

DEVELOPMENT, FEASIBILITY, AND EFFECTIVENESS OF INCLUSIVE STEM MODULE BASED ON SDGS FOR SLOW LEARNERS

Kiki Ayu Winarni¹, Hamdi Akhsan¹, Kistiono¹, Putri Angelina²

¹Master of Physics Education, Faculty of Teacher Training and Education, Sriwijaya University, Palembang, Indonesia

²Physics Education, Faculty of Teacher Training and Education, Sriwijaya University, Palembang, Indonesia

Corresponding author email: hamdiakhsan@fkip.unsri.ac.id

Article Info

Received: 13 November 2025

Accepted: 04 December 2025

Publication: 15 December 2025

Abstract :

Teaching slow-moving learners abstract scientific concepts, such as Elements, Compounds, and Mixtures, can be difficult because they need concrete instruction and less cognitive load. The learning materials available cannot be expected to include the accessibility elements needed to bridge this cognitive divide. The current study attempts this integration for the first time, combining Universal Design for Learning and a STEM-SDGs approach specifically to support slow learners. The study aimed to create a valid, usable, beneficial, and inclusive module for Phase D (Grade VIII) students using the R&D approach (ADDIE model). The study incorporated six expert validators, a practicality trial to slow learners (N=10), and a quasi-experimental field study with 73 learners (Experimental N=34 vs Control N=39). The module had a V-Aiken rating of 0.87 (Very Valid), and 92.1% was rated Very Practical. Effectiveness testing showed that the module had a significant positive differentiating factor: the experimental group had evidence of a “High” N-Gain (0.78) compared to the control group’s “Medium” N-Gain (0.40). The findings of the study attest that the UDL-based module was effective in bridging complex concepts and can serve as an adaptive resource to advance Equity in Science Education.

Keywords: Inclusive STEM Module, SDGs, Slow Learner.

This is an open-access article under the [CC BY-SA](https://creativecommons.org/licenses/by-nc-sa/4.0/) licence



INTRODUCTION

Scientific literacy is pivotal even at the Junior High School Level (Phase D). Elements, Compounds, and Mixtures provide a basic set of core concepts (Hendry, 2006; Indriyati et al., 2024). However, current educational curricula emphasize the need to elevate Higher Order Thinking Skills (HOTS) through the application of the STEM approach (Oktariani et al., 2020). On the other hand, the analysis of the Junior High School chemistry materials shows the predominance of Lower Order Thinking Skills (LOTS) that are limited to the lower four levels of thinking, C1-C4. C5 (evaluating) and C6 (creating) are infrequently taught and assessed (Syahida & Irwandi, 2015). The situation is made

worse by the inclusion of disabilities in the educational materials (Salend, 2016). Slow learners are identified as students whose academic performance falls significantly below the expected grade (Alhamuddin et al., 2022; Mohammad & Mahmoud, 2014) and have a hard time understanding material that is complex and abstract and is steeped in high levels of concentration and cognitive effort (Chew & Cerbin, 2021; Septiana et al., 2024; Sweller, 1993; Wirawan & Putri, 2025).

Since the properties of atoms and molecules are abstract and cannot be directly seen (Aisyah et al., 2023), more repetitions, longer training sessions, and more focused teaching are needed (Cleugh, 2021; Septiana et al., 2024). Thus, it is safe to assume that standard teaching materials are not enough to close the cognitive gaps. Effective development of teaching materials must offer strong cognitive scaffolding. The Guided Discovery Learning approach is highly relevant for slow learners to construct knowledge autonomously (Janssen et al., 2014; Poniwati et al., 2024). Modules are ideal media as they facilitate structured, guided learning and flexible study (Indriyati et al., 2024; Ridha, 2021).

Moreover, the design of systems that facilitate water purification embodies STEM integration, as these systems are technologically precise, designed for project-based learning, and STEM-compatible (Alhamuddin et al., 2022; Assaf et al., 2024). The identification of problems and the structured development of solutions are STEM, which offers a heuristic for breaking down concepts from abstraction to a lower level of complexity (English, 2023; Garvin, 2000). Furthermore, the integration of some SDGs (e.g., SDG 6; SDG 12) offers a relevant contextualization (Ortigara et al., 2018; Zahro et al., 2024) that guides you to the real problem. The SDGs, alongside problem linkage of abstraction, help to eliminate the burden of mental processing, and are a vital designing instrument (Ivshina et al., 2015; Nuswowati et al., 2024)

These remain a problem gap. Furthermore, no instructional tools exist that integrate UDL with STEM and SDGs, specifically targeting slow learners, focusing on Elements, Compounds, and Mixtures (M. li & Wang, 2024; Meyer et al., 2014). The modular development of STEM has been the focus of numerous studies. However, these materials are mainly directed to average to high performing learners and reflect a gap for slow learners (Afwina et al., 2021; Indriyati et al., 2024; Nurhayati et al., 2021; Rasmi et al., 2023; Sholikhah & Arif, 2024; Syahirah et al., 2020; Wildana et al., 2023; Zulaiha & Kusuma, 2020). Literature explicitly combining STEM, Inclusive Education for Slow Learners, and SDGs in a single teaching product remains highly limited.

To address this gap, this study introduces a specific novelty: the development of an instructional product that synergizes UDL principles with a STEM-SDGs framework (Fovet, 2021). Unlike previous modules, this product is uniquely designed to function as a cognitive bridge. Based on this background, the problem formulation is: "How can the development of an Inclusive STEM Module Based on SDGs on the topic of Elements, Compounds, and Mixtures yield a product that is valid, practical, and effective for slow learner students in Phase D?" The objective is to produce such a module for Grade VIII students at SMP N 1 Pemulutan Barat.

RESEARCH METHOD

Research Design

This study utilizes a Research and Development (R&D) approach to produce an educational product and rigorously test its feasibility (validity, practicality) and effectiveness (Liana et al., 2022; Yulastri et al., 2017). The development procedure follows the ADDIE model (Analyze, Design, Development, Implement, Evaluate) (Indriyati et al., 2024; Rusdi et al., 2022).

To ensure comprehensive data analysis, a Mixed Methods framework was selected. This design is considered most appropriate because quantitative data alone cannot fully capture the nuances of inclusive education. Specifically, a Concurrent Triangulation design was used during validation to synthesize scores with expert advice, while an Embedded Design was applied during field testing. Here, quantitative data (N-Gain) served as the primary measure, while qualitative data (observations) provided essential context regarding the module's function in bridging cognitive gaps (Dini et al., 2023; Oksaviona et al., 2023). The integration of the ADDIE model with the quasi-experimental and mixed-methods structure is summarized in Table 1.

Population and Sample

The research was conducted at SMP N 1 Pemulutan Barat. For the effectiveness test, the sample comprised 73 Grade VIII students divided into two groups: the Experimental Group (N=34) using the STEM-SDGs Module, and the Control Group (N=39) using the Conventional Module. For the practicality test, subjects were selected via purposive sampling, comprising 10 slow-learning students from the Experimental Group and one Science teacher.

Identification of Slow Learners

To ensure subject suitability and validity, slow learners were identified through a strict, multi-tiered screening process:

1. Academic Screening: Students with Science scores consistently below the Minimum Mastery Criteria (KKM) for the last two semesters (Iryana et al., 2024).
2. Teacher Validation: Teachers/counselors validate students' challenges in understanding and processing abstractions and the need for instructions to be repeated.
3. Professional Validation: Validated psychological testing of an individual at the lower end of the average IQ spectrum from 70-85 (Lederman et al., 2023; Nurhasanah & Nida, 2016; Septiana et al., 2024). This assessment was done at the Physiotherapy Unit of Lembaga Pendidikan Hasanah Gemilang School, a center of special education.

Data Collection and Analysis

Collection of Data and Its Analysis. The data were gathered using Expert Validation Sheets, Practicality Questionnaires, a battery of Cognitive Assessments (Pre-Test/Post-Test), and Observation Sheets. The employed analysis was

1. Validity: Calculated using the V-Aiken Coefficient.
2. Practicality: Descriptive percentages (Very Practical: 81-100%; Practical: 61-80%; Moderately Practical: 41-60%; Less Practical: 21-40%; Not Practical: 0-20%).
3. Effectiveness: Measured using Normalized Gain (N-Gain). Categories: High ($g > 0.70$), Medium ($0.30 \leq g \leq 0.70$), and Low ($g < 0.30$).
4. Prerequisite Tests: Homogeneity was confirmed via Levene's test ($p = 0.416$) and initial equality via an Independent t-test ($p = 0.883$).

Research Procedures

The procedure followed the five stages of ADDIE (Figure 1):

1. Analysis
Analysis of curriculum (Phase D), learning outcomes, and slow learner characteristics (need for concrete visualization) (Aisyah et al., 2023; Kimianti, 2019; Piskurich, 2015; Septiana et al., 2024).
2. Design
Structuring content based on guided discovery flow (Poniyati et al., 2024; Wales & Stager, 1980) integrating UDL visuals and designing instruments.
3. Development Stage
Draft I was validated by six experts (Material/STEM, Media, Inclusive Pedagogy) using V-Aiken, then revised into Draft II.
4. Implementation Stage (Field Implementation and Effectiveness Testing)
Field trial with 73 students. The Experimental Group received the STEM-SDGs Module over three sessions (45–90 minutes each). Practicality data were collected from 10 slow learners and the teacher. Effectiveness was measured by comparing pre-test and post-test gains against the Control Group.
5. Evaluation Stage
Synthesis of validity, practicality, and N-Gain data to determine final product feasibility.

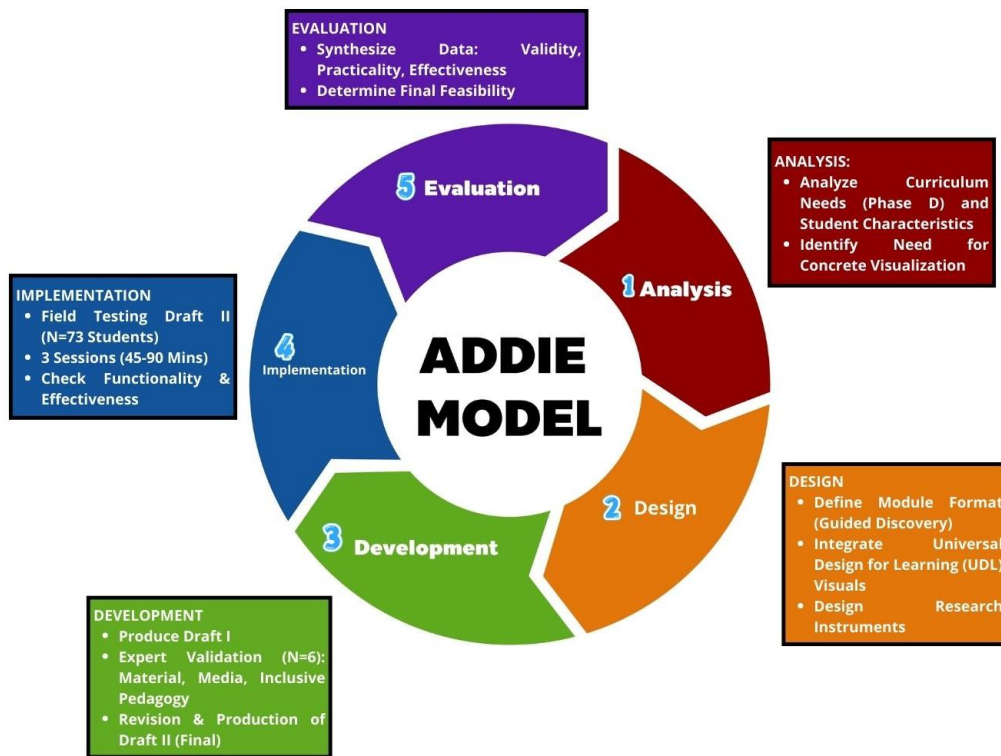


Figure 1. Research Procedure Flowchart (ADDIE Model).

Table 1 presents the ADDIE development model matrix and its integration with the mixed methods approach.

Table 1. Matrix of ADDIE Development Model and Mixed Methods Integration.

ADDIE Stage	Key R&D Activity	Quantitative Data	Qualitative Data	Mixed Methods Function
Analyze	Needs and Curriculum Analysis	-	Teacher Interviews/Curriculum Documents (Kimianti, 2019; Muhammad et al., 2013)	Identification of Inclusive Design Needs
Development	Initial Product Validation (Draft I)	V-Aiken Validator Score (Oksaviona et al., 2023)	Written Expert Input/Suggestions (Kimianti, 2019)	Triangulation of Construct & Content Validity
Implementation	Field Implementation	Teacher/Student Practicality Scores (Botutihe et al., 2025)	Field Observation Notes/Student Interviews	Confirming Usability in Real Context
Evaluation	Final Product Determination	Mean Validity, Practicality, Effectiveness (N-Gain)	Findings Analysis (Synthesis)	Determination of Product Feasibility

RESULTS AND DISCUSSION

The needs analysis revealed that slow learners struggle primarily with the microscopic distinctions between Elements, Compounds, and Mixtures due to a lack of visual scaffolding (Li et al., *DEVELOPMENT, FEASIBILITY, AND...* (Kiki Ayu Winarni) pp:389-399

2024; Poniyati et al., 2024). To address this, the module was designed using Universal Design for Learning (UDL) principles. Key features include:

1. To begin with, the author applied the Multiple Means of Representation through the use of 3D modeling for the differentiation of atoms and compounds (Kariman et al., 2019; Poniyati et al., 2024);
2. The author then discussed the Visual Accessibility (14pt fonts, high contrast) to reduce cognitive load.
3. Third, the author illustrated the Contextual Engagement through STEM activities related to SDG 6 (Clean Water), where students relate concrete engineering activities to abstract concepts (Oyewo et al., 2022; Sánchez-García & Reyes-de-Cózar, 2025).

Regarding the results for Product Validity and Practicality, the product was feasible due to the specialists' validation. As presented in Table 2, the module received a total V-Aiken Coefficient of 0.87 (Very Valid). Interestingly, the aspect of "Implementation of STEM & SDGs" received the highest score of 0.90, which affirmed the rigorous and excellent contextual framework (Septiana et al., 2024; Wintribrata et al., 2025).

Table 2. Results of the Inclusive STEM module Validity Test Based on V-Aiken Coefficient

Validation Aspect	Average V-Aiken	Validity Category
Content Suitability & Material Depth	0.88	Very Valid
Implementation of STEM & SDGs	0.90	Very Valid
Quality of Module Design & Interactivity	0.85	Very Valid
Inclusive Pedagogical Adaptability & Scaffolding	0.88	Very Valid
Overall Product Average	0.87	Very Valid

Figure 1 presents the results of the product validity test in the form of the average V-Aiken score.

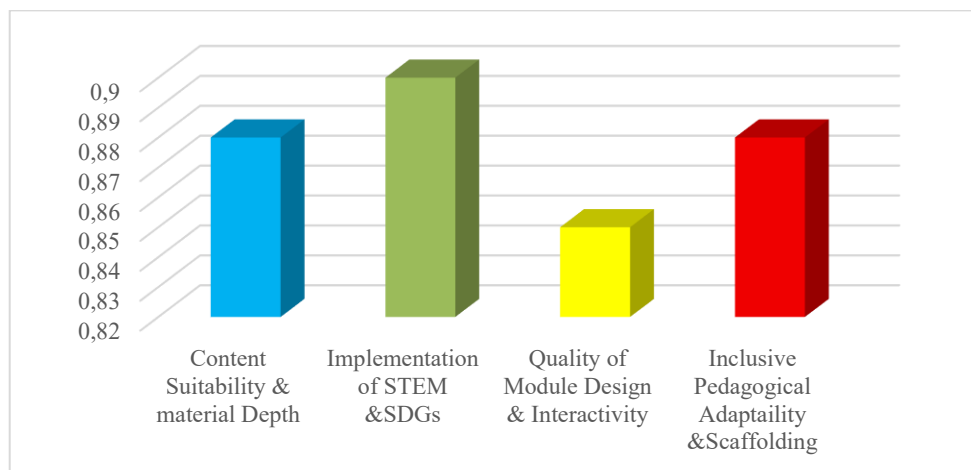


Figure 1. Results of Product Validity Test Chart (Average V-Aiken).

Regarding practicality, the limited-scale test with 10 slow learners and one teacher (Table 3) yielded an overall score of 92.1% (Very Practical). This high score confirms that the inclusive features effectively scaffolded learning and were user-friendly for students with specific needs (Guedes et al., 2024; Poniyati et al., 2024).

Table 3. Results of the Inclusive STEM module Practicality Test

Test Respondents	Practicality Aspect Assessed	Average Percentage (%)	Practicality Category
Science Teacher (N=1)	Ease of management, time suitability, teaching assistance (Botutihe et al., 2025)	95.2	Very Practical
Slow Learner Students (N=10)	Ease of understanding, learning interest, ease of interaction, and visualization features (Septiana et al., 2024)	89	Very Practical
Overall Average		92.1	Very Practical

Effectiveness was measured by comparing cognitive outcomes. As detailed in Table 4, the Experimental Group (STEM-SDGs Module) achieved an N-Gain of 0.78 (High Category), significantly outperforming the Control Group's score of 0.40 (Medium Category). This demonstrates the superior efficacy of the inclusive approach.

Table 4. Descriptive Statistics and N-Gain Score Averages

Group	Number of Students (N)	Pre-test Mean	Post-test Mean	N-Gain Mean
Experiment (STEM-SDGs Module)	34	26.68	83.38	0.78
Control (Conventional Module)	39	26.56	56.03	0.40

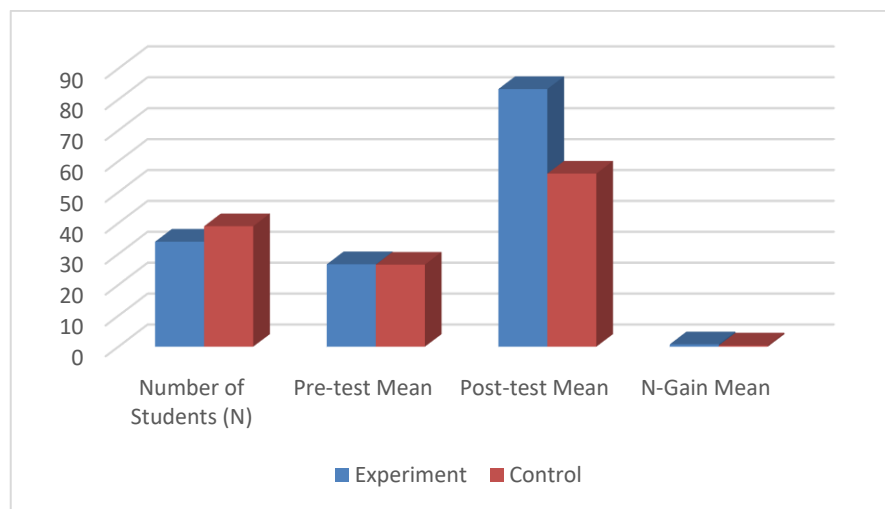


Figure 2. Comparing the N-Gain Mean score of the Experimental Group and the Control Group.

Scientific Contribution: The Module as a Cognitive Bridge. This study highlights how cognitive accessibility plays a crucial role in the learning success of slow learners by functioning as a cognitive bridge between abstract concepts and learners' mental processing. The higher N-Gain score of the experimental group (0.78) compared to the control group (0.40) supports cognitive load theory, indicating that UDL-based 3D visual models help reduce extraneous cognitive load by externally anchoring mental visualization, thereby freeing working memory to focus on concept acquisition. Furthermore, integrating STEM learning with SDG contexts, particularly SDG 6 (Clean Water), provided concrete and meaningful anchors for abstract concepts such as separation and water purification, shifting learning from rote memorization toward meaningful problem-solving. This finding expands the theoretical application of UDL within STEM education, emphasizing that accessibility involves adaptive instructional design rather than lowering academic expectations.

Limitations of the Study. Despite the positive findings, this study has several limitations that should be acknowledged. First, the research was conducted in only one school, which limits the

generalizability of the results. Second, the sample size was relatively small ($N = 10$), which may affect the strength of the conclusions, particularly regarding practicality and effectiveness. Third, the scope of the content was limited to the topics of Elements, Compounds, and Mixtures, which may not fully represent other abstract scientific topics. Finally, the short implementation duration of only three learning sessions was insufficient to assess long-term retention of scientific concepts among the learners.

Operational Recommendations and Future Research. Based on the study's findings, several recommendations are proposed for inclusive STEM classrooms and future research. Teachers are encouraged to apply heterogeneous grouping strategies in STEM projects by pairing slow learners with regular learners to support peer scaffolding, using module visuals as shared learning references. For slow learners, the engineering component of STEM activities should be carefully scaffolded by breaking tasks into smaller, clearly defined steps with checklist-based milestones to prevent cognitive overload. Future research should involve larger and more diverse samples across multiple schools to improve generalizability, incorporate longitudinal designs to examine long-term retention of scientific concepts, and extend the application of the UDL-STEM framework to other highly abstract topics, such as Energy and Genetics, to further test its broader potential.

CONCLUSION

This study developed an Inclusive STEM module based on the SDGs that addresses the cognitive needs of slow learners in Phase D and demonstrated high effectiveness (V-Aiken 0.87; N-Gain 0.78 vs. 0.40) and high practicality (92.1%), showing that UDL-based visual scaffolding and the STEM-SDGs framework can successfully make abstract science concepts more accessible. The findings confirm the module's strong scientific contribution in providing evidence that inclusive visual pathways support learning for slow learners, with instruction designed to help students adapt to the curriculum rather than simplifying content. The study recommends that teachers use the module as a guide for differentiated instruction through purposeful pairing, facilitative teaching, and contextual integration of SDG 6 (Clean Water). At the same time, educational developers should prioritize cognitive accessibility using strong visuals and real-world global issues. Future research is suggested to examine long-term retention, impacts on other learning variables such as science process skills and creativity, and the module's effectiveness in reducing achievement gaps in inclusive classrooms.

ACKNOWLEDGMENTS

The authors wish to acknowledge the Master of Physics Education Program at Sriwijaya University for the financial support that facilitated this research. Gratitude is also extended to the Head of SMP N 1 Pemulutan Barat, the science subject teachers, and all Grade VIII students for their active participation and cooperation throughout the development and validation process.

REFERENCES

- Afwina, D. A., P. P. D. A., & Budiarmo, A. S. (2021). Pengembangan modul berbasis STEM (Science, Technology, Engineering, and Mathematics) pokok bahasan alat-alat optik dalam pembelajaran IPA di SMP. *Jurnal Literasi Pendidikan Fisika*, 2(2), 126–132. <http://jurnal.fkip.unmul.ac.id/index.php/JLPF>
- Aisyah, E., Diniya, & Susilawati. (2023). Pengembangan modul pembelajaran IPA SMP/ MTs berbasis ICARE (Introduction, Connection, Application, Reflection, Extension) pada materi interaksi makhluk hidup dengan lingkungan. *Journal of Natural Science Learning*, 02(02), 38–60. <https://jom.uin-suska.ac.id/index.php/JNSL>
- Alhamuddin, Fanani, A., & Rohman, A. (2022). Developing a project-based learning model for slow learners in higher education. *Jurnal Pendidikan Islam Indonesia*, 6(2). <https://doi.org/10.35316/jpii.v6i2.404>

- Assaf, J. C., Mortada, Z., Rezzoug, S., Maache-rezzoug, Z., Debs, E., & Louka, N. (2024). Comparative review on the production and purification of bioethanol from biomass : A focus on corn. *Processes*, 12, 1001. <https://doi.org/10.3390/pr12051001>
- Botutihe, S. P., Abdullah, G., Arif, R. M., Isnanto, & Nurfailah. (2025). Pengembangan media pembelajaran mystequest untuk meningkatkan hasil belajar siswa di sekolah dasar. *Jurnal Riset Ilmiah*, 2(3), 1455–1466. <https://doi.org/10.62335>
- Chew, S. L., & Cerbin, W. J. (2021). The cognitive challenges of effective teaching. *The Journal of Economic Education*, 52(1), 17–40. <https://doi.org/10.1080/00220485.2020.1845266>
- Cleugh, mary F. (2021). *Teaching the slow learner in the special school*. Taylor & Francis.
- Dini, A., Rahmatan, H., Nurmaliah, C., Muhibbuddin, & Safrida. (2023). Application of the e-module combined with the guided inquiry learning model to increase student motivation and learning outcomes on the structure and function of plant tissues. *Jurnal Penelitian Pendidikan IPA*, 9(6), 4768–4776. <https://doi.org/10.29303/jppipa.v9i6.3857>
- English, L. D. (2023). Ways of thinking in STEM-based problem solving. *ZDM Mathematics Education*, 55(7), 1219–1230. <https://doi.org/10.1007/s11858-023-01474-7>
- Firdaus, K. H. C., Setyosari, P., & Praherdhiono, H. (2024). Universal design for learning in assistive technology. *Advances in Social Science, Education and Humanities Research*, 873, 779–786. https://doi.org/10.2991/978-2-38476-301-6_85
- Fovet, F. (2021). *Handbook of research on applying universal design for learning across disciplines: Concepts, case studies, and practical implementation*. IGI Global. <https://doi.org/10.4018/978-1-7998-7106-4>
- Garvin, D. A. (2000). *Learning in action: A guide to putting the learning organization to work*. harvard Business Press.
- Guedes, L. S., Zanardi, I., Mastrogiuseppe, M., Span, S., & Landoni, M. (2024). *Scaffolding for inclusive co-design: Supporting people with cognitive and learning disabilities bt - universal access in human-computer interaction* (M. Antona & C. Stephanidis (ed.); hal. 151–170). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-60881-0_10
- Hendry, R. F. (2006). Elements, compounds, and other chemical kinds. *Philosophy of Science*, 73(5), 864–875. <https://doi.org/10.1086/518745>
- Indriyati, T. N., Dike, D., & Sekarwinahyu, M. (2024). Pengembangan e-modul interaktif berbasis STEM materi unsur, senyawa, campuran untuk meningkatkan keterampilan abad 21 siswa SMP kelas VIII. *VOX Edukasi: Jurnal Ilmiah Ilmu Pendidikan*, 15(November), 339–349. <https://doi.org/10.31932/ve.v15i2.4021>
- Iryana, R., Hidayat, S., & Mulyadi, S. (2024). Learning model management for slow learners in an inclusive classroom setting at an elementary school. *Indonesian Journal of Primary Education*, 8(2), 129–136. <http://ejournal.upi.edu/index.php/IJPE/index>
- Ivshina, I. B., Kuyukina, M. S., Krivoruchko, A. V., Elkin, A. A., Makarov, S. O., Cunningham, C. J., Peshkur, T. A., Atlas, R. M., & Philp, J. C. (2015). Oil spill problems and sustainable response strategies through new technologies. *Environmental Science: Processes & Impacts*, 17(7), 1201–1219. <https://doi.org/10.1039/C5EM00070J>
- Janssen, F. J. J. M., Westbroek, H. B., & van Driel, J. H. (2014). How to make guided discovery learning practical for student teachers. *Instructional Science*, 42(1), 67–90. <https://doi.org/10.1007/s11251-013-9296-z>
- Kariman, D., Harisman, Y., Sovia, A., & Prahmana, R. C. I. (2019). Effectiveness of guided discovery-based module: a case study in padang city , indonesia. *Journal on Mathematics Education*, 10(2), 239–250.
- Kimianti, F. (2019). *Pengembangan e-modul IPA berbasis Problem Based Learning untuk DEVELOPMENT, FEASIBILITY, AND.... (Kiki Ayu Winarni) pp:389-399*

meningkatkan kemampuan berpikir kritis dan literasi sains. Universitas Negeri Yogyakarta.

- Lederman, N. G., Zeidler, D. L., & Lederman, J. S. (2023). *Handbook of research on science education* (Volume III). Routledge. <https://doi.org/10.4324/9780367855758>
- Li, M., & Wang, Y. (2024). Research on integration of the sustainable development goals and teaching practices in a future teacher science education course. *Sustainability*, 16(12), 4982. <https://doi.org/10.3390/su16124982>
- Li, R., Cao, Y., Tang, H., & Kaiser, G. (2024). Teachers' scaffolding behavior and visual perception. *International Journal of Science and Mathematics Education*, 22(2), 333–352. <https://doi.org/10.1007/s10763-023-10379-6>
- Liana, D. E., Muzzazinah, & Indrowati, M. (2022). Development of guided inquiry-based science e-modules to improve students' critical thinking ability. *Jurnal Penelitian Pendidikan IPA*, 8(3), 1368–1375. <https://doi.org/10.29303/jppipa.v8i3.1668>
- Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice*. CAST Professional Publishing.
- Mohammad, T. Z., & Mahmoud, A. M. (2014). Clustering of slow learners behavior for discovery of optimal patterns of learning. *International Journal of Advanced Computer Science and Applications*, 5(11), 102–109.
- Muhammad, R. R., Lawson, D., Aslam, F., & Crawford, M. (2013). Indonesian curriculum 2013 ten years on: its impact on mathematics teaching. *Journal of Research in Science, Mathematics and Technology Education*. <https://doi.org/10.31756/jrsmte.616SI>
- Novak, K. (2022). *UDL now!: A teacher's guide to applying universal design for learning* (3rd ed.). CAST Professional Publishing.
- Nurhasanah, & Nida, Q. (2016). Character building of students by guidance and counseling teachers through guidance and counseling services. *Jurnal Ilmiah Peuradeun: International Multidisciplinary Journal*, 4(1), 65–76. <https://doi.org/10.13140/RG.2.1.3085.4160>
- Nurhayati, E., Andayani, Y., & Hakim, A. (2021). Pengembangan e-modul kimia berbasis STEM dengan pendekatan etnosains. *Mandalika Mathematics and Educations Journal*, 4(2). <https://doi.org/10.29303/cep.v4i2.2768>
- Nuswawati, M., Harjito, Jabbar, A., & Taufiq, M. (2024). *Buku ajar kimia lingkungan: Terintegrasi kompetensi Education for Sustainable Development (ESD)* (M. Nasrudin (ed.); 1 ed.). PT Nasya Expanding management.
- Oksaviona, V., Islami, N., & Nasir, M. (2023). Development of PBL-based sound wave interactive multimedia using lumi for class XI high school students. *Jurnal Penelitian Pendidikan IPA*, 9(10), 8008–8015. <https://doi.org/10.29303/jppipa.v9i10.4426>
- Oktariani, Febliza, A., & Sari, Y. (2020). Konten materi kimia dalam kompetensi dasar pembelajaran IPA di SMP berdasarkan K-13. *Perspektif Pendidikan dan Keguruan*, 11(2), 11–16.
- Ortigara, A. R. C., Kay, M., & Uhlenbrook. (2018). A review of the sdg 6 synthesis report 2018 from an education, training, and research perspective. *MDPI*, 6. <https://doi.org/10.3390/w10101353>
- Oyewo, O. A., Ramaila, S., & Mavuru, L. (2022). Harnessing project-based learning to enhance STEM students' critical thinking skills using water treatment activity. *Educ. Sci*, 12(11), 780. <https://doi.org/10.3390/educsci12110780>
- Piskurich, G. M. (2015). *Rapid instructional design: Learning ID fast and right* (1 ed.). John Wiley & Sons.
- Poniyati, Zahra, A., & Setyawan, F. (2024). Development of e-worksheet with guided discovery for slow learners. *International Journal on Emerging Mathematics Education*, 8(1), 75–90. <https://doi.org/10.12928/ijeme.v8i1.29587>

- Purwaningsih, S., Yennita, Y., & Wulandari, S. (2025). Preliminary research: SDGs-based STEM approach for middle school students. *Journal of Mathematics, Science, and Computer Education*, 5(2), 130–140. <https://doi.org/10.20527/jmscedu.v5i2.15407>
- Rasmi, D. P., Hendri, M., & Azriyanti, R. (2023). *Analysis of the need for development of teaching materials in the form of stem-based electronic modules*. 9(6), 4135–4141. <https://doi.org/10.29303/jppipa.v9i6.2683>
- Ridha, A. A. (2021). *Memahami perkembangan siswa slow learner* (S. Wulandari (ed.); Pertama). Syiah Kuala University Press. Memahami Perkembangan Siswa Slow Learner
- Rusdi, M., Sirajuddin, H., & Alfah, R. (2022). Implementation of the addie model (analysis, design, development, implementation, evaluation) in PHP-Based E-learning in the era of pandemic. *JTIULM: Jurnal Teknologi Informasi Universitas Lambung Mangkurat*, 7(1), 49–56. <https://doi.org/10.20527/jtiulm.v7i1.74>
- Salend, S. J. (2016). *Creating inclusive classrooms: Effective, differentiated and reflective practices* (8th ed.). Pearson.
- Sánchez-García, R., & Reyes-de-Cózar, S. (2025). Enhancing Project-Based Learning: A framework for optimizing structural design and implementation - A systematic review with a sustainable focus. *Sustainability*, 17(11), 4978. <https://doi.org/10.3390/su17114978>
- Septiana, L., Alim, J. A., & Marhadi, H. (2024). Identifikasi peserta didik berkebutuhan khusus (PDBK) slow learner di sekolah dasar. *Journal of Social Humanities and Education*, 3(4), 189–211. <https://doi.org/10.55606/concept.v3i4.1647>
- Sholikhah, A. N. Y., & Arif, S. (2024). Pengembangan modul berbasis stem 3D untuk meningkatkan kemampuan berpikir kritis siswa. *Jurnal Tadris IPA Indonesia*, 04(01), 127–140. <http://ejournal.iainponorogo.ac.id/index.php/jtii>
- Sweller, J. (1993). Some cognitive processes and their consequences for the organisation and presentation of information. *Australian Journal of Psychology*, 45(1), 1–8. <https://doi.org/10.1080/00049539308259112>
- Syahida, A., & Irwandi, D. (2015). Analisis keterampilan berpikir tingkat tinggi pada soal ujian nasional kimia. *Edusains*, 7(1), 77–87. <https://doi.org/10.15408/es.v7i1.1404>
- Syahirah, M., Anwar, L., & Holiwarni, B. (2020). Pengembangan modul berbasis STEM (Science, Technology, Engineering and Mathematics) pada pokok bahasan elektrokimia. *Jurnal Pijar MIPA*, 15(4), 317–324. <https://doi.org/10.29303/jpm.v15i4.1602>
- Wales, C. E., & Stager, R. A. (1980). The guided design approach. In D. G. Langdon (Ed.), *The Instructional Design Library* (2 ed.). Educational Technology Publications.
- Wildana, A. A., Aristya, P. D., & Budiarmo, A. S. (2023). Pengembangan modul flipbook digital berbasis STEM materi sistem pencernaan manusia untuk meningkatkan literasi sains. *Lensa (Lentera Sains): Jurnal Pendidikan IPA*, 13(1), 57–66. <https://doi.org/10.24929/lensa.v13i1.294>
- Wintribrata, B. H., Amelia, R. N., & Listiaji, P. (2025). Thermolab for STEM : An interactive 3d virtual lab to strengthen students' computational thinking in heat, temperature, and expansion. *Jurnal Penelitian Pendidikan Sains*, 14(2), 138–156. <https://doi.org/10.26740/jpps.v14n2.p138-156>
- Wirawan, P. R., & Putri, A. S. (2025). The effect of deep learning-based contextual problem on science concept understanding in slow learners at inclusive schools. *Jurnal Phi: Jurnal Pendidikan Fisika dan Terapan*, 12(1), 9–15. <https://doi.org/10.22373/p-jpft.v12i1.31448>
- Yulastri, A., Hidayat, H., Ganefri, Islami, S., & Edya, F. (2017). Developing an entrepreneurship module by using product-based learning approach in vocational education a asmar. *International Journal of Environmental & Science Education*, 12(5), 1097–1109. <http://creativecommons.org/licenses/by/4.0/>

- Zahro, F., Hariyono, E., Setiawan, B., & Plant, I. A. (2024). Inovasi pembelajaran STEM melalui desain prototipe sistem penyiraman tanaman otomatis berbasis IoT untuk siswa SMP. *Seminar Nasional Pendidikan Biologi IX: Biologi dan Pendidikan untuk Mendukung Pencapaian SDGs*, 1–100.
- Zulaiha, F., & Kusuma, D. (2020). Pengembangan modul berbasis STEM untuk siswa SMP. *Jurnal Pendidikan Fisika dan Teknologi*, 6(2). <https://dx.doi.org/10.29303/jpft.v6i2.2182>