino Uno-based Tactual Audio Electrical Circuit KIT Trainer is feasible or not to use.

The success of product development is characterized by the achievement of feasibility standards. This standard is met if the analysis shows that the Arduino uno-based tactual audio Electrical Circuit KIT tool on the topic of Ohm's law for visually impaired students obtained a minimum category of "good enough" based on the data of feasibility percentage.

RESULT AND DISCUSSION

The validity test here is to test the feasibility of the tools developed and test them on students to train their ability to think mathematically through the use of these tools. The data that has been obtained through the assessment instrument on the trial of teaching aids is analyzed using descriptive analysis. It describes the results of product development in the form of an Arduino Uno-based Tactual Audio Electrical Circuit KIT. In addition, this analysis is used as a basis for revising the product and determine the feasibility and practicality.

The media expert validated the teaching aids. Three aspects were checked, including physical appearance, tool usage, and accuracy.

Define Stage

The tool analysis for the Arduino Uno-based tactual audio electrical circuit KIT in training the mathematical thinking skills of visually impaired students on Ohm's Law experiments was carried out through a literature study of previous research and through direct observation in one SLB. This analysis involved four main aspects. First, Media analysis. Here, the specific needs and objectives of the Arduino Uno-based tactual audio electrical circuit KIT are addressed. The main focus

is the need for media that bridges the visual limitations of visually impaired students in understanding the concept of electrical circuits and Ohm's Law as one of the experiments in learning. Second, Material analysis. It focuses on evaluating the electrical circuit system and Ohm's Law required in the development of this learning KIT. Third, User analysis. It involves understanding the characteristics of the target audience, namely, visually impaired students, to ensure effective media connectedness. And, Analysis of software requirements, tool components, and technology platforms aim to develop the Arduino Uno-based tactual audio electrical circuit kit.

Design Stage

After the need's analysis, it continued to the development, planning, and design of the teaching aids. During the product development design stage, several tasks were completed, including the creation of a braille worksheet to test on students. Design begins in Blender and SolidWorks applications to design the KIT (integrated instrument box) electrical circuits with braille writing in the form of the names of each component. This research adds several features, such as Arduino Uno microcontroller-based touch sensors and sound as output. At this stage, the design includes tool design, system programming design, and analyzing how it works, to find out what components are needed. In addition, the KIT is also equipped with audio counting aids, presented in Figure 1 and 2.

Figure 1. Electronics design

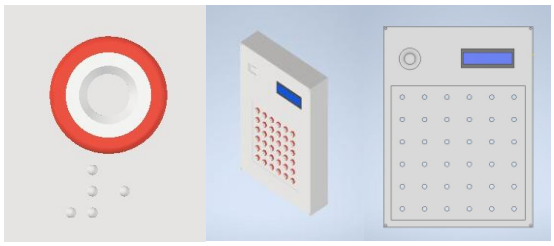

Figure 2. 3D Tactual Audio Electrical Circuit KIT

An Arduino Uno-based Tactual Audio Electrical Circuit KIT aims to train the mathematical ability of visually impaired students in Ohm's law experiments after completing the analysis and preparation stages.

Development involves a validity test process that test the feasibility of the developed product and test them on students to train their ability to think mathematically. The data that has been obtained through the assessment instrument on the trial of teaching aids is analysed using descriptive analysis that describes the results of product. This analysis is used as a basis for revising the product and determine the feasibility and practicality. Expert assessments were analysed using the Aiken's index. The results are presented in Table 3.

a. Media expert validation

Table 3 presents the findings of the media expert evaluation for the developed product.

Table 3. Media expert validation results using Aikens technique

Indicators	Sub-indicator	V	Category
Physical tools	1	1	Very High
	2	0,875	High
	3	1	Very High
	4	0,875	Very High
	5	0,75	High
Use of tools	1	1	Very High
	2	0,875	Very High
	3	0,75	High
	4	0,875	Very High
Accuracy	1	0,75	High
Average Score			0,875

Based on Table 3, all three aspects of the assessment showed "very high" results. This indicates that the tool is feasible for learning the topic of Ohm's Law in facilitating mathematical understanding in experiments. It indicates that each indicator in the Tactual Audio Electrical Circuit KIT tool has high validity (Aiken, 1980).

b. Results of teacher and student response questionnaires

The data collected through questionnaires from students and teachers were analysed and the percentage of agreement was calculated. The analysis results and the percentage of agreement were used for evaluation and making recommendations for further research. The percentage of agreement for physics teachers is presented in Table 4.

Table 4. Results of teacher's response questionnaire

Assessment	Average score	Category
Compatibility	5	Very good
Flexibility	5	Very good
Ease of Use	4	Very good
facility	4	Very good
Audio quality	4	Very good
Braille quality	4	Very good
Accuracy	4	Very good
Visual appeal	4	Very good
Safety	4	Very good
Average	4,22	

Based on Table 4, the results of the teacher's response to the tactual audio electrical circuit KIT tool are relatively high, with an average value score of 4.22 in the "very good" category. This shows that physics teachers at SLB Muhammadiyah school in Palu approve this as a learning tool. Teachers gave suggestions that teaching aids need further development in terms of sound quality as output. Material, sound, visual appeal, braille letters, and facilities have been well presented in the tool. The results of the student's response questionnaire are presented in Table 5.

Table 5. Results of student's response questionnaire

Assessment	Average score	Category
Compatibility	4,5	Very good
Flexibility	5	Very good
Ease of Use	4,25	Very good
facility	5	Very good
Audio quality	3,75	Very good
Braille quality	5	Very good
Accuracy	4,25	Very good
Visual appeal	5	Very good
Safety	4,25	Very good
Average	4,58	

Visually impaired students at SLB ABCD Muhammadiyah Palu City agree that the tactual audio electrical circuit KIT tool, which has braille letters, audio calculators, measurement results, and usage procedures with sound output, understanding the content through LKS can be used properly in experiments. The average score obtained from student's responses is 4.58 with the category "Very good." Then, all students agree that this tool is feasible for learning the topic of Ohm's Law to facilitate mathematical understanding in experiments. This is in accordance with research conducted by (Utami & Lutfi, 2021), who designed a KIT consisting of a light sensor assembled with an Arduino Uno and an audio module. The assembly is done by giving a programming language to the Arduino Uno, which functions to give commands to the light sensor and module.

C. Testing a product

The product of Arduino Uno-based Tactual Audio Electrical Circuit KIT teaching aid is designed to improve the mathematical thinking ability of visually impaired students in Ohm's law experiments.

The development of this teaching aid is designed to improve the mathematical thinking ability of visually impaired students through experimental activities on Ohm's law material. At the field trial stage, the product only tested on a small group (limited test), which analyse the response of the teacher and students to the tools that have been developed. This limited trial consisted of 4 students and 1 Physics teacher at SLB ABCD Muhammadiyah Palu school.

Experiments and Observations:

Students are asked to conduct Ohm's law experiments using the developed Tactual Audio Electrical Circuit KIT, equipped with a specially designed audio calculator that allows students to perform calculations on Ohm's law experiments. Students conduct Ohm's law experiments using the developed tools. By turning on the tactual audio electrical circuit KIT, the system will function and will emit a sound to guide the process of assembling an electrical circuit. Students feel the tool that has braille letters as a marker for each component to be assembled on the circuit board on the tool. Also, the sound will guide the correct installation of each component, such as connecting cables, resistors to the circuit board on the box. After students

successfully assemble the Ohm law experiment, the system will automatically emit a sound again when all components are successfully installed correctly. The electric current and voltage measured from the installation of the circuit will also be generated with sound output through Arduino Uno programming. After knowing the necessary data, students calculate the resistance value using an audio calculation tool.

Data analysis:

After that, students are asked to record their observations on the LKS using Braile. They must analyse data from observation data or measurement results obtained from audio through props.

Application of Ohm Law:

Students solve problems involving Ohm's law. Also, they analysis how voltage, current strength, and resistance can be calculated. They apply these concepts in real contexts, such as explaining how the principles of static electricity affect everyday life, from the use of electronic devices to natural phenomena of lightning.

Electricity affects everyday life, such as the use of electronic devices to natural phenomena of lightning.

Discussion and Reflection:

The teacher facilitates this experiment to ensure that students not only passively receive information, but are also active in the experiment. Deaf students will conduct experiments independently by assembling electrical circuits on the box. In addition to issuing a voice to guide on assembling an Ohm's Law experiment, this tool will provide a notification sound when successfully conducting an experiment. Also, it is the results of multimeter measurements.

The final product of the Arduino Uno-based tactual audio electrical circuit KIT tool is presented in Figure 1.

After product development, limited trials were conducted on teachers and students at SLB Muhammadiyah in Palu, presented in figure 2. The teacher needs to prepare the LKS after the experiment. The experimental data is obtained through the use of tools in the KIT. Then, it is analyzed by visually impaired students using audio counting tools in the KIT. This tool allows students to conduct independent experiments and solve the questions on the LKS correctly. At the same time, it trains their mathematical thinking skills. Mastery of Ohm's Law material as part of STEM does not only depend on practical activities but also mathematical calculations. Visually impaired students have difficulty when dealing with numbers in the form of fractions. With the concept of numerators and denominators which are quite complicated to calculate, they only imagine the rows of these numbers. To minimize these problems, the appropiate Arduino Uno-based Tactual Audio Electrical Circuit KIT tool is a solution for visually impaired students in training the mathematical thinking skills in conducting Ohm's law experiments. Thus, the use of this Electrical Circuit KIT can facilitate visually impaired students in learning electricity.

After conducting product trials, data was collected through questionnaires from students and teachers. Then, it analyzed and calculated the average value of approval. The results of the analysis were used for evaluation and making recommendations for further research.

The results of the teacher's response to the tactual audio electrical circuit KIT tool are relatively high, with an average value score of 4.22 in the "very good" category. Then, physics teachers in one SLB school approved this as a learning tool. The teacher gave suggestions that the teaching needs improvement in the sound produced by the developed tools.

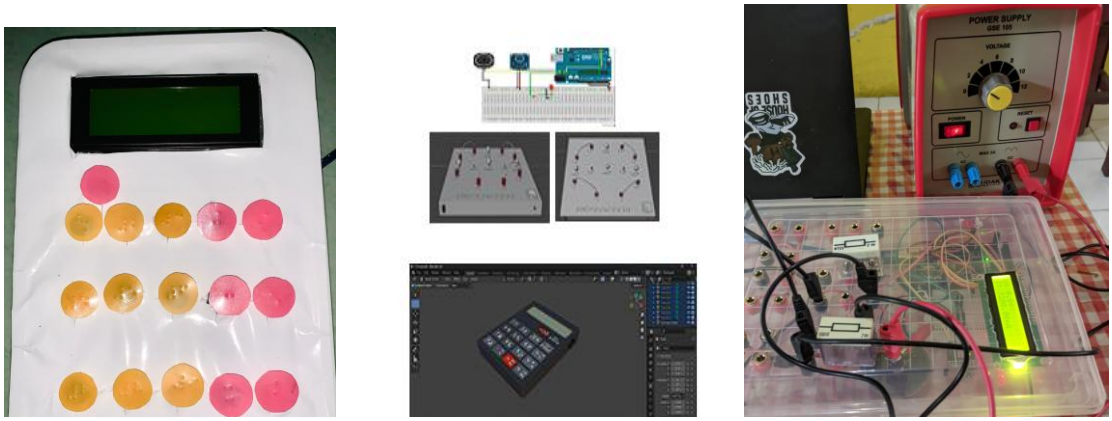

Figure 1. Product Development

Figure 2. students performing practice

Visually impaired students at SLB ABCD Muhammadiyah Palu agree that the tactual audio electrical circuit KIT tool, which has braille letters, audio calculators, measurement results and usage procedures with sound output, is help them understand the
step in improving the accessibility of inclusive

experiments. The average score of students' responses is 4.58, with the category "Very good." This shows that all students agree that this tool is feasible for learning the topic of Ohm's law to facilitate mathematical understanding in an experiment.

CONCLUSION

This research successfully developed and validated the Arduino Uno-based Tactual Audio Electrical Circuit KIT as a learning medium for visually impaired students. Through media expert validation and trials involving teachers and students, it showed very good acceptance and feasibility, as seen from the average score of teacher's responses of 4.22 and students' responses of 4.58, both in the very good category. The results of field trials show that students with visual impairments are able to conduct Ohm's law experiments and write mathematical equations after interacting with the audio output produced by the KIT. Indicating the Tactual Audio Electrical Circuit KIT is not only an effective tool, but a crucial one in education for visually impaired students.

The assignment of mathematical calculation of electric current using this KIT proved to be effective in training students' mathematical thinking skills. Therefore, further development of this KIT has great potential to improve the quality of science learning for visually impaired students. Hopefully, the successful development of this KIT can inspire educators and researchers to adopt and modify similar approach in creating innovative and accessible learning media for various materials and other types of disabilities. Thus, it contributes to the creation of a more inclusive and equitable learning environment.

REFERENCES

Abbas, A., Nayab, D.-, & Fatima, G. (2023). Determining the Influential Parameters Affecting the Ability Level of Visually Impaired Children in Mathematics. *Journal of Business and Social Review in Emerging Economies*, *9*(3), 115–126. https://doi.org/10.26710/jbsee.v9i3.2667

Abdi, M. A., Halizah, D. N., Umniah, U., Rismayanti, N., Nurlinda, N., Hayati, L. N., & Wibowo, N. R. (2021). Al-Qur'an Braille Board Interpreter Glove Bagi Tunanetra Dalam Mengatasi Buta Aksara Arab. *JTT (Jurnal Teknologi Terpadu)*, *9*(2), 142–149. https://doi.org/10.32487/jtt.v9i2.1187

Ahmad, M. A., Ahmed, T., Aslam, M., Rehman, A., Member, S., Alamri, F. S., Bahaj, S. A. L. I., Saba, T., & Member, S. (2025). MathVision : An Accessible Intelligent Agent for Visually Impaired People to Understand Mathematical Equations. *IEEE Access*, *13*(October 2024), 6155–6165. https://doi.org/10.1109/ACCESS.2024.3514079

Al-Eidarous, W., Alsiyami, A., Aljabri, M., Alqethami, S., & Almutanni, B. (2024). ExamVoice: Innovative Solutions for Improving Exam Accessibility for Visually impaired and Visually Impaired Students in Saudi Arabia. *Applied Sciences (Switzerland)*, *14*(19). https://doi.org/10.3390/app14198813

Aiken, L. R. (1980). Content Validity and Reliability of Single Items or Questionnaires. Educational and Psychological Measurement, 40(955–959).

Arikunto, S. (2011). *Proses Penelitian: Suatu Pendekatan Praktik.* Jakarta: Rineka Cipta

Bulan, S. R. S., Kaneishia, S., Amanda, S. A., Rizki, P. A., Zulfa, I., Harijanto, A., & Maryani. (2024). Design of Physics Teaching Aids on Arduino Uno-based parallel Series Circuits Article Info : *Jurnal Fisika Dan Pendidikan Fisika*, *9*(2), 133–138.

Damayanti, N. M., Sarnita, F., & Hakim, A. R. (2024). Penggunaan Kalkulator AI Sebagai Media Interaktif dalam Membentuk Pemahaman Konsep dan Melatih Kemampuan Berfikir Kreatif Siswa Tunanetra. *Jurnal PIPA: Pendidikan Ilmu Pengetahuan Alam*, *05*(02), 64–72.

Ketheeswaran, K., & Nawastheen, F. M. (2024). THE IMPACT OF INCLUSIVE EDUCATION ON STUDENTS WITH SPECIAL EDUCATIONAL NEEDS IN THE GOVERNMENT SCHOOLS OF BATTICALOA DISTRICT IN SRI LANKA. *Muallim Journal Ofm Social Science and Humanities*, *8*(1), 28–48.

Mackowski, M., & Brzoza, P. (2022). Accessible Tutoring Platform Using Audio-Tactile Graphics. *MDPI*, 1–20.

Maryam, E., Fahrudin, A., & Ramadan. (2023). Pengembangan Alat Praktikum Fisika Berbasis Digital Voice Equipment Untuk Anak Tunanetra Di SLB Kota Lubuklinggau. *Paedagoria : Jurnal Kajian, Penelitian Dan Pengembangan Kependidikan*, *14*(3), 285–291.

Ookeditse, G. B., & Garegae, K. G. (2024). Teachers' Perceptions of Mathematics-Related Barriers for Students With Visual Impairments. *SAGE Open*, *14*(4), 1–16. https://doi.org/10.1177/21582440241293594

Pramata, A. D., Ardhyananta, H., Widyastuti, W.,

& Felicia, D. M. (2023). Desain Pengembangan Thermometer dengan Output Audio untuk Siswa Tunanetra SMPLB-A YPAB Surabaya untuk Menunjang Pembelajaran Ilmu Pengetahuan Alam. *Sewagati*, *7*(5), 659–665. https://doi.org/10.12962/j26139960.v7i5.7

Riga, P., & Kouroupetroglou, G. (2024). *How Visually impaired Individuals Recall Mathematical Expressions in Auditory , Tactile , and Auditory – Tactile Modalities*.

Shidqi, T. S., & Budi, S. (2023). Penggunaan Metode Multisensori untuk Meningkatkan Kemampuan Membaca Anak Berkebutuhan Khusus: Studi Literatur. *Jurnal Pendidikan Tambusai*, *7*, 22076–22079. https://www.jptam.org/index.php/jptam/article/view/10032%0Ahttps://www.jptam.org/index.php/jptam/article/download/10032/8123

Sugiyono. (2020). *Metode Penelitian Pendidikan Kuantitatif, Kualitatif, dan R&D* (Alfabeta).

Sukma, M. N. B. W., Rusilowati, A., & Khumaedi. (2024). Rancang dan Analisis Alat Ukur Arus dan Tegangan pada Rangkaian Listrik Berbasis. *Unnes Physics Education Journal*, *13*(3), 212–218.

Utami, W. M., & Lutfi, A. (2021). Kit Praktikum Media Pembelajaran Materi Campuran Dan Larutan Peserta Didik Tunanetra di SMPLB. *Jurnal Pendidikan Kimia Indonesia*, *5*(1), 16–24. https://doi.org/10.23887/jpk.v5i1.30742

Utreras, E., & Pontelli, E. (2020). Design of a tangible programming tool for students with visual impairments and low vision. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 12189 LNCS*. Springer International Publishing. https://doi.org/10.1007/978-3-030-49108-6_22

Widiyawati, Y., & Nurwahidah, I. (2020). *Elclivs berbasis inquiry untuk meningkatkan penguasaan konsep siswa tuna netra pada materi rangkaian listrik Elclivs-inquiry based to enhance visual impairment student conceptual understanding in electricity circuit topics*. *4*(2), 212–223.

Widoyoko, S. E. P. (2014). Evaluasi program pembelajaran: Panduan praktis bagi pendidik dan calon pendidik. Yogyakarta: Pustaka Pelajar

Yulanto, D. M., Iskandar, H., & Anggoro, A. B. (2022). PENGEMBANGan Media Pembelajaran Multimeter Berbasis Video Pada Mata. *Jurnal Pendidikan Teknik Mesin*, *2*(22), 7–10.