JURNAL PENDIDIKAN MATEMATIKA DAN IPA

Vol. 17, No. 1 (2026) h. 129 - 140

http://jurnal.untan.ac.id/index.php/PMP

STUDENTS RESPONSE TO THE READABILITY OF POGIL-BASED INTERACTIVE E-MODULE ON HEAT TOPIC

Fian Rifqi Irsalina[1], Lina Aviyanti[2], Mimin Iryanti[3]

[1]Master of Physics Education, Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia

[2,3]Department of Physics Education, Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia, Dr. Setiabudhi Street No. 229, Isola, Sukasari District, Bandung City, West Java 40154

Email Corresponding: fianrfq@upi.edu

DOI: http://dx.doi.org/10.26418/jpmipa.v17i1.99768

Abstract

This study aimed to analyze the readability of a POGIL-based interactive e-module on heat for 12th-grade students. This study is urgent due to the abstract nature of heat concepts in physics and the increasing use of digital learning resources, which require instructional materials that are not only technologically advanced but also readable and pedagogically effective. The research employed a descriptive survey with a quantitative approach, collecting data via a questionnaire designed to assess three main aspects of the e-module: format, language, and content. A purposive sampling technique was employed, selecting 33 students who had previously studied the heat topic and had experience with e-modules. The data obtained were analyzed using a Likert scale to evaluate the effectiveness and practicality of the e-module. The results showed that the e-module received high ratings across all aspects, with an overall average score of 91.89%, categorizing it as "Very Practical." The format aspect scored 90.06%, indicating that the e-module's design and structure were user-friendly and supported comprehension. The language aspect scored 92.73%, reflecting the clarity and simplicity of the language used. The content aspect scored 92.88%, indicating that the e-module effectively enhanced student engagement and understanding of the material. Overall, the study concludes that the e-module is a highly effective learning resource and is recommended for future instructional use.

Keywords**:** *Learning Materials, Learning Media, Module Electronic, Physics Learning, POGIL*

Received **: 2025-09-26**
Revised **: 2026-01-14**
Accepted **: 2026-01-25**

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

INTRODUCTION

Education in the current digital era has undergone a significant transformation, including the use of technology in the learning process. One rapidly developing technology is e-modules, a digital learning tool that allows students to access learning materials more interactively and flexibly [1], [2]. These e-modules enable more dynamic information delivery using various media, such as text, images, animation, and video, which can be adapted to various student learning styles [3]. In education, implementing e-modules has become an attractive alternative, particularly in supporting efficient and effective technology-based learning [4], [5].

E-modules designed with POGIL (Process-Oriented Guided Inquiry Learning) offer a more immersive learning experience [6]. POGIL promotes critical thinking and problem-solving through collaboration and investigation [7]. Students use this method to explore concepts by answering questions that guide them to discover answers independently [8], [9], [10]. This approach fits the abstract nature of thermal content in physics. Key concepts include heat transfer, temperature change, and energy conservation [11]. These ideas are abstract and not directly observable. Therefore, the POGIL e-module uses guided inquiry steps, real-life thermal examples, and data analysis tasks [12], [13]. These features help students analyze processes, spot patterns, and connect micro- and macroscopic thermal interactions, supporting coherent and meaningful learning.

However, while POGIL-based e-modules have significant potential to improve learning quality, several factors influence their effectiveness, including readability. Readability in the context of e-modules refers to the extent to which the material presented is easily understood by students, in terms of language, text structure, and visual design [14]. Good readability can facilitate students' better understanding of learning materials, while e-modules that are difficult to read or poorly designed can hinder students' learning [15]. This issue becomes particularly critical for physics topics that demand strong conceptual reasoning, such as heat.

Heat is widely recognized as an abstract, demanding physics topic [16]. Heat, which involves the transfer of thermal energy and changes in temperature, often makes it hard for students to connect theory with everyday phenomena. Although highly relevant, many students struggle to explain heat and temperature phenomena accurately. This is due to the overlapping, interrelated nature of concepts such as energy and temperature, which require a deep understanding to connect [17], [18]. POGIL-based interactive e-modules present thermal concepts with clear explanations and structured activities, helping students engage meaningfully and reduce misconceptions [19], [20]. Insufficient attention to readability can cause cognitive overload, frustration, and reduced engagement, harming learning [21], [22], [23].

The readability of an e-module is influenced not only by linguistic simplicity but also by visual design and navigational structure. Design elements such as font size, color

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

contrast, layout consistency, and ease of navigation play a crucial role in determining how effectively content is conveyed to learners [24]. When these elements are carefully considered, e-modules can foster a supportive learning environment that enhances comprehension and learner motivation [25]. Thus, evaluating the readability of POGIL-based e-modules on heat is essential to ensure their instructional suitability and effectiveness.

Existing studies primarily develop or implement POGIL-based learning materials or assess learning outcomes, with little focus on systematically examining the readability of POGIL e-modules from learners' perspectives, especially for abstract physics topics such as heat. Empirical evidence directly linking readability, format, language, and content to students' perceptions of usability and learning support is also scarce.

This study's novelty lies in its focused investigation of the readability of a POGIL-based e-module on heat. It uses quantitative analysis of students' responses to format, language, and content. Unlike achievement-focused studies, it positions readability as a prerequisite for technology-based physics learning. To address this gap, this study asks: How do students perceive the readability of a POGIL-based heat e-module in terms of format, language, and content?

This study examines how students respond to various readability aspects in POGIL-based e-modules on hot topics. By involving students as respondents, this study aims to determine whether the e-module design and delivery of materials are appropriate for their understanding. Furthermore, this study aims to identify factors that influence readability, including language use, text structure, and visual aspects within the e-module. Thus, this study will provide deeper insights into the effectiveness of e-modules in improving the quality of physics learning.

By identifying and understanding student responses to the readability of POGIL-based e-modules on heat, this study is expected to provide recommendations for developing more effective e-modules. This will help educators and e-module developers create learning tools that are engaging and easy for students to understand. Furthermore, the results of this study are expected to contribute to the development of more effective technology-based learning that better supports the achievement of educational goals.

Overall, this study not only provides a deeper understanding of the readability of POGIL-based e-modules on the topic of heat but also provides insights for developing digital learning media that can improve the quality of education. With these research results, it is hoped that future e-modules will be more targeted and effective in improving student learning outcomes, particularly in understanding complex physics concepts.

METHOD

Research Type

This study used a survey method with a descriptive quantitative approach, which aims to describe the relevance of phenomena and events within a population [26]. The survey was used to analyze students' readability of a POGIL-based interactive e-module on heat. Data

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

were collected using a Likert-scale questionnaire and analyzed descriptively to evaluate the e-module's readability in terms of format, language, and content, without examining relationships among variables.

Time, Place, and Participants

The study took place in April 2025 at a State Islamic Senior High School (MAN) in Nganjuk Regency. The population included all 12th-grade science-track students (N = 92). Using purposive sampling, 33 students were selected because their completion of the heat topic and prior use of e-modules made them suitable for evaluating the e-module's readability [27].

Research Procedures

The research began with the preparation of a POGIL-based e-module on heat, which was revised based on expert validator feedback to ensure adequate readability across format, language, and content. After the revision stage, the finalized e-module was implemented, and data were collected from students who had previously studied the heat topic.

Data Collection Instruments and Techniques

Data were collected using a non-test questionnaire adapted from [28], The questionnaire consisted of 12 items that measured three readability aspects: (1) Format, which included visual design, layout, font selection, navigation, and ease of use; (2) Language, which focused on clarity, communicativeness, and suitability for students' comprehension level; and (3) Content, which covered conceptual clarity and accuracy of heat concepts, logical presentation sequence, use of contextual examples, readability of explanations, and the alignment and effectiveness of questions and exercises in reinforcing understanding.

Responses were measured using a five-point Likert scale. Students completed the questionnaire after using the e-module. They were given sufficient time to review the material and provide objective evaluations.

Data Analysis Techniques

Data obtained from the student questionnaire responses were analyzed using a formula adapted from [29], as listed in Equation 1, to calculate the Percentage of readability or practicality of the e-module:

$$P\ (\%) = \frac{x}{x_i} x100\% \qquad (1)$$

Where:
P = Percentage of readability
x = Total score obtained
x_i = Maximum score obtained

Data Interpretation

The readability scores obtained will be compared with the practicality criteria adapted from [29], which classifies e-modules into five interpretation categories as follows:

Table 1. Criteria and interpretation of e-module readability by students

P Value (%)	Interpretation
$\boldsymbol{P \geq 81}$	Very Practical
$\boldsymbol{61 < P \leq 80}$	Quite Practical
$\boldsymbol{41 < P \leq 60}$	Less Practical
$\boldsymbol{21 < P \leq 40}$	Not Practical
$\boldsymbol{P \leq 20}$	Very Not Practical

RESULT AND DISCUSSION

Analyzed and classified using practicality criteria adapted from [30], the results of the student questionnaire on the readability of the POGIL-based interactive e-module on heat are presented in Table 2. This table details readability scores for each student

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

across the format, language, and content aspects, illustrating variations in individual perceptions of the e-module's readability and usability.

To provide a clearer overall evaluation, the data in Table 2 were summarized into average scores for each readability aspect. Specifically, Table 3 shows that the e-module achieved an overall average readability score of 91.89%, placing it in the Very Practical category. Consequently, this result indicates that, on average, students perceived the e-module as clear, easy to use, and effective as a learning medium for the heat topic.

Consistently high average scores were obtained for all assessed aspects, namely format (90.06%), language (92.73%), and content (92.88%), demonstrating that the e-module effectively supports students' independent learning. These findings suggest that the POGIL-based interactive e-module is well-designed, readable, and suitable for use in Grade 12 physics learning.

Students' Perception of Format Readability

The e-module's format achieved an average score of 90.06%, indicating that students found its visual design and structural organization highly readable and easy to use. This suggests that the layout, typography, and navigation effectively support students' interaction with the learning material. In line with the cognitive theory of multimedia learning [31], a well-organized visual design helps reduce cognitive load, allowing students to focus on understanding concepts rather than processing the interface [16].

From a POGIL perspective, the clear and consistent format supports each stage of the learning process. Specifically, structured layouts and visual representations assist students in the orientation and exploration stages by helping them identify key information and analyze data presented in tables, figures, or diagrams. In the concept formation stage, coherent presentation enables students to recognize patterns and construct understanding. During the application stage, accessible navigation and well-organized content allow students to efficiently revisit explanations and complete inquiry-based tasks [6], [30]. Previous studies have demonstrated that effectively integrating text and visual elements enhances comprehension and supports deeper conceptual processing [32]. In summary, the high-format readability of the e-module is essential for effective POGIL implementation and directly facilitates students' understanding of heat concepts.

Table 2. Details readability score of the POGIL-Based interactive e-module on heat for each student

Student Code	Aspect (%)			Average (%)	Interpretation
	Format	Language	Content		
S1	92.00	86.67	95.00	91.22	Very Practical
S2	88.00	93.33	95.00	92.11	Very Practical
S3	88.00	100.00	95.00	94.33	Very Practical
S4	88.00	93.33	85.00	88.78	Very Practical
S5	92.00	93.33	95.00	93.44	Very Practical
S6	92.00	93.33	100.00	95.11	Very Practical

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

Student Code	Aspect (%)			Average (%)	Interpretation
	Format	Language	Content		
S7	96.00	93.33	100.00	96.44	Very Practical
S8	100.00	86.67	100.00	95.56	Very Practical
S9	88.00	100.00	95.00	94.33	Very Practical
S10	96.00	93.33	90.00	93.11	Very Practical
S11	88.00	86.67	95.00	89.89	Very Practical
S12	88.00	93.33	95.00	92.11	Very Practical
S13	100.00	93.33	90.00	94.44	Very Practical
S14	100.00	100.00	100.00	100.00	Very Practical
S15	92.00	100.00	80.00	90.67	Very Practical
S16	56.00	60.00	65.00	60.33	Less Practical
S17	76.00	73.33	75.00	74.78	Quite Practical
S18	92.00	86.67	95.00	91.22	Very Practical
S19	84.00	93.33	80.00	85.78	Very Practical
S20	92.00	100.00	90.00	94.00	Very Practical
S21	60.00	86.67	90.00	78.89	Quite Practical
S22	100.00	100.00	100.00	100.00	Very Practical
S23	100.00	100.00	100.00	100.00	Very Practical
S24	100.00	100.00	100.00	100.00	Very Practical
S25	88.00	93.33	90.00	90.44	Very Practical
S26	96.00	93.33	90.00	93.11	Very Practical
S27	88.00	86.67	90.00	88.22	Very Practical
S28	84.00	100.00	100.00	94.67	Very Practical
S29	96.00	100.00	95.00	97.00	Very Practical
S30	88.00	100.00	100.00	96.00	Very Practical
S31	100.00	100.00	100.00	100.00	Very Practical
S32	96.00	93.33	100.00	96.44	Very Practical
S33	88.00	86.67	95.00	89.89	Very Practical

Table 3. Students' readability of the POGIL-Based E-Module on heat

Readability Aspect	Average Score (%)	Interpretation
Format	90.06	Very Practical
Language	92.73	Very Practical
Content	92.88	Very Practical
Overall Average (%)	**91.89**	**Very Practical**

Students' Perception of Language Readability

The language readability aspect obtained an average score of 92.73%, indicating that students perceived the language used in the e-module as clear, communicative, and appropriate for their level of understanding [28]. The absence of ambiguous instructions enabled students to follow each learning activity smoothly, minimizing confusion during the learning process [31]. Clear linguistic expression and careful selection of terminology are crucial for supporting students' comprehension, particularly in physics learning, where conceptual precision is essential [32].

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

From an instructional perspective, the use of accessible language helps reduce linguistic barriers that may interfere with students' cognitive processing of scientific concepts. When explanations and inquiry prompts are presented in familiar, well-defined terms, students can focus more effectively on analyzing phenomena and constructing meaning. In contrast, the use of complex or inappropriate terminology can hinder understanding and negatively affect learning outcomes [33]. Within the POGIL approach, clear language is especially important, as students are required to independently interpret questions, discuss ideas, and draw conclusions. Accordingly, the high rating in this aspect suggests that the language used in the e-module effectively supports inquiry-based learning and facilitates students' engagement with the heat content.

Students' Perception of Content Readability

The content readability aspect obtained the highest average score of 92.88%. Students perceived the material as highly clear, relevant, and supportive of their understanding of heat concepts, suggesting that the content was presented in a way that not only facilitated comprehension but also encouraged deeper engagement with the learning material. By aligning with the learning objectives, the e-module effectively supports the intended instructional goals [34], ensuring a direct connection between the content and the desired outcomes.

The inclusion of structured questions and exercises played a central role in enhancing content readability by guiding students to actively apply concepts and evaluate their understanding. Consistent with constructivist learning theory, meaningful learning occurs when students actively construct knowledge through inquiry and reflection [31]. In this e-module, inquiry-based tasks encouraged students to analyze thermal phenomena, interpret information, and refine their conceptual understanding .

Moreover, presenting content with contextual and real-life examples enabled students to relate abstract thermal concepts to everyday experiences, thereby strengthening conceptual connections and reducing misconceptions [35]. From a POGIL perspective, the material's organization supports progressive learning, allowing students to move from concept exploration to application in a coherent manner. The consistently high ratings across all readability aspects further indicate that integrating clear content, guided inquiry, and contextual examples creates a supportive learning environment. Overall, these findings confirm that the POGIL-based interactive e-module is well-suited for Grade 12 physics learning and effective in facilitating students' understanding of heat concepts.

CONCLUSION

This study examined students' perceptions of the readability of a POGIL-based interactive e-module on heat, focusing on format, language, and content, and found an overall average score of 91.89%, categorized as Very Practical. As a result, the e-module is visually well-

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

structured, uses clear, communicative language, and presents content in a coherent, meaningful way, enabling Grade 12 students to understand heat concepts more easily and independently. Furthermore, the consistently high ratings across all aspects suggest that integrating readability principles into the POGIL learning stages effectively supports student engagement and self-directed learning. Taken together, these findings imply that readability is crucial to the successful implementation of inquiry-based digital learning materials, particularly for abstract physics topics. To build on these results, further development of interactivity, such as adding more dynamic simulations or applications, and increased integration with other digital learning platforms, can enhance user experience and enrich the learning process. Finally, it is also recommended to conduct regular evaluations of this e-module based on student feedback to ensure that it remains relevant and effective in enhancing understanding of more complex physics concepts.

ACKNOWLEDGMENTS

I express my deepest gratitude to the Indonesian Endowment Fund for Education (LPDP) for generously funding this research. With their support, I have been able to carry out this study and pursue my academic goals.

REFERENCES

[1] F. Delita, N. Berutu, and N. Nofrion, "Online learning: the effects of using e-modules on self-efficacy, motivation and learning outcomes," *Turkish Online Journal of Distance Education*, vol. 23, no. 4, pp. 93–107, Oct. 2022, doi: 10.17718/tojde.1182760.

[2] A. Holisoh, J. Pahamzah, and S. Hidayat, "Literature Review on the Use of Electronic Modules in Independent Learning in Higher Education," *Journal of General Education and Humanities*, vol. 4, no. 1, pp. 153–164, Feb. 2025, doi: 10.58421/gehu.v4i1.368.

[3] S. Dewi, A. Alfiandra, and S. Safitri, "Enhancing Pancasila Education through Differentiated Learning: The Role of E-Modules Developed with Flip PDF Professional," *AL-ISHLAH: Jurnal Pendidikan*, vol. 16, no. 4, pp. 4630–4640, Nov. 2024, doi: 10.35445/alishlah.v16i4.5337.

[4] N. Sikumbang, Jasrial, Ridwan, and Rayendra, "Development of E-Modules Integrate with PBL (Problem Base Learning) in High School Physicts Subject Class XI," *Jurnal Penelitian Pendidikan IPA*, vol. 11, no. 6, pp. 423–434, Jun. 2025, doi: 10.29303/jppipa.v11i6.11627.

[5] A. M. Wulandari, E. Handoyo, S. Wardani, B. Subali, and N. Widiarti, "Literature Study of E-Modules Based on Project-Based Learning to Improve Critical Thinking Skills of Students," *Edunesia : Jurnal Ilmiah Pendidikan*, vol. 6, no. 2, pp. 1039–1054, Jun. 2025, doi: 10.51276/edu.v6i2.1241.

[6] A. W. Ningsih, A. F. Hidayatullah, and Rofi'ah Ndzani Latifatur, " Development of Biology E-

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

Module Based on POGIL in Virus and Bacteria Material to Train HOTS X Graders of Senior High School," *Bioeduca: Journal of Biology Education*, vol. 5, no. 2, pp. 105–110, Sep. 2023.

[7] S. Al Neyadi, "Assessing the Effects of POGIL-Based Instruction versus Lecture-Based Instruction on Grade 12 Self-Efficacy and Performance in Circular Motion Unit," *Journal of Ecohumanism*, vol. 3, no. 3, pp. 1219–1238, Jul. 2024, doi: 10.62754/joe.v3i3.3625.

[8] H. H. Hu and T. D. Shepherd, "Using POGIL to help students learn to program," *ACM Transactions on Computing Education*, vol. 13, no. 3, pp. 1–23, Aug. 2013, doi: 10.1145/2499947.2499950.

[9] B. Samosir, "Implementation of Process Oriented Guided Inquiry Learning Model Learning (Pogil) on Understanding of Science Concepts, Skills Science Process and Student's Critical Thinking Ability," *International Journal of Multidisciplinary: Applied Business and Education Research*, vol. 3, no. 9, pp. 1673–1682, Sep. 2022, doi: 10.11594/ijmaber.03.09.08.

[10] Q. Gao, M. Tong, J. Sun, C. Zhang, Y. Huang, and S. Zhang, "A Study of Process-Oriented Guided Inquiry Learning (POGIL) in the Blended Synchronous Science Classroom," *J Sci Educ Technol*, vol. 34, no. 1, pp. 103–121, Feb. 2025, doi: 10.1007/s10956-024-10155-3.

[11] F. R. Irsalina, L. Aviyanti, and R. Fredyan, "A rasch model approach to gender-based thermal concept analysis in East Java high schools," *Momentum: Physics Education Journal*, vol. 9, no. 1, pp. 92–108, Jan. 2025, doi: 10.21067/mpej.v9i1.11007.

[12] R. S. Moog, F. J. Creegan, D. M. Hanson, J. N. Spencer, and A. R. Straumanis, "Process-Oriented Guided Inquiry Learning: POGIL and the POGIL Project," *Metrop Univ*, vol. 17, no. 4, pp. 41–52, 2006.

[13] E. Toyo, S. D. Aji, and C. Sundaygara, "The Effect of POGIL Model Toward Science Process Skills and Physics Acquisition of Student," *Berkala Ilmiah Pendidikan Fisika*, vol. 7, no. 3, pp. 157–163, 2019.

[14] A. Sanova, D. A. Kurniawan, S. M. Husna, and E. Triani, "Analysis of Responses to the Development of E-Modules to Improve Students' Critical Thinking Skills in Reaction Rate Materials in the Form of Android Applications," *JST (Jurnal Sains dan Teknologi)*, vol. 13, no. 3, pp. 464–475, Oct. 2024, doi: 10.23887/jstundiksha.v13i3.85758.

[15] A. K. S. Kadir and D. Purwaningsih, "Development of Electronic Modules Based on Collaborative Problem Solving on Buffer Solution Materials," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 3, pp. 1115–

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

1123, Mar. 2024, doi: 10.29303/jppipa.v10i3.5794.

[16] N. A. Putri, W. Liliawati, and R. Efendi, "Flipbook E-Module-Assisted 8e Learning Cycle Model on Improving High School Students' Concept Mastery on Heat and Heat Transfer Material," *Jurnal Pendidikan Fisika dan Teknologi*, vol. 10, no. 1, pp. 16–28, Jun. 2024, [Online]. Available: http://www.jurnalfkip.unram.ac.id/index.php/JPFT/article/view/6738

[17] R. T. Leinonen, "Improving the learning of thermal physics at university," *Nordic Studies in Science Education*, vol. 10, no. 1, p. 123, Apr. 2014, doi: 10.5617/nordina.816.

[18] H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 11th edition. San Fransisco: Addison-Wesley Longman, Inc., 2004.

[19] S. R. Simonson, *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*. New York: Routledge, 2023. doi: 10.4324/9781003446330.

[20] E. F. Asda, I. W. Dasna, P. Parlan, and S. Suharti, "The role of inquiry learning in enhancing creativity generating ideas from a self-efficacy perspective," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 21, no. 5, pp. 1–22, May 2025, doi: 10.29333/ejmste/16276.

[21] C. Huang, "Designing high-quality interactive multimedia learning modules," *Computerized Medical Imaging and Graphics*, vol. 29, no. 2–3, pp. 223–233, Mar. 2005, doi: 10.1016/j.compmedimag.2004.09.017.

[22] M. M. Daghio, G. Fattori, and A. V. Ciardullo, "Assessment of Readability and Learning of Easy-to-Read Educational Health Materials Designed and Written with the Help of Citizens by Means of Two Non-Alternative Methods," *Advances in Health Sciences Education*, vol. 11, no. 2, pp. 123–132, May 2006, doi: 10.1007/s10459-005-7852-2.

[23] S. Yulando, S. Sutopo, and T. Franklin Chi, "Electronic Module Design and Development: An Interactive Learning," *Am J Educ Res*, vol. 7, no. 10, pp. 694–698, Oct. 2019, doi: 10.12691/education-7-10-4.

[24] L. T. S. Wahyuni and I. B. P. Arnyana, "E-Module Based on Tri Kaya Parisudha Effectively Improves Science Learning Outcomes," *MIMBAR PGSD Undiksha*, vol. 10, no. 2, pp. 358–366, Aug. 2022, doi: 10.23887/jjpgsd.v10i2.46733.

[25] F. R. Irsalina, F. F. Andini, and D. Rusdiana, "Development of Learning Media Based on Arduino Load Cell on Pascal's Law Topic to Improve Students' Learning Outcomes," *Jurnal Pendidikan Fisika*, vol. 14, no. 1, pp. 27–44, Jun. 2025, doi: 10.24114/jpf.v14i1.64338.

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

[26] T. Zheng, M. Ardolino, A. Bacchetti, M. Perona, and M. Zanardini, "The impacts of Industry 4.0: a descriptive survey in the Italian manufacturing sector," *Journal of Manufacturing Technology Management*, vol. 31, no. 5, pp. 1085–1115, Nov. 2019, doi: 10.1108/JMTM-08-2018-0269.

[27] J. W. Cresswell and J. D. Cresswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. Los Angeles: SAGE, 2018.

[28] M. Sarip, S. Amintarti, and N. H. Utami, "Validitas Dan Keterbacaan Media Ajar E-Booklet Untuk Siswa SMA/MA Materi Keanekaragaman Hayati," *JUPEIS: Jurnal Pendidikan dan Ilmu Sosial* , vol. 1, no. 1, pp. 43–59, Jan. 2022.

[29] S. Akbar, *Instrumen Perangkat Pembelajaran*, Cetakan keenam. Bandung: PT Remaja Rosdakarya Offset, 2022.

[30] R. D. Cahayningrum, M. Nurjayadi, and A. Rahman, "Pengembangan E-Module Kimia Berbasis Pogil (Process Oriented Guided Inquiry Learning) Pada Materi Reaksi Reduksi-Oksidasi Sebagai Sumber Belajar Siswa," *JRPK: Jurnal Riset Pendidikan Kimia*, vol. 7, no. 1, pp. 59–65, Jul. 2017, doi: 10.21009/JRPK.071.07.

[31] E. Nsabayezu, O. Habimana, W. Nzabalirwa, and F. N. Niyonzima, "Contribution of Activities-Enhanced Rubrics in the Multimedia-Supported Flipped Classroom Approach on Students' Conceptual Understanding in Organic Chemistry: A Scoping Review," *The International Journal of Technologies in Learning*, vol. 32, no. 1, pp. 77–112, 2024, doi: 10.18848/2327-0144/CGP/v32i01/77-112.

[32] K. T. Kotsis, "The Language of Physics: Shaping Conceptual Understanding and Scientific Communication," *Bulletin of Language and Literature Studies*, vol. 2, no. 2, Jun. 2025, doi: 10.59652/blls.v2i2.581.

[33] A. Alya and D. Purwaningsih, "Development of Interactive e-Modules Based on Socio-Scientific Issues Integrated Micro-Project to Train Students' Understanding of Concepts and Science Process Skills," *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran*, vol. 11, no. 1, p. 75, Mar. 2025, doi: 10.33394/jk.v11i1.13932.

[34] L. Safitri, N. Hidayati, and S. Suryanti, "Integrating Problem-Based Learning into E-Modules : A Development Study with Validation and Student Response Analysis," *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran*, vol. 11, no. 1, pp. 397–409, Mar. 2025, doi: 10.33394/jk.v11i1.14836.

[35] M. Stefanou, G. Stylos, K. Georgopoulos, and K. Kotsis, "Primary Preservice Teachers'

Jurnal Pendidikan Matematika dan IPA
Vol. 17, No. 1 (2026) h. 129-140

Misconceptions and Reasoning of Thermal Concepts in Everyday Contexts," *The International Journal of Learning in Higher Education*, vol. 31, no. 1, pp. 127–157, 2023, doi: 10.18848/2327-7955/CGP/v31i01/127-157.