



Practicality Evaluation of an Inquiry-Based Practicum Module on Atomic Structure and Nanomaterials for Vocational Chemistry Learning

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Keywords: article; iot; remote sensing; unila; writing instructions

1. INTRODUCTION

The development of scientific literacy and higher-order thinking skills has become a primary agenda in global education reform, especially in subjects that require experimental engagement such as chemistry. In vocational education, the need is even more urgent because students are expected to master practical competencies that align with industrial requirements while simultaneously building conceptual understanding of scientific principles. Chemistry topics such as atomic structure and nanomaterials present unique pedagogical challenges due to their abstract nature, multilevel representations, and the cognitive demand required to relate submicroscopic phenomena with macroscopic observations. These challenges necessitate the use of structured learning modules that not only guide laboratory work but also facilitate student inquiry and conceptual integration.

Recent educational research highlights that vocational school students often face persistent difficulties in visualizing atomic models, understanding electron configurations, and explaining the behavior of particles at the nanoscale (Zhang et al., 2023). These cognitive barriers stem from multiple sources: limited exposure to hands-on experiments, insufficient scaffolding to relate theory to practice, and the reliance on teacher-centered instruction that emphasizes memorization rather than exploration.

Nanomaterials an increasingly crucial topic in the 21st-century curriculum due to their role in advanced technologies are even more challenging for students because the phenomena involved operate at dimensions beyond direct experience. Without effective instructional design, students struggle to develop deep and relational understanding of these concepts.

Over the last five years, inquiry-based learning has gained significant attention as an effective pedagogical strategy to address these issues. Inquiry-based learning shifts the learning paradigm from passive knowledge reception to active knowledge construction. Students are encouraged to pose questions, generate hypotheses, design experiments, collect and interpret data, and formulate evidence-based conclusions. A growing body of empirical research shows that inquiry-based instruction leads to improved conceptual understanding, stronger scientific reasoning, and higher levels of autonomy in learning (Maknun, 2020; Jegstad, 2024; Vilela et al., 2025). In chemistry education specifically, inquiry has been shown to help students develop connections between abstract concepts and laboratory experiences, allowing them to understand not only "what happens" during an experiment but "why it happens." However, simply implementing inquiry tasks without structured support often results in cognitive overload for students, especially those in vocational schools who may have diverse academic backgrounds. For

this reason, educational researchers emphasize the importance of well-designed practicum modules that integrate inquiry phases into clear, accessible, and practical instructional materials (Thimmappa, 2024). Practicum modules serve as scaffolds that organize the learning process, guide student exploration, and facilitate teacher management of laboratory activities. When modules are thoughtfully designed, they support student independence while reducing unnecessary cognitive load, making inquiry-based learning more feasible.

Despite the recognized benefits of inquiry-based modules, their adoption in vocational schools remains limited. Teachers often cite several obstacles: lack of time to develop instructional materials, limited laboratory resources, unfamiliarity with inquiry pedagogy, and the perception that inquiry activities take longer than traditional verification-based labs. As a result, laboratory practices in vocational chemistry classes frequently revert to step-by-step “cookbook” procedures that prioritize outcome replication rather than conceptual exploration. These traditional approaches do little to enhance critical thinking or real-world problem solving competencies essential for vocational graduates entering technologically-driven industries. In response to these challenges, module practicality becomes a central concern. Practicality refers to the extent to which an educational product is usable, feasible, and efficient when applied in real learning environments. According to recent research, practicality is strongly correlated with teacher acceptance and sustained implementation of instructional innovations (Martel-Santana et al., 2025). Even a module with strong theoretical foundations and high content validity will fail to be adopted if it is perceived as difficult to use, poorly aligned with classroom conditions, or too demanding in terms of time and resources. Therefore, practicality must be assessed under realistic conditions with real users teachers and students to determine whether an inquiry-based practicum module can be effectively integrated into daily teaching practices.

The relevance of practicality assessment becomes even greater in the context of vocational education. Vocational classrooms often operate under constraints such as limited laboratory time, high student-teacher ratios, diverse learner profiles, and varying levels of student motivation. Consequently, a successful practicum module should not only support inquiry learning but also address these contextual difficulties. For example, a practical module should contain clear step-by-step instructions, intuitive inquiry prompts, efficient procedures that fit within standard class durations, and visual aids that support students in navigating complex concepts like electron orbitals and nanoparticle behavior. In the last five years,

several studies have reaffirmed the importance of practicality in the development of science learning materials. Severini et al. (2022) reported that usability and clarity were the strongest predictors of student engagement in laboratory-based learning. Martel-Santana et al. (2025) also found that modules with clear visual design and manageable workloads were preferred by both teachers and students, leading to higher adoption rates and more effective classroom implementation. Similarly, Orosz et al. (2023) emphasized that instructional tools addressing nanoscale concepts must be user-friendly to help students overcome inherent conceptual difficulties. These findings emphasize that practicality is not an optional supplement to learning module design but a fundamental criterion that determines the success of pedagogical innovation.

Considering these challenges and the latest research trends, the development of a practical inquiry-based practicum module for atomic structure and nanomaterials is both timely and necessary. Such a module has the potential to transform vocational chemistry learning by enabling students to engage deeply with scientific concepts through structured inquiry, while still being feasible for teachers to implement within existing classroom constraints. The combination of inquiry pedagogy and practical design considerations can facilitate meaningful learning experiences that align with 21st-century skill demands and industrial competency standards. Therefore, this study focuses exclusively on evaluating the practicality of the developed module. By involving teachers and students directly in the evaluation, this research provides empirical evidence on how the module performs in real learning environments. The study offers insights into module usability, clarity, student engagement, and alignment with learning objectives, contributing valuable knowledge to the growing literature on inquiry-based and vocational chemistry education.

2. MATERIALS AND METHOD

This study employed a **Research and Development (R&D)** approach using the **ADDIE model**, consisting of the analysis, design, development, implementation, and evaluation stages. For the purposes of this article, emphasis is placed on the implementation and evaluation phases, specifically the **practicality testing** of the inquiry-based practicum module on atomic structure and nanomaterials. The focus on practicality aligns with recent educational research that underscores the importance of ensuring a product’s usability and feasibility before widespread adoption, particularly in vocational settings with unique contextual challenges such as limited laboratory time, heterogeneous student

abilities, and resource constraints (Martel-Santana et al., 2025). Practicality testing is therefore essential to determine whether a theoretically valid module can function effectively in real-world chemistry learning environments.

The study was conducted at **SMK Negeri 2 Banjit**, Way Kanan District, selected purposively due to its adequate laboratory facilities and experienced chemistry teachers. Participants included **three chemistry teachers** and **32 eleventh-grade students** from the Agribusiness and Horticulture program. Teachers were selected based on a minimum of five years of teaching chemistry and involvement in laboratory instruction. Students were chosen to represent diverse academic abilities and typical classroom characteristics, ensuring realistic assessment conditions. This sampling approach is consistent with recent development-based educational research, which emphasizes the importance of involving authentic end-users in evaluating the practicality of instructional products (Orosz et al., 2023; Vilela et al., 2025).

The product tested in this phase was the **Inquiry-Based Practicum Module on Atomic Structure and Nanomaterials**, designed to support investigative, hands-on laboratory activities. The module integrates conceptual explanations of electron configuration, atomic models, and fundamental nanomaterial properties with guided inquiry procedures. It incorporates a complete sequence of inquiry stages—problem orientation, question formulation, hypothesis development, experimentation, data interpretation, and conclusion drawing. Visual scaffolding such as atomic diagrams, nanoscale illustrations, and inquiry flowcharts were included to facilitate understanding of abstract and microscopic concepts, in line with contemporary recommendations in science and STEM education (Zhang et al., 2023; Thimmappa, 2024).

Data were collected using two instruments: the **Teacher Practicality Questionnaire** and the **Student Practicality Questionnaire**. These instruments were developed based on modern instructional design criteria, assessing clarity of instructions, usability, layout quality, efficiency, and

perceived learning benefits (Severini et al., 2022). The teacher questionnaire evaluated aspects such as the coherence of the inquiry syntax, feasibility of laboratory procedures, and the module’s potential to enhance student engagement. The student questionnaire focused on readability, visual appeal, step-by-step followability, and perceived support for inquiry activities. Both questionnaires used a 0–100 scale, subsequently interpreted using conventional practicality categories (very practical, practical, moderately practical, and less practical), consistent with current literature on instructional material evaluation (Jegstad, 2024).

The implementation procedure began with distributing the module to teachers and students prior to the practicum session. Teachers familiarized themselves with the module before guiding students through the inquiry activities in the laboratory. During the practicum, students followed the structured inquiry steps, recorded observations, and engaged in discussions to interpret experimental findings. Teachers observed the flow of activities, noting the extent to which the module facilitated smooth laboratory work, reduced confusion, and supported higher-level investigative thinking. Upon completion of the practicum, students completed the practicality questionnaire independently, while teachers provided evaluations based on their observations of the module’s usability and instructional feasibility.

Data were analyzed using descriptive quantitative techniques. Scores obtained from the questionnaires were converted into percentage values to determine the practicality level of the module. This analysis approach follows standard evaluation practices in instructional design research, where percentage-based scoring provides a clear and comparable measure of usability (Maknun, 2020). In addition to numerical analysis, open-ended responses from teachers and students were reviewed qualitatively to identify recurring themes related to the module’s strengths, limitations, and suggestions for improvement. These qualitative insights enriched the interpretation of the quantitative findings and guided recommendations for future revisions, consistent with current methodologies in science education research (Martel-Santana et al., 2025).

Table 1. Acquisition parameters in the field

Measurement Parameters	Value
Time	± 30 minutes
Sampling Rate	500 SPS
Sampling Period	0.002 seconds

Number of Axis	3
Number of Measurement Points	30

3. Results and Discussions

The practicality testing of the inquiry-based practicum module on atomic structure and nanomaterials demonstrated highly positive

results from both teachers and students, indicating that the module is feasible, usable, and well aligned with the learning characteristics of vocational school environments. The analysis of practicality data revealed that the chemistry teachers provided an overall score of 98%, which is categorized as “very practical.” This exceptionally high score reflects the teachers’ strong approval of the module’s clarity, organization, and ease of implementation. They reported that the module’s inquiry procedures were well structured, allowing them to guide students effectively through each investigative stage despite the limited practicum time available in SMK settings. Teachers also highlighted that the module reduced preparation burdens, as all essential information—tools, materials, procedures, safety notes, and inquiry prompts—was clearly presented. These findings are consistent with international studies emphasizing that usability and clarity are key determinants of practicality in science learning modules, especially when laboratory activities must be managed efficiently within strict time frames (Jegstad, 2024; Martel-Santana et al., 2025).

The students’ responses likewise indicated strong practicality, with an overall score of 89.13%, also in the “very practical” category. Students expressed that the module was easy to understand and visually engaging, particularly due to its use of diagrams, atomic illustrations, and simplified nanoscale representations. They reported that the step-by-step inquiry instructions reduced confusion during the practicum and helped them follow the experimental flow more independently. Additionally, the guided inquiry structure—beginning with problem orientation, followed by questioning, hypothesis formulation, experimentation, data analysis, and conclusion—supported their confidence in conducting laboratory tasks. This aligns with recent research findings indicating that visually supported and well-scaffolded inquiry modules enhance student engagement and reduce cognitive load when learning abstract scientific concepts (Zhang et al., 2023; Severini et al., 2022). Students also noted that the module stimulated curiosity, increased motivation, and provided a more meaningful learning experience compared to traditional verification-based laboratory worksheets.

Overall, the combined perspectives of teachers and students suggest that the module possesses strong practicality and is well suited for chemistry instruction in vocational schools. Several factors contributed to this high level of practicality. First, the integration of clear inquiry syntax helped guide learners through

logical steps, making the inquiry process manageable even for students with varying academic abilities. Second, the alignment of the module with the vocational chemistry curriculum ensured that its content remained relevant and directly connected to required competencies. Third, the visual supports within the module enhanced comprehension of microscopic concepts such as electron configurations, atomic models, and properties of nanomaterials, which students commonly find difficult when presented solely through textual explanations. Fourth, the module’s laboratory procedures were efficient and realistic for the available teaching time, enabling teachers to implement inquiry-based learning without logistical barriers.

These findings resonate with broader international literature noting that practicality is a critical precursor to the successful adoption of inquiry-based materials in real classroom settings. Studies by Orosz et al. (2023) and Thimmappa (2024) highlight that inquiry modules are most effective when they are not only theoretically sound but also operationally feasible for teachers and understandable for students. The results of this study reinforce that principle, as the high practicality scores reflect strong acceptance from both user groups. The teachers’ exceptionally high rating (98%) demonstrates that the module provides an instructional structure that fits the realities of vocational laboratories, which often operate under constraints such as limited resources and heterogeneous student readiness levels. When teachers perceive a module as convenient and functional, they are more likely to integrate it consistently into their teaching practices, increasing the module’s sustainability and long-term impact.

From the students’ perspective, the 89.13% practicality score indicates that learners found the module accessible, engaging, and supportive of their inquiry processes. This is particularly significant in vocational education, where many students tend to prefer hands-on, practical learning experiences. The module’s guided inquiry format created opportunities for students to participate actively in constructing knowledge rather than merely following procedural steps without reflection. Such engagement is crucial, as active participation has been shown to improve conceptual understanding, retention, and the development of scientific reasoning skills. Likewise, the module’s visual and inquiry-oriented features helped bridge the gap between abstract atomic theory and tangible laboratory activities, supporting the development of meaningful connections between concepts. This resonates

with research by Severini et al. (2022), who emphasized that usability and visual clarity are vital for the successful implementation of inquiry-based science materials.

Taken together, these findings confirm that the inquiry-based practicum module developed in this study meets the criteria for high practicality and is ready for broader implementation in vocational chemistry classrooms. The module's strong usability, clarity, alignment with curriculum needs, and visual scaffolding make it a promising instructional resource that can enhance the quality of practicum-based learning. The results also underscore the importance of evaluating practicality as a core component of instructional material development, as practicality directly influences teacher adoption, student engagement, and the overall success of inquiry-based learning interventions. With its high practicality ratings, this module establishes a strong foundation for subsequent evaluations of effectiveness, particularly regarding improvements in relational understanding, conceptual mastery, and inquiry skills among vocational school students.

4. CONCLUSIONS

The results of this study demonstrate that the inquiry-based practicum module on atomic structure and nanomaterials possesses a very high level of practicality when implemented in vocational chemistry learning. The exceptionally strong ratings from teachers (98%) and the highly positive responses from students (89.13%) indicate that the module is easy to use, clearly structured, visually supportive, and well aligned with the learning conditions and needs of SMK students. Teachers found the module efficient and feasible for classroom implementation, particularly because the inquiry procedures were systematically organized and required minimal additional preparation, while students reported that the module helped them navigate laboratory activities more confidently and meaningfully. These findings confirm that the module not only meets theoretical expectations of inquiry-based learning design but also functions effectively in real classroom settings, fulfilling key indicators of practicality outlined in contemporary instructional design research. The high practicality scores suggest that the module can be sustainably adopted in vocational schools and has the potential to enhance students' engagement and inquiry-based learning experiences. Furthermore, the strong acceptance by both teachers and students provides a solid foundation for future studies examining the module's effectiveness in improving relational understanding and

higher-order cognitive skills. Overall, this study concludes that the developed practicum module is a practical and valuable instructional resource that can support the implementation of inquiry-oriented chemistry learning in vocational education.

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