JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Development of an ESP32 Microcontroller-Based Temperature Laboratory Instrument to Facilitate the Digital Literacy of Undergraduate Students

Holis Angga Saputra[1*], Karnan[1]

[1] Master of Science Education, Postgraduate, University of Mataram, Mataram, Indonesia

Received: July 19, 2026
Revised: October 13, 2026
Accepted: October 26, 2026
Published: October 31, 2026

Corresponding Author:
Holis Angga Saputra
holisgga@gmail.com

DOI: 10.29303/jossed.v7i2.16060

Open Access

© 2026 he Authors. This article is distributed under a (CC-BY License)

Abstract: This study aims to develop a valid and practical ESP32 microcontroller-based temperature laboratory instrument to facilitate the digital literacy skills of undergraduate students. The study utilized the Research and Development (R&D) method with the ADDIE (Analyze, Design, Develop, Implement, Evaluate) instructional model. The large-scale trial involved 130 target undergraduate students using a One-Group Pre-test-Post-test design. Data collection utilized expert validation sheets, practicality questionnaires, and a Likert-scale digital literacy questionnaire. The analysis results indicate that the developed physical instrument and questionnaire are highly feasible for use, obtaining Aiken's V indices of 0.84 and 0.86, respectively (Highly Valid). The digital interface of this device was also considered highly user-friendly, with a practicality percentage of 91.41% from the practicum assistants and 81.98% from the undergraduate students. The evaluation of digital literacy improvement yielded an average N-Gain of 0.07 (Low category). Empirically, this quantitative finding does not represent the ineffectiveness of the instrument, but rather is purely due to a ceiling effect phenomenon caused by the exceptionally high baseline technological readiness of the undergraduate students as digital natives. It can be concluded that the ESP32 instrument innovation is proven to be highly robust and successful in fulfilling its essential function as a facilitator that accommodates the scientific computational skills of undergraduate students in the laboratory, with a note recommending reinforcement in the realm of hardware troubleshooting.

Keywords: Ceiling Effect; Digital Literacy; ESP32 Microcontroller; Laboratory Instrument; R&D

Introduction

The development of information and communication technology in the era of the Fourth Industrial Revolution has fundamentally transformed the 21st-century education landscape (Pratama et al., 2025; Zuhri et al., 2024). According to Fitriyani and Nugroho (2022), this transformation demands that undergraduate students not only master conventional reading-writing literacy but also possess digital literacy skills. Digital literacy is a comprehensive concept defined as an individual's ability to use technological devices and digital information effectively, efficiently, and responsibly (Nisa et al., 2025; Restianty, 2018). This capability is crucial to support high-quality academic information-seeking behavior while simultaneously countering hoaxes in the digital space (Fauzi & Marhamah, 2021; Mahesa & Siregar, 2026; Saputri & Manggalani, 2023)

A recent systematic review by Tinmaz et al. (2022) even emphasizes that digital literacy currently serves as an "umbrella term" encompassing technical operational skills, critical information evaluation, and computational-based problem-solving. The importance of digital literacy as an essential competency is now being massively promoted across educational levels, ranging from its introduction in early childhood and elementary schools (Aprilita et al., 2025; Fitriani & Rukli, 2025; Handayani, 2022; Naimah et al., 2024) to its implementation as a prerequisite for adapting the *Merdeka* Curriculum and 21st-Century Curriculum at the secondary and higher education levels (Asiah et al., 2026; Assis & Almeida, 2020; Jannah et al., 2024)

How to Cite:
Saputra, H. A., & Karnan, K. (2026). Development of an ESP32 Microcontroller-Based Temperature Laboratory Instrument to Facilitate the Digital Literacy of Undergraduate Students. *Journal of Science and Science Education*, *7*(2), 132–138. https://doi.org/10.29303/jossed.v7i2.16060

In the context of science education at the higher education level, the demand for digital literacy mastery should be optimally facilitated through experimental activities in the laboratory. This aligns with the findings of Saputra et al. (2025), which assert that the integration of Internet of Things (IoT) technology into laboratory monitoring systems has proven effective in digitalizing conventional workflows into more advanced and automated processes. Unfortunately, the reality in the field indicates that practicum activities, particularly concerning Temperature and Heat materials, remain heavily dependent on analog measuring instruments. This reliance on conventional mercury or alcohol thermometers confines the learning experiences of undergraduate students solely to the mechanical routine of manually reading measurement scales, thereby providing absolutely no room for them to explore computational digital literacy skills.

The absence of digital instruments in the laboratory actually triggers an academic irony. An empirical study by Dinata (2021) proves that the current generation of undergraduate students has essentially achieved a "Very Good" level of operational literacy in their daily use of gadgets. In line with this, Ririen and Daryanes (2022) also confirm that the basic technological readiness (entry behavior) of science undergraduate students is fundamentally highly capable. However, their proficiency as technology consumers will not be able to transform into scientific analytical skills if the laboratory ecosystem fails to facilitate it. Without the presence of smart devices, undergraduate students are not trained to navigate instrument data in real-time, extract automatic graphical presentations, or perform troubleshooting actions when errors occur in the hardware circuits.

Based on this gap, it is highly urgent to develop and introduce digital-based laboratory instrument innovations to accommodate and direct the technological literacy potential of undergraduate students in a structured manner. The proposed innovative solution is to design an automated physics laboratory instrument using an ESP32 microcontroller calibrated with a precision DS18B20 sensor. This smart hardware is not merely intended as a pure temperature data collector; rather, it is specifically designed as a digital interface to comprehensively train the digital literacy indicators of undergraduate students. Based on this urgency, this study aims to develop an ESP32 microcontroller-based temperature laboratory instrument that is valid and practical, and specifically to analyze the extent to which the intervention of this instrument can accommodate and facilitate the digital literacy achievements of undergraduate students.

Method

This study applied the Research and Development (R&D) method. According to Setyosari (2016), development is a process utilized systematically to develop and validate educational products. The development model adopted in this study was the ADDIE (Analyze, Design, Develop, Implement, Evaluate) instructional design (Hidayat & Nizar, 2021). Branch (2009) asserts that the ADDIE model is a highly systematic and product-oriented instructional design framework, making it highly relevant for developing technology-based learning devices.

During the empirical implementation phase in the laboratory, this study utilized a pre-experimental One-Group Pre-test-Post-test Design. The large-scale trial involved undergraduate students from the Mathematics Education Study Program at the University of Mataram who were taking the Basic Physics Practicum course. Participants were selected using a purposive sampling technique, with inclusion criteria comprising a uniformity of academic background and no prior experience in using the ESP32 microcontroller device (Aini et al., 2020).

Data collection focused on using expert validation sheets, practicality questionnaires, and a digital literacy questionnaire. The validity of the product was evaluated using the Aiken's V index formula (Suhardi, 2022; Utami et al., 2024). The validity equation is formulated in Equation (1) as follows.

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

Description:

V = Aiken's V validity index

$\sum s$ = The difference between the score assigned by the validator and the lowest rating score ($r - l_o$)

n = Number of expert validators

c = Number of rating scale categories

Based on the above formulation, the product validity level was interpreted referring to the stipulations of Retnawati (2016), namely the "Highly Valid" category ($V > 0.8$), "Moderate Validity" ($0.4 < V \leq 0.8$), and "Less Valid" ($V \leq 0.4$). Furthermore, to ensure that the agreement among the experts was consistent and free from bias, a reliability test of the Percentage of Agreement (PA) was conducted using Equation (2) (Emmer & Millett, 1970).

$$PA = \left(1 - \frac{A-B}{A+B}\right) \times 100\% \quad (2)$$

Description:

PA = Percentage of Agreement (Instrument reliability)

A = Higher rating score from the validator

B = Lower rating score from the validator

An instrument is declared to have good dependability and reliability if the percentage of agreement among validators reaches a minimum threshold of 75% (Borich, 2011). On the other hand, the extent to which the product can be easily applied in the field was measured using the practicality percentage through Equation (3) below (Akbar, 2013; Irawan & Hakim, 2021).

$$\%\text{Practicality} = \frac{\text{Total score from raters}}{\text{Maximum total scor}} \times 100\% \quad (3)$$

The practicality evaluation criteria were interpreted into five ranges, where the product is declared to meet the "Highly Practical" requirements if the obtained percentage breaks through the 81% to 100% mark (Akbar, 2013).

Finally, to measure the product's effectiveness on the digital literacy variable of the undergraduate students, a Likert-scale questionnaire instrument was utilized. This instrument was designed with four alternative answer choices (Ririen & Daryanes, 2022) and deliberately structured to include positive statement items as well as negative statements (unfavorable) that require a reverse scoring technique. The availability of reverse scoring items functions as a cognitive pause that effectively reduces the probability of respondents providing distracted answers (İlhan et al., 2024). The percentage of the final digital literacy score was then calculated by comparing the cumulative score achieved with the maximum score using Equation (4) (Dinata, 2021).

$$\text{DL Score} = \left(\frac{\text{Total obtained score}}{\text{Maximum total score}}\right) \times 100 \quad (4)$$

The significance of the improvement margin in the undergraduate students' digital literacy post-intervention was then objectively calculated using the Normalized Gain (N-Gain) test in Equation (5) (Hake, 1998; Wahab et al., 2021)

$$\text{N} - \text{Gain} = \frac{(\text{posttest score} - \text{pretest score})}{(\text{maximum score} - \text{pretest score})} \quad (5)$$

The results of the N-Gain calculation were subsequently classified into three achievement levels, namely the "High" category ($g > 0.7$), the "Medium" category ($0.3 \leq g \leq 0.7$), and the "Low" category ($g < 0.3$) (Hake, 1998; Law et al., 2018).

Result and Discussion

Feasibility of the Instrument and Digital Literacy Questionnaire

Before being implemented in the laboratory, the feasibility of the ESP32 microcontroller-based laboratory instrument and its measurement instrument must be ensured through validity and reliability tests. Physically, the final product of the ESP32 smart measuring device has been packaged into a portable and precise form, integrated with a display screen for real-time data reading, as presented in Figure 1.



Figure 1. The developed ESP32-based temperature practicum tool

Based on the expert judgment test using the Aiken's V index, the ESP32 practicum device obtained a score of 0.84 (Highly Valid) with an inter-validator Percentage of Agreement consistency level of 94.56% (Reliable). Furthermore, the non-test instrument in the form of a digital literacy questionnaire that will be used to measure the achievement of undergraduate students also obtained a validity index of 0.86 (Highly Valid) and a reliability of 92.86% (Reliable). Validation using Aiken's V is a highly stringent standard recommended to justify the content feasibility of science learning devices (Listari et al., 2023; Suhardi, 2022; Utami et al., 2024). Furthermore, the non-test instrument in the form of a digital literacy questionnaire that will be used to measure the achievement of undergraduate students also obtained a validity index of 0.86 (Highly Valid) and a reliability of 92.86% (Reliable). The high values of validity and reliability are absolute prerequisites confirming that all experimental devices are highly feasible to be implemented for objective field data collection.

Product Practicality

The practicality level of the device was reviewed from its ease of operation during the practicum without encountering significant technical obstacles. The analysis results of the responses from the practicum assistants (expert users) showed a percentage of 91.41% (Highly Practical). In line with this, the trial on 130 undergraduate students yielded a practicality level of 81.98% (Highly Practical). This high practicality percentage qualitatively proves that the device interface

is highly user-friendly and significantly capable of reducing the mechanical technical barriers that often occur with analog thermometers (Saputra et al., 2025). The use of the DS18B20 sensor on the ESP32 microcontroller is proven to be highly practical in extracting thermal data with high precision accuracy, minimizing reading errors (parallax), and accelerating the efficiency of experiment time (Baehaqi et al., 2023; Hercog et al., 2023; Linggarjati, 2022). IoT innovations of this kind have empirically been widely proven capable of increasing the enthusiasm and learning practicality of undergraduate students in the physics laboratory (Isnaini et al., 2024).

The Role of the ESP32-Based Temperature Laboratory Instrument in Facilitating Digital Literacy

The primary focus of this research is to evaluate the extent to which the presence of the automated ESP32 instrument is capable of accommodating and facilitating the digital literacy skills of undergraduate students in the laboratory. Undergraduate students are required not merely to be passive device consumers, but rather to act proactively in extracting and processing data from the instrument's screen. The documentation of the undergraduate students' interaction with the digital device can be seen in Figure 2.



Figure 2. Students' interaction with the digital interface during practicum

The impact of this device intervention was then analyzed quantitatively through a comparison of the pre-test and post-test questionnaire score margins using the Normalized Gain (N-Gain) test. A summary of the digital literacy achievement for each indicator is presented in Table 1.

Based on Table 1, the overall average N-Gain of the undergraduate students' digital literacy is at an index of 0.07, which is classified into the "Low" category. This highly minimal margin of improvement is also clearly visualized in Figure 3.

Table 1. Students' Digital Literacy Outcomes by Indicator

DL Indicators	Average pre-test	Average post-test	N-Gain	Category
1. Operational Skills	2.87	2.88	0.01	Low
2. Data Navigation	2.96	3.06	0.10	Low
3. Data Processing	2.91	3.02	0.10	Low
4. Technical Troubleshooting	2.76	2.83	0.06	Low
Overall Average	2.87	2.95	0.07	Low

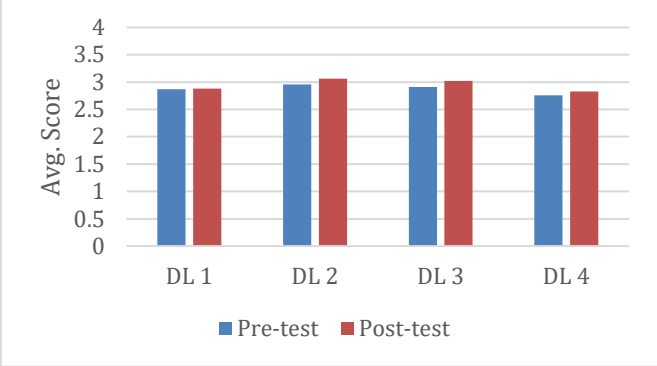


Figure 3. The graph of digital literacy achievement per indicator

Although mathematically this improvement figure (N-Gain) appears to be very low, an in-depth analysis of the graphs and raw data tables actually reveals the reality of the high baseline of technological readiness (digital readiness) possessed by the target undergraduate students. In the three main operational indicators, namely Data Navigation, Data Processing, and Operational Skills, the undergraduate students' initial scores (pre-test) had respectively reached 2.96, 2.91, and 2.87 out of a maximum scale of 4.00.

This high baseline achievement triggered a ceiling effect phenomenon (Ceiling Effect). Because the digital literacy skills of the undergraduate students were fundamentally highly established since before the treatment was given, the resulting final scores (post-test) only had a very narrow empirical room for improvement. This stagnation phenomenon in score acquisition due to the ceiling effect occurs when a measurement cannot detect sensitive improvements because the subject's initial score (baseline) has absolutely approached the upper limit of the assessment scale (Edwards & Soland, 2024; Staus et al., 2021). This is directly confirmed by the study of Sihotang and Ameylia (2024) in Halimah and Fathurrohman (2025), and is strongly supported empirically by Azdawi et al. (2024), Utama et al. (2026), and Yudianto et al. (2026) who directly observed margin stagnation caused by high baseline values. This is also emphasized by (2026) who assert that this limited space for variation will statistically weaken the ability of the Gain test to

significantly detect the margin of improvement post-intervention.

These high pre-intervention indicators prove that undergraduate students as the digital native generation did not essentially experience any technological stuttering (technology shock) at all when operating the microcontroller-based instrument in the laboratory. This is compared and aligned with the research of Dinata (2021), which concludes that the foundation of the 21st-century undergraduate students' operational and navigational digital literacy is already very solidly formed from their daily gadget routines. In other words, the acquisition of an N-Gain of 0.07 in this study is absolutely not a representation of the failure or ineffectiveness of the ESP32 device, but rather tangible proof that this device has successfully carried out its essential role as a "facilitator/vessel" that accommodates the high literacy of undergraduate students that has thus far been unchanneled in analog measuring devices.

On the other hand, however, in the fourth indicator, namely Technical Troubleshooting, the average achievements of the pre-test (2.76) and post-test (2.83) tended to lag behind the other three indicators. This is highly natural to occur because undergraduate students are not technically accustomed to dealing with hardware (hardware) system constraints from the Internet of Things (IoT) infrastructure, such as the occurrence of sensor reading delays or connection network dropouts. This finding theoretically confirms the literature of Ririen dan Daryanes (2022), which asserts that the high proficiency of undergraduate students in using software as technology consumers is often not balanced by their analytical diagnostic skills in repairing errors (damage resolution) on hardware mechanical circuits.

Conclusion

Based on the results of the Research and Development that have been conducted, it can be concluded that the innovation of the ESP32 microcontroller-based temperature laboratory instrument is proven to be highly feasible, practical, and functional in facilitating the digital literacy skills of undergraduate students in the laboratory. The feasibility of this product was confirmed through the achievement of an Aiken's V index of 0.84 for the physical instrument and 0.86 for the digital literacy questionnaire instrument (Highly Valid). In terms of its usability, the digital device interface has proven to be highly user-friendly in reducing the mechanical technical barriers of the experiment, as evidenced by the high percentage of practicality obtained from the practicum assistants (91.41%) and the target undergraduate students (81.98%).

Furthermore, regarding its impact on digital literacy skills, the overall average N-Gain acquisition of 0.07 (Low category) is empirically not a representation of the instrument's ineffectiveness, but rather purely the result of a ceiling effect phenomenon (ceiling effect). The target undergraduate students, who are notably the digital native generation, already possessed a highly established operational technological readiness (baseline) before the intervention was administered. Thus, this ESP32 instrument has successfully carried out its strategic role as a "facilitator," which accommodates and transforms the passive habits of undergraduate students in consuming gadgets into scientific computational data navigation skills. Nevertheless, these findings also recommend the need for the integration of a mechanical troubleshooting module (troubleshooting) in future research, considering that undergraduate students are not yet fully accustomed to independently diagnosing and resolving constraints in the hardware circuits of the Internet of Things (IoT) infrastructure.

Acknowledgments
The authors express their deepest gratitude to the Master's Program in Science Education, Postgraduate School of Mataram University, and the Physics Education Laboratory, Faculty of Teacher Training and Education, Mataram University, for the facility support and research implementation permits. High appreciation is also extended to the expert validators, practicum assistant colleagues, and all undergraduate students who actively participated during the field trial stages, ensuring the successful execution of this study.

Author Contributions
Conceptualization, H.A.S., A.D., and K.; methodology, H.A.S. and A.D.; software, H.A.S.; validation, A.D. and K.; formal analysis, H.A.S.; investigation, H.A.S.; resources, H.A.S. and K.; data curation, H.A.S.; writing—original draft preparation, H.A.S.; writing—review and editing, A.D. and K.; visualization, H.A.S.; supervision, A.D. and K.; project administration, H.A.S. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

Aini, H., Sutrio, S., & Doyan, A. (2020). Pengaruh Model Pembelajaran Perolehan Konsep Berbasis Masalah Terhadap Kemampuan Pemecahan Masalah dan

Pemahaman Konsep Fisika Peserta Didik Kelas XI MIA MAN 1 Mataram. *ORBITA: Jurnal Kajian, Inovasi dan Aplikasi Pendidikan Fisika*, *6*(1), 188. https://doi.org/10.31764/orbita.v6i1.1629

Akbar, S. (2013). *Instrumen Perangkat Pembelajaran*. Remaja Rosdakarya.

Aprilita, R., Yolanda, S., Safitri, N., & Arrosyad, M. I. (2025). *Hubungan Literasi Digital dengan Hasil Belajar Bahasa Indonesia pada Siswa Sekolah Dasar*. *3*(10), 1388–1396.

Asiah, N., Lakilaki, E., Jumriatunnisah, N., Malintang, J., & Rizky, M. (2026). Literasi Digital Guru dan Kesiapan Implementasi Kurikulum Abad 21 di Indonesia : Sintesis Tematik Temuan Studi Systematic Literature Review. *PESHUM: Jurnal Pendidikan, Sosial dan Humaniora*, *5*(3), 5713–5723.

Assis, M. P. De, & Almeida, M. E. B. De. (2020). Letramento digital no Ensino Superior. *Revista Educação em Questão*, *58*(57), 1–26. https://doi.org/10.21680/1981-1802.2020v58n57ID21359

Azdawi, M. Y., Ramadhani, A. D., Yuniza, C. R., Harahap, L. A., & Yusuf, M. (2024). Efektivitas Permainan JumpTrix dalam Meningkatkan Kemampuan Operasi Perkalian Siswa Kelas III SDN 13 Kubu Gulai Bancah. *EKSAKTA: Jurnal Penelitian dan Pembelajaran MIPA*, *10*(2), 101–106.

Baehaqi, M., Rosyid, A., Siswanto, A., & Subiyanta, E. (2023). Performance Testing of DHT11 and DS18B20 Sensors as Server Room Temperature Sensors. *Mestro: Jurnal Teknik Mesin Dan Elektro*, *2*(02), 6–11. https://doi.org/10.47685/mestro.v5i02.466

Borich, G. D. (2011). *Observation Skills for Effective Teaching* (SIXTH EDIT). Pearson Education, Inc.

Branch, R. M. (2009). *Instructional Design: the ADDIE approach*. Springer.

Dinata, K. B. (2021). Analisis Kemampuan Literasi Digital Mahasiswa. *Edukasi: Jurnal Pendidikan*, *19*(1), 105–119. https://doi.org/10.31571/edukasi.v19i1.2499

Edwards, K. D., & Soland, J. (2024). How Scoring Approaches Impact Estimates of Growth in the Presence of Survey Item Ceiling Effects. *Applied Psychological Measurement*, *48*(3), 147–164. https://doi.org/10.1177/01466216241238749

Emmer, E. T., & Millett, G. B. (1970). *Improving Teaching Through Experimentation: a laboratory approach*. Prentice-Hall, Inc.

Fauzi, F., & Marhamah, M. (2021). Pengaruh Literasi Digital Terhadap Pencegahan Informasi Hoaks pada Remaja di SMA Negeri 7 Kota Lhokseumawe. *Jurnal Pekommas*, *6*(2), 77–84. https://doi.org/10.30818/jpkm.2021.2060210

Fitriani, F., & Rukli, R. (2025). Implementasi Literasi Digital di Sekolah Dasar: Studi Tentang Kesiapan, Tantangan, dan Peluang. *Elementar: Jurnal Pendidikan Dasar*, *5*(1), 20–30. https://doi.org/10.15408/elementar.v5i1.46931

Fitriyani, F., & Nugroho, A. T. (2022). Literasi Digital di Era Pembelajaran Abad 21. *Literasi Jurnal Pengabdian Masyarakat Dan Inovasi*, *2*(1), 307–314. https://doi.org/10.58466/literasi.v2i1.1416

Habibi, R. Z., Oktavia, B. V., Alqorina, A. Z., Pufindrayana, E. Y. P., & Ulhaq, M. A. D. (2026). Pengaruh Green Product Trust dan Green Product Value terhadap Green Behavioral Intention pada Mahasiswa Universitas Negeri Semarang. *Jurnal Multidisiplin Ilmu Akademik (JMIA)*, *3*(3), 1326–1338. https://doi.org/10.61722/jmia.v3i3.10725

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Halimah, I. N., & Fathurrohman, M. (2025). Pengaruh Media E-Modul terhadap Hasil Belajar Siswa Kelas VII pada Mata Pelajaran Islamic Faith Education di Sekolah Menengah Pertama Al Abidin Bilingual Boarding School Surakarta Tahun Pelajaran 2024/2025. *Jurnal Manajemen Pendidikan*, *10*(3), 1608–1617. https://doi.org/10.34125/jmp.v10i3.858

Handayani, I. N. (2022). Peran Orang Tua pada Pengenalan Literasi Digital untuk Anak Usia Dini di Era Teknologi Digital. *The 6th Annual Conference on Islamic Early Childhood Education (ACIECE)*, *6*, 101–110.

Hercog, D., Lerher, T., Truntič, M., & Težak, O. (2023). Design and Implementation of ESP32-Based IoT Devices. *Sensors*, *23*(15), 6739. https://doi.org/10.3390/s23156739

Hidayat, F., & Nizar, M. (2021). Model ADDIE (Analysis, Design, Development, Implementation and Evaluation) dalam Pembelajaran Pendidikan Agama Islam. *Jurnal Inovasi Pendidikan Agama Islam (JIPAI)*, *1*(1), 28–38. https://doi.org/10.15575/jipai.v1i1.11042

İlhan, M., Güler, N., Teker, G. T., & Ergenekon, Ö. (2024). *The Effects of Reverse Items on Psychometric Properties and Respondents ' Scale Scores According to Different Item Reversal Strategies*. *11*(1), 20–38. https://doi.org/10.21449/ijate.1345549

Irawan, A., & Hakim, M. A. R. (2021). Kepraktisan Media Pembelajaran Komik Matematika pada Materi Himpunan Kelas VII SMP/MTs. *PYTHAGORAS Jurnal Program Studi Pendidikan Matematika*, *10*(1), 91–100. https://doi.org/10.33373/pythagoras.v10i1.2934

Isnaini, A. H., Ramdhani, A., Saputra, H. A., Rifaldy, R.,

& Ansori, A. (2024). Pembuatan Alat Peraga Hukum Ohm untuk Materi Listrik Dinamis. *Edu Research Indonesian Institute For Corporate Learning And Studies (IICLS)*, *5*(2), 76–83.

Jannah, S., Maulana, M. A. R., & Khairunnisa, D. (2024). Peran Penting Literasi Digital Dalam Pendidikan. *Jurnal Ilmiah Penelitian Mahasiswa*, *2*(4), 16–23. https://doi.org/10.61722/jipm.v2i4.208

Law, N., Woo, D., Torre, J. de la, & Wong, G. (2018). *A Global Framework of Reference on Digital Literacy Skills for Indicator 4.4.2 (Information Paper No. 51; p. 146)*. (Nomor 51). UNESCO Institute for Statistics.

Linggarjati, J. (2022). Design and Prototyping of Temperature Monitoring System for Hydraulic Cylinder in Heavy Equipment Using ESP32 with Data Logging and WiFi Connectivity. *IOP Conference Series Earth and Environmental Science*, *998*(1), 12042. https://doi.org/10.1088/1755-1315/998/1/012042

Listari, A., Doyan, A., Ayub, S., & Hikmawati, H. (2023). Pengembangan Media Pembelajaran Fisika Berbasis Videoscribe Pada Materi Momentum dan Impuls Untuk Meningkatkan Pemahaman Konsep. *Jurnal Ilmiah Profesi Pendidikan*, *8*(1), 22–28. https://doi.org/10.29303/jipp.v8i1.1140

Mahesa, K., & Siregar, F. P. (2026). Peran Literasi Digital dalam Menangkal Penyebaran Hoaks di Platform Media Sosial. *Karakter : Jurnal Riset Ilmu Pendidikan Islam*, *3*(2), 138–145. https://doi.org/10.61132/karakter.v3i2.2222

Naimah, N., Muttaqin, M. F., & Meilina, M. (2024). Implementasi Literasi Digital pada Siswa Sekolah Dasar. *Jurnal Ilmiah Pendidikan Profesi Guru*, *7*(1), 85–94. https://doi.org/10.23887/jippg.v7i1.75992

Nisa, A., Nurfadlilah, F., Fahrezi, F., & Mulyana, A. (2025). *Kajian Kualitatif Tentang Tantangan Etika Digital Dalam Dunia Pendidikan*. 18395–18405.

Pratama, S., Ashari, M., Zulkarnain, S. A. B., & Sabrina, E. (2025). The Importance of Digital Literacy in the World of Education: Learning Transformation in the Digital Era. *JKIP: Jurnal Kajian Ilmu Pendidikan*, *6*(2), 554–561.

Restianty, A. (2018). Literasi Digital, Sebuah Tantangan Baru Dalam Literasi Media. *Gunahumas: Jurnal Kehumasan*, *1*(1), 72–87. https://doi.org/10.17509/ghm.v1i1.28380

Retnawati, H. (2016). *Analisis Kuantitatif Instrumen Penelitian*. Parama Publishing.

Ririen, D., & Daryanes, F. (2022). Analisis Literasi Digital Mahasiswa. *Research and Development Journal of Education*, *8*(1), 210–219. https://doi.org/10.30998/rdje.v8i1.11738

Saputra, H. A., Isnaini, A. H., Rifaldy, R., & Fathoni, J. W. (2025). Implementation of an IoT-based Temperature and Humidity Monitoring System in the Physics Education Laboratory. *Indonesian Journal of Educational Innovation*, *1*(2), 54–60.

Saputri, V. A. M., & Manggalani, R. (2023). Pengaruh Literasi Digital Terhadap Perilaku Pencarian Informasi di Kalangan Mahasiswa. *PAEDAGOGY: Jurnal Ilmu Pendidikan dan Psikologi*, *3*(4), 229–236.

Setyosari, P. (2016). *Metode Penelitian Pendidikan & Pengembangan*. Penerbit KENCANA.

Staus, N. L., O'Connell, K., & Storksdieck, M. (2021). Addressing the Ceiling Effect when Assessing STEM Out-Of-School Time Experiences. *Frontiers in Education*, *6*(July), 1–9. https://doi.org/10.3389/feduc.2021.690431

Suhardi, I. (2022). Perangkat Instrumen Pengembangan Paket Soal Jenis Pilihan Ganda Menggunakan Pengukuran Validitas Konten Formula Aiken's V. *Jurnal Pendidikan Tambusai*, *6*(1), 4160.

Tinmaz, H., Lee, Y. T., Fanea-Ivanovici, M., & Baber, H. (2022). A Systematic Review on Digital Literacy. *Smart Learning Environments*, *9*(1). https://doi.org/10.1186/s40561-022-00204-y

Utama, D. A., Sudirman, F., Badjuka, B. Y., Mustafa, Y., Age, S. P., & Suma, J. (2026). Implementasi Ecosink Berbasis Limbah Plastik: Strategi Edukatif Pengelolaan Sampah dan Peningkatan Sanitasi Sekolah. *JMM (Jurnal Masyarakat Mandiri)*, *10*(2), 2226–2234. https://doi.org/10.31764/jmm.v10i2.37592

Utami, L., Festiyed, F., Ilahi, D. P., Ratih, A., & Yenti, E. (2024). Analisis Indeks Aiken Untuk Mengetahui Validitas Isi Instrumen Scinetific Habbits of Mind. *Journal of Research and Education Chemistry*, *6*(1), 59. https://doi.org/10.25299/jrec.2024.vol6(1).17430

Wahab, A., Junaedi, J., & Azhar, M. (2021). Efektivitas Pembelajaran Statistika Pendidikan Menggunakan Uji Peningkatan N-Gain di PGMI. *Jurnal Basicedu*, *5*(2), 1039–1045. https://doi.org/10.31004/basicedu.v5i2.845

Yudianto, E., Firmansyah, F. F., Sulihah, N. T., Febriyanto, E. Y., & Sari, V. R. (2026). Menu Sehat, Angka Tepat: Pemberdayaan Ibu dan Anak di Desa Serut, Jember. *As-Sidanah : Jurnal Pengabdian Masyarakat*, *8*(1), 1–19. https://doi.org/10.35316/assidanah.v8i1.1-19

Zuhri, S., Suwindia, I. G., & Winangun, I. M. A. (2024). Literasi digital dan kecakapan abad ke-21: analisis komprehensif dari literatur terkini. *Education and Social Sciences Review*, *5*(2), 149–155. https://doi.org/10.29210/07essr500300