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Development Of Practicum Modules to Improve Students' Science Process Skills - Systematic Literature Review

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Abstract— This study aims to systematically review how trends, approaches, and outcomes of laboratory modules can enhance students' science process skills. The review was conducted using the Systematic Literature Review (SLR) method by collecting and analyzing published research from 2015 to 2024, sourced from the Dimensions and Scopus databases. The articles reviewed were relevant, high-quality, and available in full text. To examine the relationships between keywords and research themes, the VOSviewer application was utilized. The results of the review indicate that many laboratory modules remain focused on technological aspects and feasibility testing, but few integrate design development, instrument evaluation, and field testing comprehensively. Modules designed using the ADDIE model, validated by experts, and tested through pretest–posttest methods with a control group, have proven effective in enhancing students' scientific process skills. This study provides a comprehensive overview and serves as an important foundation for developing better and more needs-appropriate practical modules.

Keywords— Higher Education; Instrument Validation; Practicum Module; Science Process Skills.
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1. Introduction

Practical modules are learning tools designed to integrate theoretical concepts with practical experience through experiments or laboratory-based activities [1]. These modules play a strategic role in supporting students' scientific process skills, which include the ability to observe, classify, measure, interpret data, and communicate scientific results systematically. These skills are an integral part of 21st-century science competencies and form the foundation for students to think critically, solve problems, and conduct scientific investigations independently or collaboratively [2]. Therefore, the development of effective laboratory modules must not only consider the substance of the material but also instructional design, contextual approaches, and alignment with student characteristics and curriculum needs [3].

In order for a practical module to be implemented effectively, comprehensive content validation and structured development model design are required [4]. Content validation serves to ensure that the module meets quality standards and learning objectives, which usually involves media and material experts [5]. On the other hand, development models such as ADDIE (Analysis, Design, Development, Implementation, Evaluation) are widely used in education due to their ability to guide a systematic process in developing modules that align with learning needs [6]. Evaluation instruments are also a crucial component in measuring module quality, encompassing dimensions such as strategy, learning resources, and the pedagogical approaches applied. Without robust validation and development structures, practical modules risk failing to create meaningful and impactful learning experiences [7].

The results of the study indicate that the use of technology and contextual approaches in practical modules can significantly improve student learning outcomes and engagement [8]. E-modules in chemistry laboratory sessions have proven to be superior to conventional methods, as evidenced by a significant difference in scores (t-value = 4.872), as well as a 93.24% increase in learning motivation compared to 72.98% in traditional methods [9]. Contextual-based laboratory modules developed in science education have also been found to be effective, with a validity score of 85.86 in enhancing students' scientific process skills and environmental awareness [10]. However, gaps were still found in the integration of technology in teacher training programs, where improvements are needed in mentoring and digital practice experiences to ensure that prospective educators are prepared to effectively handle digital classrooms [11].

Conventional laboratory modules still face various limitations that impact the low mastery of important skills among students. Work skills such as communication, teamwork, and problem-solving have not developed optimally [12]. In the field of

English language education, for example, novice teachers demonstrate a lack of reflective ability and unmet professional development needs [13]. The shift to online learning also poses challenges in practical skill training, particularly in physical education, where monitoring and student learning autonomy are key challenges [14]. Additionally, the current curriculum is not yet fully responsive to the specific needs of students, whether in the context of adaptive physical education [15] or in competency-based medical education, which still faces challenges in adequately addressing contemporary health issues [16].

Efforts to develop learning modules must be accompanied by a rigorous validation process and the application of a systematic development model in order to produce superior educational products. For example, the PISA-based literacy e-module achieved a validity score of 85% with an effectiveness value (n-gain) of 75.5%, categorized as highly effective ("Development of PISA-Based Literacy E-Modules," 2023). The geography module also demonstrated high effectiveness after being validated through the Content Validity Index by experts [17]. The ADDIE model has been successfully used in the development of the needle stick injury prevention (N-SIP) module, resulting in comprehensive content and instructional design [18]. A similar model was also applied to the Physical Education 4 module, where the integration of expert feedback improved the quality of content and pedagogy [19]. In terms of evaluation, the development of adequate instruments is essential for objectively assessing learning strategies, resources, and pedagogical approaches [20].

Although much research has been conducted in the development of practical modules, most studies are still fragmented in terms of technology or validation without integrating all components holistically [21]. Research gaps remain in the integration of instrument validation, the use of pedagogy-based development models, and pretest–posttest experimental designs to objectively assess the effectiveness of modules [22]. This research offers an original contribution (novelty) by developing a practical module that is not only valid and contextual but also empirically tested in the context of science education through a quantitative approach and rigorous evaluative design. Therefore, the objective of this study is to develop a laboratory module that can effectively, systematically, and appropriately enhance students' science process skills in line with current science education needs [23].

2. Research Method

This research is a qualitative research with Systematic Literature Review (SLR) approach. This method is used to identify, evaluate, and interpret all relevant research results regarding the Development of Practicum Modules to Improve Students' Science Process Skills. This approach aims to collect and analyze data from various relevant sources systematically, so as to provide a deep understanding of the topic under study. The data in this study were sourced from the Dimensions (https://app.dimensions.ai) and Scopus (https://www.scopus.com) databases with publication intervals of the last 10 years to ensure that the data used were current and relevant to the Development of Practicum Modules to Improve Student Science Process Skills.

Data eligibility criteria in this study were established to ensure that only relevant and high-quality literature was analyzed. The criteria include (1) scientific articles published in reputable national and international journals; (2) studies that specifically address the Development of Practicum Modules to Improve Students' Science Process Skills; (3) publications published in the last 10 years (2015-2024); (4) articles available in full text and in English or Indonesian. The research procedure is as shown in Fig. 1.

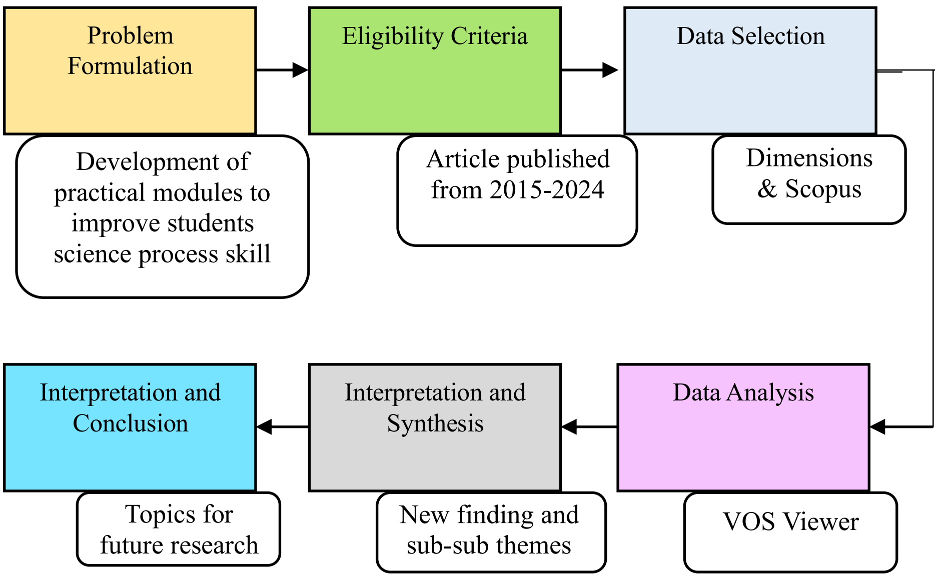

Fig. 1. Research Procedure

Figure 1 shows that this research was conducted in several stages, namely problem formulation, determination of eligibility criteria, data selection, data analysis, data interpretation and synthesis, and conclusion drawing. The problem formulation stage is important to limit the topic discussed, namely the Development of Practicum Modules to Improve Students' Science Process Skills. Eligibility criteria were determined to filter data that fit the topic with relevant keywords such as "(Practicum Module Development) OR (Improving Students' Science Process Skills)". Subsequently, data was selected from the Dimensions database and a filter was applied for data published in the last 10 years (2015-2024). Next, the collected data was imported into VOSviewer software to create a visualization of the relationship between keywords and themes in this study. The results of visualization and data analysis from VOSviewer were interpreted to explain the key variables in the Development of Practical Modules to Improve Students' Science Process Skills.

3. Results And Discussion

3.1 Data Selection Results

The search results in the indexer database found a total of 1,659 data, including 1,593 open access data and the rest were closed access. Of the 1,593 data, 1,524 data are articles and 389 data are books and proceedings. Thus, there are 200 data that will be analyzed in the next stage. The distribution of the amount of data is in accordance with Fig. 2.

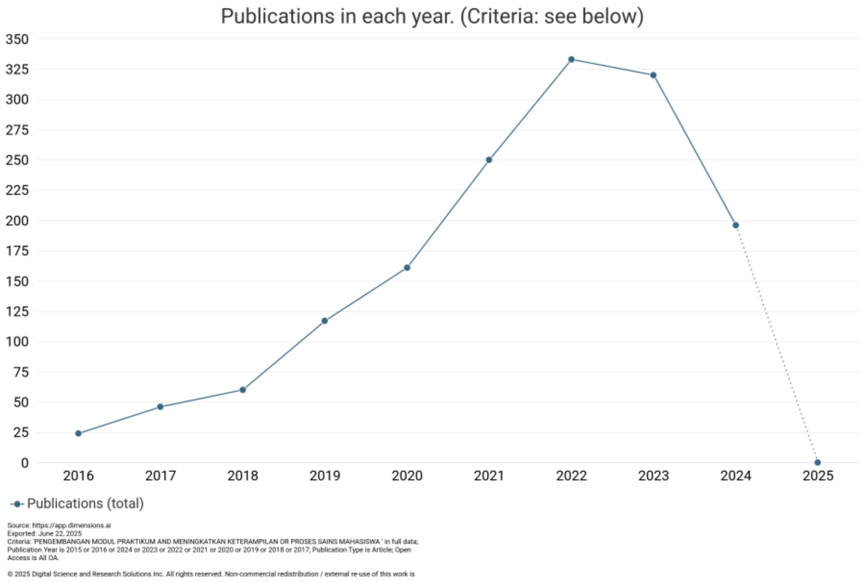

Fig. 2. Distribution of the amount of data over a decade

Fig. 2 shows the publication trend of data collected through the Dimensions platform until June 22, 2025. The publications analyzed are scientific articles in open access that contain the keywords “Practical Module Development” or “Improving Student Science Process Skills”. 2016-2018: There was gradual growth, starting with around 25 publications in 2016, increasing to more than 60 publications in 2018. 2019-2021: A period of significant growth. Publications increased sharply from ~120 articles (2019) to peak in 2021 with more than 330 articles. 2022-2023: High stability is maintained, although there is a slight decline from 330 to around 320 articles. 2024: A significant drop to around 190 publications. 2025: An extreme decline is observed, but this is due to incomplete data for the current year (cut-off June 2025), so full estimates for this year are not yet available. Academic Interpretation, Growth in Academic Interest (2016-2021): The surge in publications in this period shows the increasing urgency and scientific attention to the development of practicum modules and strengthening science process skills, along with the encouragement of 21st century education, the Industrial Revolution 4.0, and the shift in the learning paradigm towards a more contextual and learner-centered. Peak and Stability (2021-2023): The two-year stability of publication numbers reflects the consolidation of research in this area, including the integration of learning technologies, online learning during the pandemic, and the development of performance-based validation and evaluation instruments. Temporary Decline (2024-2025): The sharp decline in 2024 may be due to several factors, such as the post-pandemic transition, a shift in research focus to other areas of education technology (e.g. AI in education), or research funding policies. The 2025 data is not representative as it does not include publications for the entire year. Scientific Implications, This trend shows that practicum module development has been a rapidly growing area in the past decade. However, the recent downward trend is an important indication that there is a need for methodological innovation, expansion of the context of study (e.g. cross-disciplinary, cross-cultural), and synergy with cutting-edge technologies such as smart labs, AI-driven modules, or immersive practicum tools to maintain the sustainability of academic contributions in this area.

3.2 Network Visualization of Data

The data that has gone through the selection process is then visualized using VOS viewer to see the research variables and the relationship between variables. The visualization results are as shown in Fig. 3.

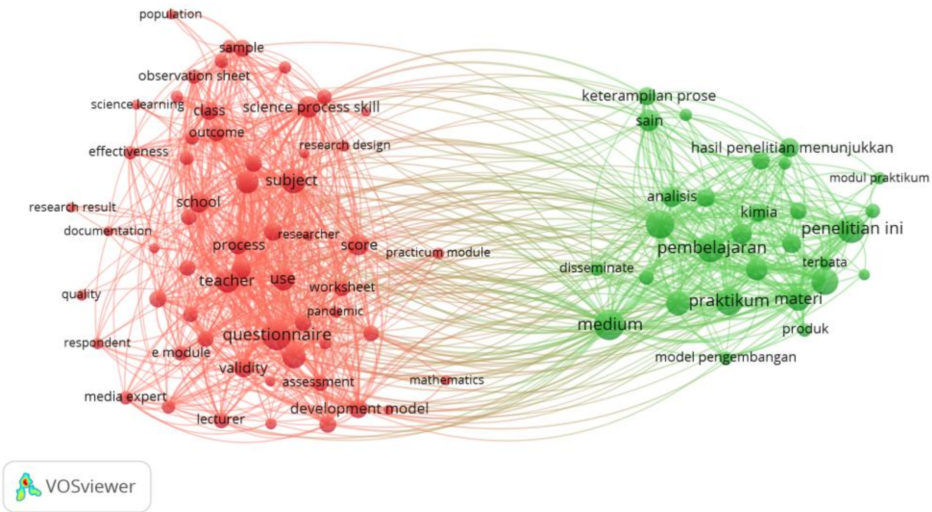

Fig. 3. Network visualization of research variables

Figure 3 is a network visualization of all the variables studied over the past 10 years and depicts four different color groups: green, red, yellow, and blue. The interpretation of each variable is as follows.

a. Green Cluster (Module Implementation and Learning Effectiveness)
Important keywords: "learning," "material," "practicum," "science," "process skills," "research results show," "chemistry," "analysis," "practicum module," "medium," "development model," and "product."

b. Red Cluster (Research Methodology and Instrument Validation)
This cluster includes keywords such as: "questionnaire," "teacher," "subject," "score," "school," "sample," "science process skill," "validity," "development model," "lecturer," "media expert," "worksheet," "assessment," and "pandemic."

Based on the cluster division, researchers can make a more in-depth study of several topics as follows.

a. The Effectiveness of Practical Modules in Improving Science Process Skills The consistent use of pretest and posttest strategies has proven effective in improving student learning outcomes in various educational contexts. In elementary education, for example, the average score of fifth-grade students increased from 40.238 to 83.476 after an intervention using educational videos [24]. In medical education, the application of pre- and post-tests on first-year MBBS students resulted in a significant increase from 35.37% to 80.95%, with some students even achieving their best performance for the first time [25]. In nursing education, the use of a mobile app for stroke care showed a statistically significant increase in knowledge ($p < .001$), confirming the effectiveness of digital approaches in the context of self-directed learning [26].
Similar results were also found in asynchronous learning approaches. A retrospective analysis of 400 veterinary students showed a significant increase in posttest scores ($p < .001$) after taking an online shelter surgery course, supporting the effectiveness of asynchronous online learning ("A Retrospective Analysis…", 2022). Additionally, a study by [27] confirmed that the presence of a pretest can accelerate learning patterns among medical students, with both groups of participants showing higher posttest scores compared to their pretest scores. Furthermore, a comparison between the control and experimental groups showed that the use of innovative media, such as Adobe Flash CS6, yielded better learning outcomes than conventional methods [28], and that active student engagement in knowledge-based discussions was proven to enhance learning productivity [29]. In the field of molecular biology, the choice of control type (biological vs. temporal) also influences the number of differentially expressed genes in RNA-seq studies, highlighting the importance of proper experimental design [30].
Based on these findings, it can be concluded that the evaluative approach based on pretest and posttest, as well as experimental designs involving control and experimental classes, have a significant impact on learning outcomes and biological research outputs. In the context of Developing Practical Modules to Enhance Students' Science Process Skills, the use of such a design is highly relevant for objectively testing the effectiveness of the modules [31]. Modules designed with consideration of baseline initial abilities (pretest) and tested through comparison of experimental and control groups allow for in-depth analysis of the extent to which science process skills such as observation, classification, data interpretation, and scientific communication can be improved through structured educational interventions [32].

b. Validity of Instruments and Development Models Used
Content validity is an important indicator in ensuring the effectiveness and usability of learning media. Content validity assessment is conducted through expert evaluation, both from the media and material perspectives, to ensure that the module content is in line with learning objectives and student needs [33]. Evaluation methods include quantitative approaches, such

as validation scores or the Content Validity Index (CVI), and qualitative approaches in the form of expert suggestions or feedback [34]; [35]. One study reported a CVI value of 0.93 for the media aspect and 0.95 for the material aspect, indicating a very high level of content relevance [35]. Validation by a multidisciplinary expert panel further strengthens the reliability of the instrument, as demonstrated in the development of a health information perception scale [36].

The validation results generally indicate that the developed media obtained the categories of "highly valid" and "suitable for use" in an educational context, both in conventional and digital learning settings [34]; [37]. Additionally, high content validity contributes to improved learning outcomes because the material presented aligns with curriculum standards and learner characteristics [38]. This implication becomes even stronger when the media is continuously validated to address the rapid dynamics of digital development [36].

In addition, the diversity of backgrounds of the experts involved in the validation adds credibility to the module development process. The relevance of the development model to the learning objectives plays an important role in ensuring the achievement of educational outcomes. Learning models such as social interaction and problem-based learning facilitate the formulation of contextual and measurable objectives [39]. In its implementation, this model can adapt the learning approach to the characteristics of learners and the complexity of the material, as applied in the chronic disease management curriculum [40]. Furthermore, in teacher training programs, the relevance between outputs and outcomes is an important benchmark in monitoring the achievement of learning objectives [41]. Thus, content validity assessment and the selection of appropriate development models need to go hand in hand so that practicum modules are truly effective in supporting students' scientific process skills holistically and systematically.

4. Conclusion

Based on the synthesized findings, it can be concluded that a pretest and posttest-based evaluative design combined with an experimental approach using control and experimental groups proved effective in objectively measuring learning outcomes. This strategy not only enables comparative analysis of the effectiveness of practicum modules, but also provides a solid basis for data-driven pedagogical decision-making. In addition, the integration between the content validity of the learning media and the selection of a development model that suits the instructional objectives proved to contribute significantly in supporting the achievement of students' science process skills holistically. The success of the practicum module is largely determined by the extent to which its design is responsive to the characteristics of the learners, the demands of the curriculum, and the dynamics of the science content being taught.

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