JPF | Volume 13 | Number 2 | 2025 | 177 - 190

p - ISSN: 2302-8939
e - ISSN: 2527-4015

Jurnal Pendidikan Fisika

https://journal.unismuh.ac.id/index.php/jpf

DOI: 10.26618/jpf.v13i2.17738

Development and Feasibility of a BME 280 Sensor-Based Practicum Tool for Boyle–Gay-Lussac Law Experiments

Elsa Sagita[1)*], Tri Isti Hartini [2)]

Department of Physics Education, University of Muhammadiyah Prof. Dr. Hamka, East Jakarta, 13830, Indonesia

**Corresponding author: elsasgt980@gmail.com*

Received: January 18, 2025; Accepted: March 24, 2025; Published: April 28, 2025

Abstract – *The integration of sensor-based technology into physics learning is essential in the context of the Industrial Revolution 4.0, particularly for improving practicum-based conceptual understanding. This study aims to evaluate the effectiveness and feasibility of a Boyle–Gay-Lussac Law practicum tool developed using the BME280 sensor, which is capable of measuring pressure, temperature, and humidity simultaneously. The research adopted a Research and Development (R&D) approach based on the Jan van den Akker model, involving preliminary research, prototyping, validation by experts, and small-scale field testing. Data were collected through Likert-scale questionnaires validated by physics education experts and tested among high school students. Media validation results achieved an average score of 93.6%, and material validation scored 78%, indicating excellent and good quality, respectively. Small-scale trials yielded average scores of 87.84% for media and 87% for material, categorized as excellent. The developed tool facilitated real-time experimentation, improved measurement accuracy, and enhanced student engagement and conceptual understanding of gas laws. The novelty of this tool lies in its integration of a multi-function sensor and real-time LCD display, offering a compact, reusable, and interactive practicum experience. Conclusions indicate that the BME280 sensor-based tool is both effective and feasible for physics instruction. This innovation contributes to physics education by modernizing practicum resources, promoting active learning, and bridging the gap between abstract thermodynamic concepts and practical experimentation.*

Keywords: *BME 280 sensor; Boyle-Gay-Lussac's law; gas laws; physics practicum; thermodynamics*

I. INTRODUCTION

Education is a crucial aspect of life, particularly in the era of the Industrial Revolution 4.0, which is characterized by the rapid development of science and technology (Natalia & Sukraini, 2021). Technology-based learning media has become an interesting area of discussion, as technology significantly supports the success of education (Nurillahwaty, 2022; Julita & Purnasari, 2022). The development of science and technology has had a profound impact, especially in the education sector. The educational paradigm has shifted with the integration of technology into adaptive and constantly evolving learning media, making the potential of learning media essential (Ramli et al., 2025; Sanaky, 2009; Nurfadhillah, 2021). Educators are now expected to create, design, and manage learning using digital-based media (Karo-Karo & Rohani, 2018; Luthfi et al., 2023). At the high school level, students are expected to be more active and develop positive character traits, especially in science subjects such as physics. Positive attitudes toward learning tend to shape students' acceptance or rejection of concepts that do not align with their thinking (Rini et al., 2021). However, students sometimes develop their own interpretations of physics concepts that may not align with expert views (Risnawati et al., 2022).

Physics, a branch of science that explains the properties of nature and the interactions within it, plays a significant role in shaping students' scientific understanding (Astalini et al., 2022). Low learning outcomes in physics are often attributed to textbooks containing materials considered too complex to comprehend and the ineffectiveness of learning media (Sandari, 2020). Practical tools or teaching aids are crucial for classroom learning, especially in physics concepts that require direct observation, such as Boyle's and Gay-Lussac's law concerning absolute temperature scales (Aminoto et al., 2020; Yovan et al., 2021).

Students' views on physics are one of the key factors influencing the physics learning process (Septi et al., 2021). One theory within physics, thermodynamics, explores relationships in energy systems and explains the behavior of substances under the influence of heat (Warokka & Boedi, 2020; Fatiatun et al., 2022). The concept of an ideal gas suggests that all gases at high temperatures and low pressures exhibit a straightforward relationship between their macroscopic properties (Kua, 2021). Boyle's Law and Gay-Lussac's Law provide explanations for the relationships between temperature, pressure, and volume of gases under typical conditions, though they have limitations related to imbalances in intermolecular and interparticle forces in gases (Kunlestiawati et al., 2023; Pangestu & Perdana, 2023).

An innovative solution for measuring the temperature and pressure of objects is through sensors connected to an Arduino Uno, such as the BME280 sensor (Dinata & Rahayu, 2021; Lukman et al., 2023). The BME280 sensor, manufactured by Bosch Sensortec, is capable of measuring air temperature, pressure, and humidity with a voltage range of 1.71 to 3.6 Volts. This sensor can measure temperatures ranging from -40°C to 85°C, air pressure between 300 and 1,100 hPa, and relative humidity from 0% to 100% (Saptadi & Kiswanto, 2020).

Based on a needs analysis conducted through the distribution of questionnaires at schools on Monday, October 19, 2024, it was found that of the 123 students who filled out the questionnaire, the majority expressed the need for practical tools in physics learning, particularly for the Boyle-Gay-Lussac law practicum. Observations at State Senior High School 1 Tambelang revealed that physics instruction still relies heavily on conventional methods, where educators convey substantial material verbally and depend on summative assessments. This approach has led to difficulties in student comprehension and a lack of confidence in asking questions due to the absence of summative feedback and appropriate learning media (Gamage et al., 2019; Faila et al., 2025). In response to these challenges, this study proposes the development of a practicum tool based on the BME280 sensor for the Boyle-Gay-Lussac Law. The tool is expected to provide an innovative solution to support physics learning, enhance students' understanding of concepts, and improve the quality of practicums in schools.

II. METHODS

This study employed the Research and Development (R&D) approach, which is appropriate for generating educational products, such as practicum tools, and addressing the limitations of conventional instructional media in enhancing educational effectiveness (Okpatrioka, 2023). The development of innovative, technology-based tools is consistent with the objectives of R&D methodology. A Likert scale was utilized to measure students' and teachers' perceptions of the effectiveness of the developed tool, allowing for quantitative analysis of attitudes and responses. The analysis was guided by the framework proposed by Sugiyono (2010), which is widely adopted in educational research for processing quantitative data.

A distinctive feature of this study is the incorporation of the BME280 sensor, which offers an advantage over previous research utilizing components such as Wemos and LM35. The BME280 integrates both temperature and pressure measurement capabilities in a single sensor, thereby improving the efficiency and integration of the developed practicum tool. The development process followed a systematic sequence based on the Akker model (Akker, 2006), encompassing stages of preliminary research, prototyping, and assessment, all of which align with standard procedures in R&D-based studies.

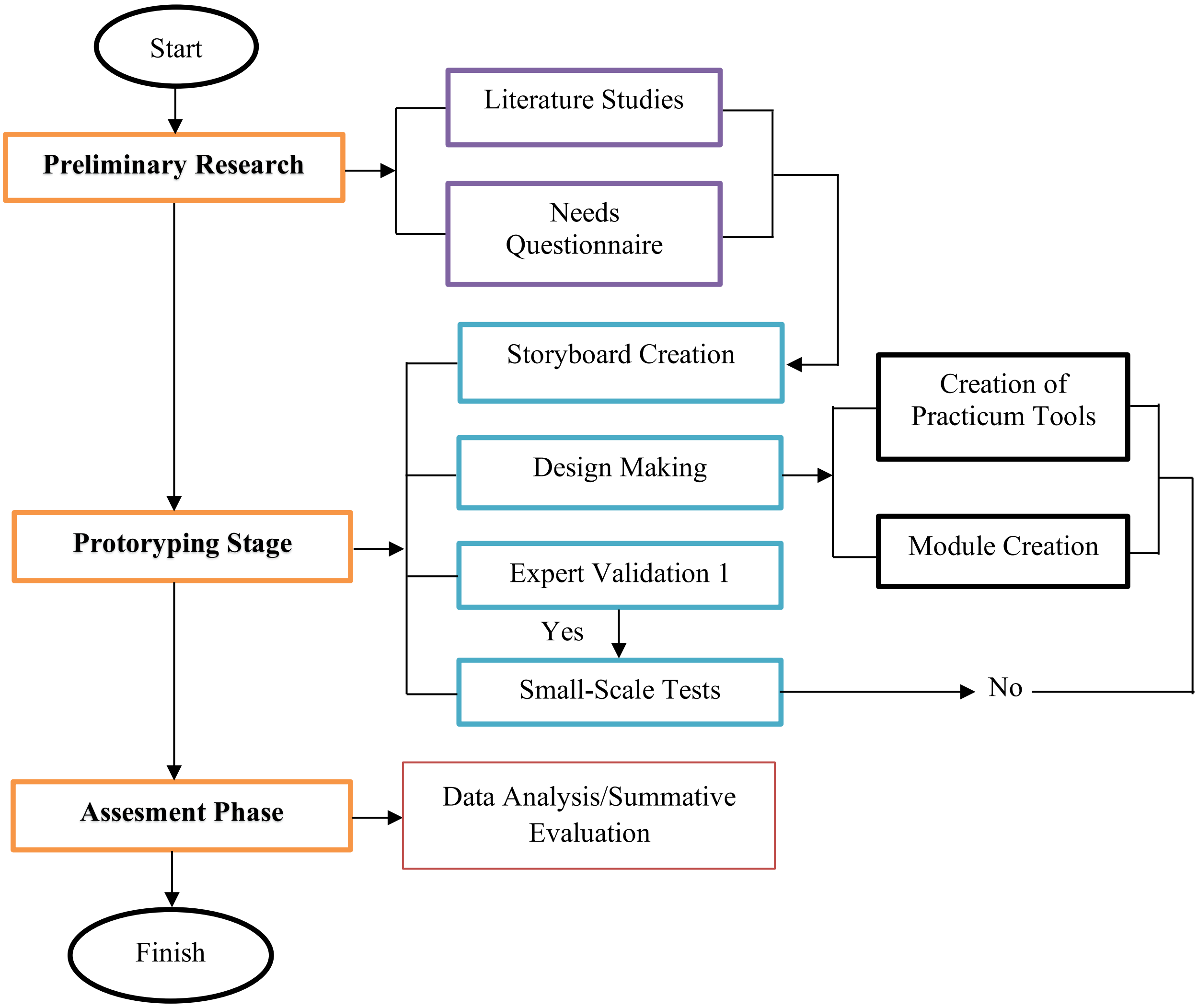

Figure 1. Research and development flowchart based on the Akker model

The feasibility and validity of the developed tool were evaluated through expert validation sheets, reviewed by two qualified experts. The opinions of two validators from the field of physics education offer in-depth and relevant perspectives on the accuracy of the materials and media design. The validator team, comprising lecturers from UIN Jakarta and the University of Muhammadiyah Prof. Dr. Hamka, ensured that the evaluation was conducted by qualified experts in physics education, thereby enhancing the credibility of the research.

A small-scale trial involving 15 respondents at State Senior High School 1 Tambelang provided preliminary data on the effectiveness of the tool in the context of real-world learning. This approach aligns with the prototyping and assessment phases of the Jan van den Akker model. The sample size of 15 students was sufficient to offer valuable initial feedback, particularly in identifying the strengths and weaknesses of the tool before broader application. The validation instrument is designed to assess the feasibility aspect of the tool, a crucial element in the R&D

method. This ensures that the developed tools are not only innovative but also practical and effective for student use.

The purpose of the validation sheet is to assess the feasibility and validity of the BME280 sensor-based tool. This is especially important, as validation is a critical first step before moving on to wider trials. The Likert scale serves as an effective tool for evaluating the perceptions, responses, or opinions of validators regarding the product's feasibility. The explanation of the scoring system is structured and easy to understand. The data analysis process includes the collection of questionnaires, categorization according to the assessment criteria, and the calculation of percentages using the following formula:

$$NP = \frac{R}{SM}\, x\, 100\% \qquad (1)$$

Information:
NP : Percentage Figures
R : Value you are looking for Percentage
SM : Number of frequencies/number of individuals
100% : Setting values

This method aligns with the cited literature, ensuring more standardized evaluation results. The validity criteria for products are classified within a score range (41-60%), which simplifies data interpretation. This is consistent with the referenced theory (Putri & Saehana, 2021; Sugiyono, 2010).

Table 1. Product validity classification based on value range (Sugiyono, 2010)

No	Value range	Letter values	Predicate
1	81-100%	A	Excellent
2	61-80%	B	Good
3	41-60%	C	Enough
4	21-40%	D	Bad
5	0-20%	E	Very bad

III. RESULTS AND DISCUSSION

Practicum tools play a crucial role in the physics teaching process, ensuring that learning is conducted effectively, and that material is delivered optimally. Education must maximize its support for students to achieve the intended learning goals. The developed practicum tool must also include clear instructions for use or a practicum module. Based on Table 2, the results of the media validation test conducted by physics lecturers on the Boyle-Gay-Lussac Law practicum tool, based on the BME280 sensor, include three aspects with an average score of 93.6%, categorized as Very Good.

Table 2. Media validation test results

Aspects	Score	Category
Display eligibility	85.00%	Excellent
Feasibility of the concept of practicum tools	100.00%	Excellent
Utilization of practicum tools	96.00%	Excellent
Average	**93.60%**	**Excellent**

Figure 2 shows the histogram of the results of the media validation test conducted by the validators. The score for the display eligibility aspect is 85%, which still falls in the Excellent category, although slightly lower than the other aspects. The Concept Feasibility aspect received a perfect score of 100%, indicating that the practicum tool is highly aligned with the physics concept. The Utilization aspect scored 96%, demonstrating that the practicum tool is highly effective and practical for use. The high score for concept feasibility suggests that the development of the BME280 sensor-based tool significantly supports in-depth physics learning (Sanaky, 2009). From the results of the media validation test conducted by lecturers, it can be seen in Table 2 and Figure 2 that the Boyle-Gay-Lussac law practicum tool, based on the BME280 sensor, received an average score of 93.6%, categorized as very good. These results indicate that the tool designed by the researcher is highly suitable for use as a practicum tool.

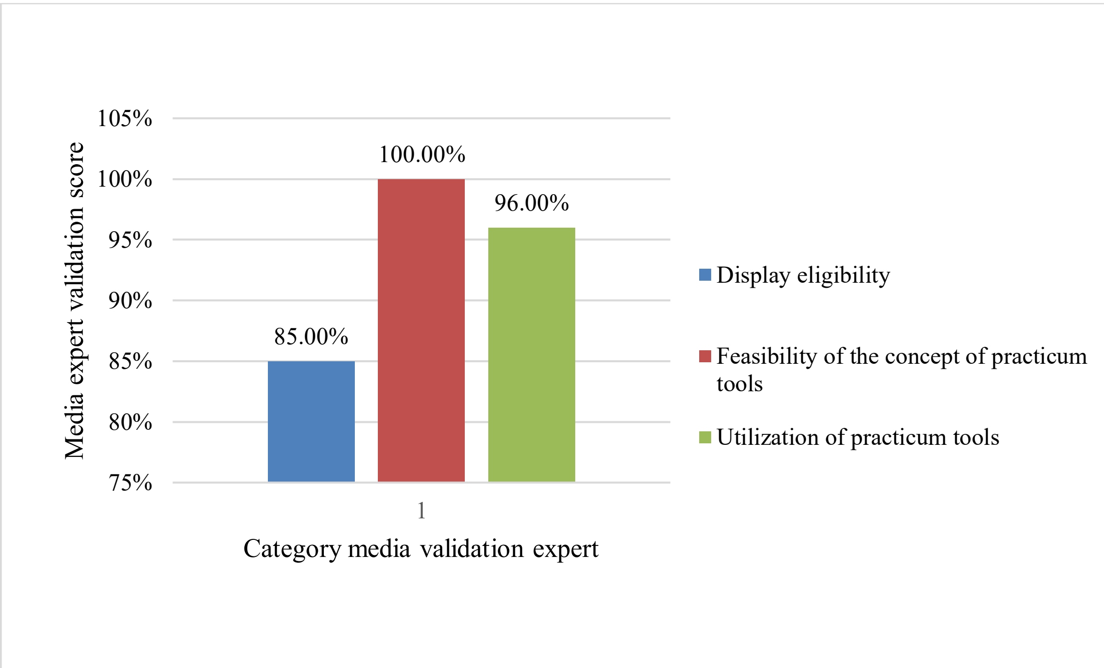

Figure 2. Histogram of media validation test results

Based on the material validation test results in Table 3, conducted by physics lecturers, the material for the Boyle-Gay-Lussac law, which includes six aspects, received an average score of

78%, categorized as good. The results of the assessment indicate that the material is appropriate for use as practicum instructions.

Table 3. Material validation test results

Aspects	Score	Category
Accuracy of the material	80%	Good
Suitability of the material with the developed practicum tools	72%	Good
Techniques, support, and presentation of learning	80%	Good
The language used is straightforward and communicative	80%	Good
Conformity with good and correct Indonesian rules	80%	Good
Contextual nature and components	76%	Good
Average	**78%**	**Good**

Figure 3 shows that the accuracy of the material was 80%, suitability with the developed tools was 72%, learning techniques and presentation scored 80%, language clarity, and communicativeness were 80%, conformity with proper Indonesian language conventions scored 80%, and contextual relevance and component completeness scored 76%. Therefore, these results indicate the material is suitable for instructional use.

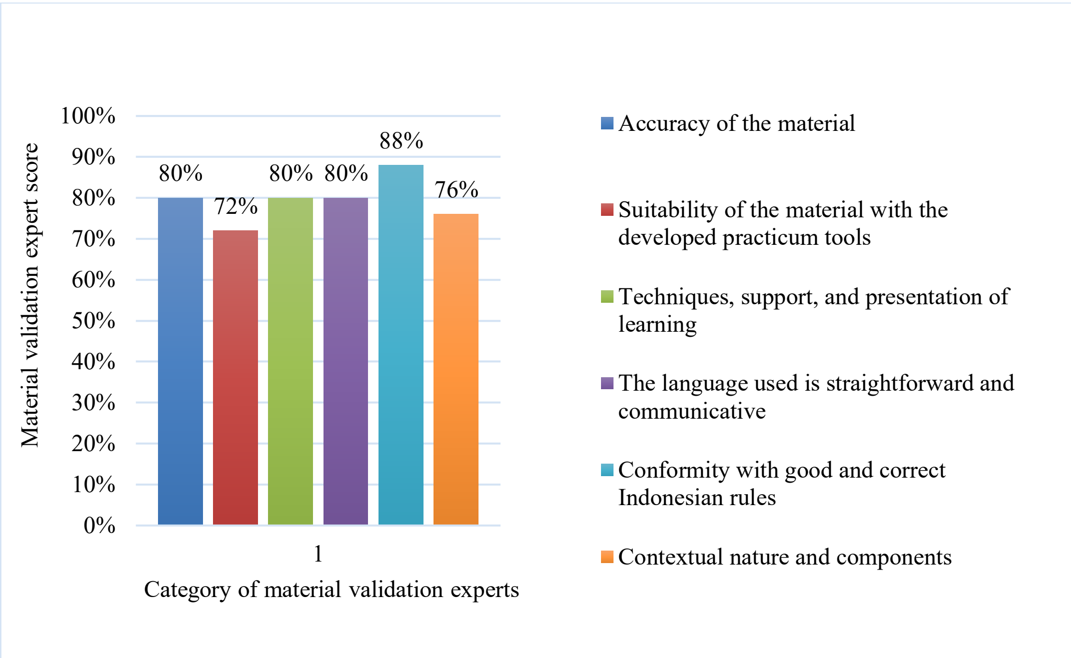

Figure 3. Histogram of material validation test results

After the validation test by experts, the researcher conducted a small-scale test, as shown in Table 4 and Figure 4. Table 4 presents the results of the small-scale media test, evaluating three aspects: display eligibility, concept feasibility, and tool utilization. The average score was 87.84%. classified as excellent. These results indicate that the developed tools effectively support student learning during physics practicums.

Table 4. Results of small-scale media tests

Aspects	Score	Category
Display eligibility	87.66%	Excellent
Feasibility of the concept of practicum tools	90.00%	Excellent
Utilization of practicum tools	85.86%	Excellent
Average	**87.84%**	**Excellent**

Figure 4 illustrates the results of the small-scale media test, with 87.66% for display feasibility, 90.00% for concept feasibility, and 85.86% for tool utilization. These scores place the tool in the "Excellent" category and indicate its strong potential as an instructional medium for the BME280 sensor-based Boyle-Gay-Lussac law practicum.

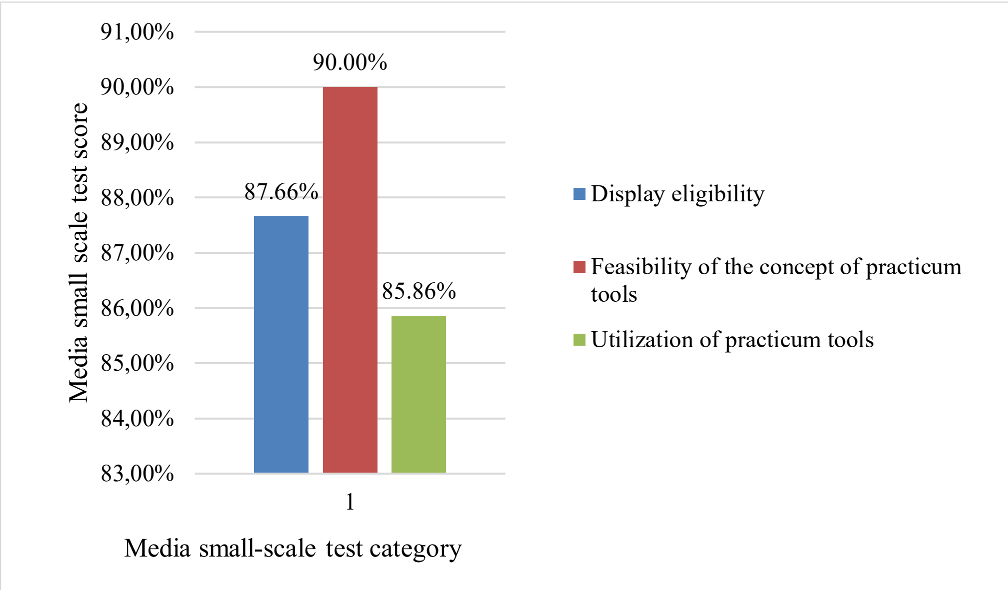

Figure 4. Histogram small-scale test media

Table 5 presents the small-scale test results gathered from student evaluations. The Boyle-Gay-Lussac law material, covering six aspects, received an average score of 87%, categorized as Excellent. These findings suggest that the material is suitable for use as a guideline in the Boyle-Gay-Lussac law practicum.

Table 5. Small-scale test results of materials

Aspects	Score	Category
Accuracy of the material	83.2%	Excellent
Suitability of the material with the developed practicum tools	85.6%	Excellent
Techniques, support, and presentation of learning	90.1%	Excellent
The language used is straightforward and communicative	85.3%	Excellent
Conformity with good and correct Indonesian rules	88.0%	Excellent
Contextual nature and components	89.8%	Excellent
Average	**87%**	**Excellent**

Figure 5 shows the small-scale material test results: 83.20% for material accuracy, 85.60% for tool suitability, 90.10% for learning techniques and presentation, 85.30% for language clarity, 88.00% for linguistic conformity, and 89.80% for contextual relevance. These results confirm the suitability of the material for use in learning activities related to the Boyle-Gay-Lussac law practicum using the BME280 sensor.

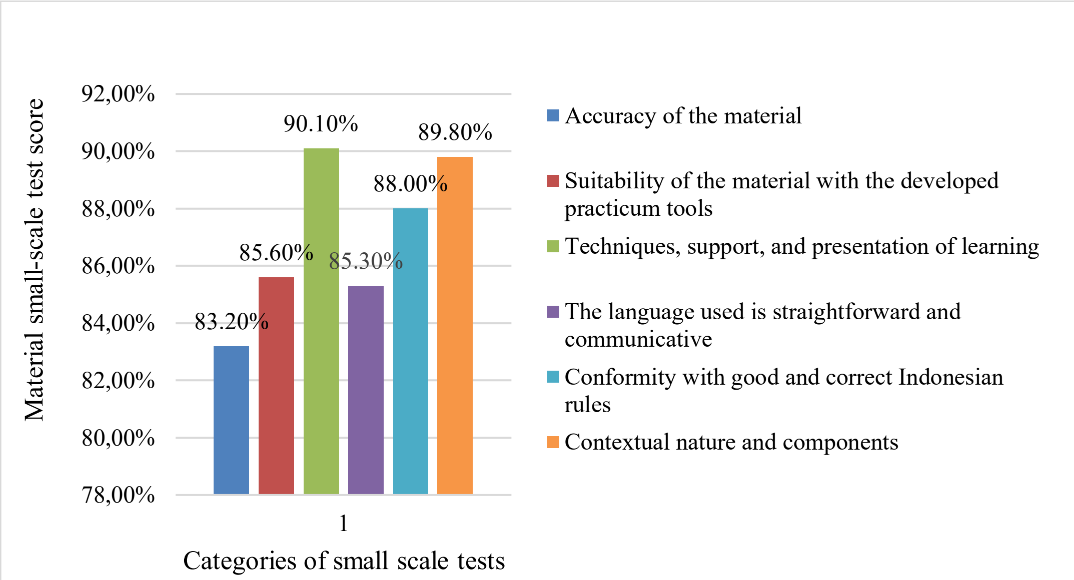

Figure 5. Histogram of small-scale test results of material

Practicum tools play a crucial role in the physics teaching process by enabling effective learning and optimizing the delivery of educational materials. Education must comprehensively facilitate students to achieve the intended learning goals. Therefore, the practicum tool developed should be equipped with a user guide or module to assist practitioners during the experiment. The practicum tools developed in this study offer significant advantages. They can measure and display temperature, pressure, and humidity values on a liquid crystal display screen, facilitating easier data collection during the Boyle-Gay-Lussac law experiment. However, a notable drawback of the tool is the absence of an on/off button. The final product of this study is the Boyle-Gay-Lussac law practicum tool based on the BME280 sensor, which effectively represents the concepts of Boyle's and Gay-Lussac's laws. Key variables such as temperature, pressure, and humidity can be observed and used in calculations involving hot water in an electric mug container. Moreover, the tool is reusable, which increases its practicality in an educational context.

This tool was deemed feasible based on evidence obtained from expert tests and field trials. The study builds on previous research and integrates their findings for comparison to assess the effectiveness of the developed tool. Several related studies have developed similar tools.

Detasari et al. (2022) in used a 4D model (data analysis, product design, product manufacturing, and validation/trial). The developed tool achieved an average validation score of 89.55%, categorized as very feasible. Student responses showed strong approval with an average score of 90.8%, classified as strongly agree. Hidayah (2021), in her study, aimed to develop a practicum tool to directly observe temperature and pressure changes, equipped with Wemos for graphical data representation. This study followed Jan van den Akker's development research model (initial research, prototype, summative evaluation, and systematic reflection/documentation). Hamzah et al. (2021) in their study developed a tool used in the black body radiation practicum. The tool was validated with scores of 75% for effectiveness and 83.56% for the practicality of the manual, demonstrating its feasibility.

Furthermore, previous studies involving LM35, Arduino Uno, Wemos, and other microcontroller systems have shown that sensor-based practicum tools enhance student motivation and learning outcomes. However, the alignment between measured data and conceptual frameworks remains an area needing refinement. The tool developed in this study attempts to address this by directly linking real-time data collection to Boyle's and Gay-Lussac's laws, thereby facilitating immediate application of theoretical principles to experimental contexts.

The findings from this study offer both theoretical and practical implications for the advancement of physics instruction. Theoretically, the integration of multi-sensor systems into practicum tools reinforces constructivist learning approaches by enabling students to build knowledge through active experimentation and data interpretation. Practically, the tool contributes to modernizing laboratory instruction in schools, especially in contexts where traditional practicum facilities are limited. The use of compact, low-cost, and reusable technology enhances accessibility while promoting inquiry-based learning. Future development should prioritize the inclusion of basic operational features (e.g., power control and timing) and consider broader field testing to validate the tool's impact on learning outcomes across diverse educational settings.

IV. CONCLUSION AND SUGGESTION

This study evaluated the effectiveness and feasibility of a BME280 sensor-based practicum tool designed to support the learning of Boyle's and Gay-Lussac's gas laws in high school physics. The development process, following the Jan van den Akker R&D model, resulted in a practicum tool capable of measuring pressure, temperature, and humidity in real time, displayed via an integrated LCD screen. Validation by expert reviewers yielded an average score of 93.6% for media and 78% for material, both indicating high feasibility. Small-scale trials conducted with students confirmed the tool's effectiveness, with average scores of 87.84% and 87% for media and material usability, respectively. The tool significantly enhanced students' experimental accuracy, engagement, and understanding of thermodynamic relationships, particularly by enabling direct observation and interaction during practicum sessions.

Despite these promising outcomes, several limitations were identified. The study was restricted to small-scale implementation and the absence of key features such as an on/off button and an integrated timer limited operational flexibility and data stability. Future research should expand the scale of testing, assess the long-term learning impact, and integrate advanced features to improve user experience and data precision. This study contributes to physics education by offering an innovative, sensor-based practicum tool that supports interactive, technology-integrated learning. The approach aligns with 21st-century pedagogical demands by enhancing students' conceptual understanding through real-time data exploration and active experimentation.

ACKNOWLEDGMENTS

The authors would like to express sincere gratitude to Dr. Tri Isti Hartini, M.Pd., for her invaluable guidance, knowledge, and continuous support throughout the research process. Appreciation is also extended to Dr. Imas Ratna Ermawati, M.Pd., and Mr. Sugiyanto, M.Si., for their insightful feedback and academic assistance. Special thanks are due to the lecturers of the Physics Education Study Program at the University of Muhammadiyah Prof. Dr. Hamka and the Physics Laboratory for their contribution to the authors' academic development. The authors are also grateful to the State Islamic University of Jakarta for granting permission to conduct the material validation. Lastly, heartfelt appreciation is extended to all individuals who contributed to the successful completion of this research but are not mentioned individually.

REFERENCES

Akker, J. V. D., Gravenmeijer, K., McKenney, S., & Nieveen, N. (2006). *Design research from alearning design perspective.* Educational Design Research.

Aminoto, T., Dani, R., & Lestari, N. (2020). Penerapan inovasi termometer gas sebagai media pembelajaran fisika di SMAN 3 dan SMAN 5 Sungai Penuh. *Jurnal Karya Abdi*, *4*(1), 54–62. https://doi.org/10.22437/jkam.v4i1.9817

Astalini, A., Darmaji, D., Kurniawan, D. A., & Putri, W. A. (2022). Description of basic science process skills of students at SMA 6 Muaro Bulian. *Edu-Sains: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam, 11*(2), 1–11. https://doi.org/10.22437/jmpmipa.v12i1.25423

Detasari, A. T., Hadiati, S., & Sukadi, E. (2022). Pengembangan alat ukur suhu berbasis mikrokontroler arduino nano sebagai media pembelajaran pada materi suhu dan kalor. *Vidya Karya, 37*(2), 68-76. http://dx.doi.org/10.20527/jvk.v37i2.14531

Dinata, A. S., & Rahayu, U. P. (2021). Rancang bangun alat penetas telur otomatis berbasis arduino uno. *Jurnal Ilmiah Mahasiswa Kendali dan Listrik*, *2*(2), 66–74. https://doi.org/10.33365/jimel.v2i2.1477

Faila, R. E., Supahar, S., & Pebriana, I. N. (2025). An assessment to measure problem-solving ability and science process skills: A feasibility test. *Jurnal Pendidikan Fisika, 13*(1), 90-102. https://doi.org/10.26618/jpf.v13i1.15654

Fatiatun., Pratiwi, A. D., Wirdati, A. C., & Avifatun, N. (2022). Penerapan termodinamika heating dan colling pada dispenser. *Jurnal Penelitian dan Pengabdian Kepada Masyarakat Unsiq*, *9*(2), 146–150. https://doi.org/10.32699/ppkm.v9i2.2658

Gamage, S. H. P. W., Ayres, J. R., Behrend, & Smith, E. J. (2019). Optimising moodle quizzes for online assesment. *Internatioanl Journal of STEM Education*, *6*, 1–14. https://doi.org/10.1186/s40594-019-0181-4

Hamzah, H., Musdar, M., & Hasrul. H. (2021). Pengembangan alat ukur suhu menggunakan sensor lm35 berbasis arduino uno sebagai media pembelajaran fisika. *Phydagogic: Jurnal Fisika Dan Pembelajarannya*, *4*(1), 6-15. https://doi.org/10.31605/phy.v4i1

Hidayah, S. N. (2021). *Pengembangan alat praktikum hukum gay lussac berbasis wemos untuk meningkatkan hasil belajar siswa SMA*. Skripsi. Universitas Islam Negeri Syarif Hidayatullah Jakarta.

Julita, & Purnasari, P. D. (2022). Pemanfaatan teknologi sebagai media pembelajaran dalam pendidikan era digital. *Journal of Educational Learning and Innovation*, *2*(2), 227-239. https://doi.org/10.46229/elia.v2i2.460

Karo-Karo, I. R., & Rohani. (2018). Manfaat Media Dalam Pembelajaran. *Axiom: Jurnal Pendidikan dan Matematika*, *7*(1), 94-95.

Kua, M. Y. (2021). Tabung suntik untuk hukum boyle, simulasi pengukuran tekanan udara dengan real world problem sebagai alternatif pemecahan masalah. *Imedtech (Instructional Media, Design and Technology)*, *4*(2), 43. https://doi.org/10.38048/imedtech.v4i2.225

Kunlestiawati, K., Muldiani, R. F., & Pratama, D. (2023). Analisis model persamaan gas nyata pada eksperimen hukum gay-lussac dan boyle. *Science and Physics Education Journal (SPEJ)*, *7*(1), 1–7. https://doi.org/10.31539/spej.v7i1.6869

Lukman, R., Fernando, Y., & Jayadi, A. (2023). Perancangan alat pakan bebek otomatis terjadwal berbasis arduino uno dengan penjadwalan android. *Jurnal Informatika dan Rekayasa Perangkat Lunak*, *4*(1), 10–21. https://doi.org/10.33365/jatika.v4i1.2454

Luthfi, T., Azzahra, S., Farhan, Z. A., Puradireja, S. M., Iskandar, S., & Sari, N. T. A. (2023). Media pembelajaran digital sebagai penunjang mata pelajaran IPA di sekolah dasar. *Indonesian Journal of Teaching and Learning* *2*(4), 484–492. https://doi.org/10.56855/intel.v2i4.374

Natalia, K., & Sukraini, N. (2021). Pendekatan konsep "merdeka belajar" dalam pendidikan era digital. *Prosiding Digitalisasi Pendidikan Sekolah Dasar*, *3*, 22-34. https://doi.org/10.33363/sn.v0i3.93

Nurfadhillah. S. (2021). *Media pembelajaran: Pengertian media pembelajaran, landasan, fungsi, manfaat, jenis-jenis media pembelajaran, dan cara penggunaan kedudukan media pembelajaran*. CV Jejak

Nurillahwaty, E. (2022). Peran teknologi dalam dunia pendidikan. *Prosiding Seminar Nasional Pendidikan, 1*, 1-8.

Okpatrioka. (2023). Reearch and development (R&D) penelitian yang inovatif dalam pendidikan. *Jurnal Pendidikan, Bahasa dan Budaya*, *1*(1), 86–100. https://doi.org/10.47861/jdan.v1i1.154

Pangestu, D. A., & Perdana, R. (2023). Pengembangan alat peraga air mancur sederhana untuk meningkatkan minat dan motivasi belajar pada materi hukum boyle. *Jurnal Inovasi Penelitian dan Pembelajaran Fisika*, *4*(1), 29-36. https://doi.org/10.26418/jippf.v4i1.60430

Putri, A., & Saehana, S. (2021). Pengembangan alat praktikum menggunakan sensor ultrasonik dikombinasikan dengan arduino sebagai media bantu praktikum materi gelombang. *Jurnal Inovasi dan Pembelajaran Fisika, 8*(1), 1–13.

Ramli, I., Nuraisa., & Khaerati. (2025). Android based multimedia for teaching science in junior high school. *Jurnal Pendidikan Fisika, 13*(1), 59-72. https://doi.org/10.26618/jpf.v13i1.17202

Rini, E. F. S., Fitriani, R., Putri, W. A., Ginting, A. A. B., & Matondang, M. M. (2021). Analisis kerja keras dalam mata pelajaran fisika di SMAN 1 kota jambi. *SAP (Susunan Artikel Pendidikan*, *5*(3), 221-226.

Risnawati, W. O., Takda, A., Eso, E., & Tahir. (2022). Identifying the misconceptions of temperature and heat in class X science high school students negeri 5 Kendari using four tier diagnostic test. *Jurnal Penelitian Pendidikan Fisika*, *7*(1), 26-35. https://doi.org/10.36709/jipfi.v7i1.23466

Sanaky, H. A. H. (2009). *Media pembelajaran*. Safiria Insania Press.

Sandari, T. (2020). Analisis minat siswa terhadap mata pelajaran fisika di SMA N 1 Batanghari. *Schrödinger: Journal of Physics Education*, *2*(4), 72-75.

Saptadi, A. H., & Kiswanto, A. (2020). Rancang bangun web server penampil data cuaca berbasis arduino menggunakan sensor BME280 dan BH1750FVI dengan tiga mode tampilan data. *Jurnal Teknik Elektro dan Komputasi, 2*(2), 112-121. https://doi.org/10.32528/elkom.v2i2.3516

Septi, S. E., Deswalman, D., Maison, M., & Kurniawan, D. A. (2021). Pengaruh model pembelajaran discovery learning terhadap keterampilan proses sains siswa pada mata pelajaran fisika di SMAN 10 Kota Jambi. *Jurnal Phi: Jurnal Pendidikan Fisika dan Fisika Terapan*, *7*(2), 10-18. http://dx.doi.org/10.22373/p-jpft.v7i2.13225

Sugiyono. (2010). *Penelitian pendidikan pendekatan kuantitatif, kualitatif, dan R&D*. Alfabeta.

Warokka, A., & Boedi, S. (2020). *Termodinamika teknik.* Polimdo Press.

Yovan, R. A. R., Ningsari, I. S., Sukma, A. K., Qomariah, Y. N., & Hidaayatullaah, H. N. (2021). Analysis of physics university students' knowledge and understanding of thermodynamic scientists. *Studies in Philosophy of Science and Education*, *2*(1), 17–23. https://doi.org/10.46627/sipose.v2i1.59