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## Effects of Inquiry-Based Learning Methods on Students' Science Process Skills: A Systematic Literature Review

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### ABSTRACT

This study examined the effects of inquiry-based learning (IBL) methods on the development of students' science process skills (SPS) across multiple scientific disciplines and educational settings. Using a systematic literature review guided by the PRISMA framework, eleven quasi-experimental studies published between 2020 and 2025 were analyzed. These studies, conducted in Indonesia, the Philippines, Turkey, Ethiopia, and Pakistan, explored different forms of IBL, including project-based inquiry, ethnoscience-based inquiry, flipped classroom integration, argument-driven inquiry, process-oriented guided inquiry learning, and inquiry-based laboratory approaches. Findings revealed a consistent positive effect of IBL on both basic and integrated SPS. Students exposed to inquiry-driven instruction demonstrated significant gains in their SPS compared to those in traditional learning environments. The results further indicated that the success of IBL lies in its active, student-centered nature that promotes exploration, evidence-based reasoning, and reflective learning. Variations in IBL models proved equally effective when they encouraged collaboration, questioning, and independent investigation.

### INTRODUCTION

Inquiry-Based Learning (IBL) has increasingly been recognized as a transformative instructional approach that reshapes students' engagement with scientific concepts. Rooted in the belief that learning is best achieved through exploration and discovery, IBL positions learners as active participants who formulate questions, investigate real-world phenomena, and build understanding through evidence-based reasoning and reflection. Rather than emphasizing rote memorization, it nurtures advanced cognitive skills such as critical thinking, analytical reasoning, and problem-solving, which are essential for developing scientific literacy in a rapidly advancing world. Scientific literacy, in this sense, extends beyond knowing facts as it involves applying scientific understanding to real-world situations and making informed decisions based on conceptual understanding and evidence, which lies at the heart of meaningful science education (Kotsis, 2024; Urdanivia Alarcon *et al.*, 2023).

The theoretical roots of IBL date back to educational philosophers John Dewey and Lev Vygotsky, who emphasized learning as an active, social, and meaning-making process. Dewey's advocacy of experiential learning underscores the idea that students learn best through hands-on engagement and reflection on real-world problems. He viewed inquiry as a transformative process through which uncertain situations are clarified via observation and experimentation, positioning learners as active participants rather than passive recipients of information (Kotsis, 2024). Vygotsky's social constructivist theory complements this by emphasizing that learning is a social process shaped by interaction and cultural context. Within IBL, this

perspective manifests through collaborative discussions, peer learning, and cooperative problem-solving, where students co-construct understanding by sharing and debating ideas (Moemeke *et al.*, 2025). Together, Dewey and Vygotsky's insights provide the foundation for IBL as a balance between experiential discovery and social collaboration.

In science education, inquiry can be viewed through two interconnected frames: as a teaching approach and as a learning outcome. When viewed as a teaching approach, inquiry serves as the pathway through which learners explore concepts, test ideas, and develop understanding. Conversely, as a learning outcome, inquiry encompasses the skills and dispositions students acquire, such as questioning, analyzing, experimenting, and reasoning scientifically (Teig, 2021). Effective IBL instruction bridges these two frames, ensuring that students not only master scientific content but also cultivate the habits of mind essential for authentic scientific inquiry.

Essential to IBL are two core components: inquiry-based instruction and a supportive classroom culture. Inquiry-based instruction entails guiding students through processes of formulating questions, designing investigations, analyzing data, and communicating findings. Meanwhile, a supportive classroom culture promotes cooperation, curiosity, and reflective thinking, motivating students to engage in genuine scientific practices and encouraging teachers to promote critical thinking, problem-solving, and growth mindsets (Guerrero & Bautista, 2023).

At the core of IBL lies the development of Science Process Skills (SPS), which form the foundation of scientific literacy. SPS equip learners with the ability to observe, think, and operate in ways similar to practicing

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scientists (Rusmini *et al.*, 2021). These skills are broadly categorized as basic (e.g., observation, classification, measurement, and communication) and integrated (e.g., identifying and controlling variables, formulating hypotheses, experimenting, and interpreting data), forming a continuum from fundamental observation to advanced reasoning (Gizaw & Sota, 2023). The cultivation of SPS equips students not only with technical proficiency but also with the cognitive flexibility and analytical capacity to address complex, real-world problems through scientific reasoning (Chakraborty & Kidman, 2022). Thus, IBL and SPS are inherently interconnected, as inquiry-based environments provide authentic opportunities for learners to apply and refine these process skills in meaningful contexts.

Globally, the implementation of IBL varies by educational systems but shows promising developments in countries such as Japan and Singapore. In Japan, educational reforms since 2008 have promoted inquiry-driven instruction complemented by integrating digital tools, collaborative classroom cultures, and a balanced approach combining teacher guidance with student-led activities. On the other hand, Singaporean teachers exemplify structured, student-centered practices that emphasize questioning, scaffolding, perspective-taking, and engagement in core scientific practices to nurture inquiry and scientific thinking effectively (Baildon, 202; Yonezawa & Nakai, 2024).

In the Philippine context, IBL has gained growing attention as part of efforts to enhance learner-centered and competency-based science education. Many Filipino teachers are increasingly employing inquiry-oriented strategies such as hands-on experiments, collaborative projects, and contextualized discussions that link scientific concepts to students' everyday experiences. These practices have shown promise in stimulating curiosity, enhancing engagement, and deepening scientific understanding. However, the consistent implementation of IBL across schools remains a challenge due to factors such as limited laboratory resources, large class sizes, rigid curricular frameworks, and variations in teachers' confidence and preparedness to facilitate inquiry-based instruction. Despite these constraints, the recognized potential of IBL to improve the quality of science learning continues to drive pedagogical innovation and reform efforts in the country (Bioco & Echaure, 2021; Buendia *et al.*, 2025).

Given this context, the present study seeks to synthesize and analyze existing studies that explore the relationship between IBL and the development of SPS. Specifically, this literature review examines how IBL significantly affects learners' SPS development across different scientific disciplines. By consolidating findings from previous research, this study endeavors to identify patterns, consistencies, and insights regarding the impact of IBL on SPS development, offering a comprehensive perspective on how inquiry-driven instruction supports

scientific literacy and authentic learning across diverse educational settings.

## LITERATURE REVIEW

Inquiry-Based Learning (IBL) is a student-centered instructional approach that encourages active engagement, exploration, and discovery of scientific questions. Moving beyond rote memorization, IBL prioritizes critical thinking, problem-solving, and evidence-based reasoning, fundamental skills needed in the fast-evolving scientific landscape. Educators facilitate knowledge construction by guiding learners to connect theory with real-world contexts, enabling them to apply scientific concepts authentically and develop a meaningful appreciation for science as a dynamic discipline (Kotsis, 2024; Urdanivia Alarcon *et al.*, 2023). The theoretical foundations of IBL draw heavily from John Dewey's experiential education, which emphasizes hands-on engagement and reflective problem-solving, and Lev Vygotsky's social constructivism, which values learning through social interaction and collaborative knowledge building. Together, these philosophies create an environment fostering critical thinking, adaptability, and shared meaning-making (Kotsis, 2024; Moemeke *et al.*, 2025).

Empirical studies further support the value of IBL in promoting cognitive and affective learning outcomes. Kotsis (2024), drawing from Santos *et al.* (2023), highlights that IBL enhances students' conceptual understanding of scientific processes by allowing them to actively construct knowledge through experimentation, analysis, and interpretation of evidence. Inquiry-based learning also mirrors the authentic processes scientists use, such as hypothesis testing, evaluation of evidence, and peer review, which help students refine analytical reasoning (Urdanivia Alarcon *et al.*, 2023). Lestari *et al.* (2024) also emphasize that inquiry-based learning improves scientific literacy through structured questioning, writing, and communication which are key processes that encourage learners to think and communicate like scientists. However, for inquiry to be truly meaningful, it must connect to learners' lived experiences. Mulyono *et al.* (2024) propose integrating ethnoscience, which involves embedding scientific inquiry in local and cultural contexts, so students see how science relates to their own communities. When inquiry is relevant and contextualized, learning becomes not only more effective but also more empowering.

Science Process Skills (SPS) form the foundation of scientific inquiry and literacy. These skills guide how students observe the world, test their ideas, and interpret results, forming the backbone of both classroom investigations and professional scientific practice. SPS encompasses both the cognitive and practical dimensions of science, blending logical reasoning with hands-on engagement (Rusmini *et al.*, 2021). As Chakraborty and Kidman (2022) describe, they are not merely procedural

techniques but also habits of mind that cultivate curiosity and evidence-based thinking.

The emphasis on developing SPS has a long history, dating back to the Science-A Process Approach introduced by the American Association for the Advancement of Science (AAAS) in 1967. This initiative marked a shift from teaching science as a body of facts to presenting it as a dynamic process of investigation. According to Gizaw and Sota (2023), developing SPS means developing individuals capable of critical reasoning, informed decision-making, and active participation in science-related societal issues.

SPS are generally divided into two categories: basic and integrated. Basic SPS involve foundational skills such as observing, classifying, measuring, predicting, inferring, and communicating. These abilities form the groundwork for exploring scientific phenomena. Integrated SPS, on the other hand, involve higher-order thinking to perform complex tasks such as identifying and controlling variables, formulating hypotheses, designing and conducting experiments, constructing models, and interpreting data (Gizaw & Sota, 2023).

Kelp *et al.* (2023) emphasize that all learners, regardless of whether they pursue scientific careers, benefit from acquiring both basic and integrated SPS, as these skills promote critical participation in problem-solving and community discourse. Through the acquisition of SPS, learners not only grasp scientific concepts more deeply but also develop the capacity to apply them meaningfully in real-world contexts (Rusmini *et al.*, 2021). By equipping students with these skills, teachers lay the groundwork for future scientists, informed decision-makers, and responsible global citizens capable of addressing complex societal challenges through science.

Inquiry-based learning (IBL) and the development of Science Process Skills (SPS) are inherently connected. IBL provides the context where SPS are practiced, while SPS give structure to the process of inquiry. When students ask questions, design investigations, and draw evidence-based conclusions, they are simultaneously engaging in the very processes that define scientific thinking (Teig, 2021). In this sense, inquiry is both the method and the outcome: learners use science process skills to investigate problems, and through inquiry, these skills become more refined and meaningful.

Studies reveal that IBL provides authentic opportunities for students to practice and refine SPS in meaningful, real-world contexts. By posing questions, designing investigations, and drawing conclusions from empirical evidence, learners internalize the scientific processes that mirror the work of practicing scientists (Rusmini *et al.*, 2021). Moreover, inquiry-based environments encourage the development of higher-order cognitive skills, bridging the gap between theoretical knowledge and applied reasoning (Kotsis, 2024). In this way, IBL and SPS reinforce each other, wherein IBL provides the structure for scientific practice, while SPS supply the cognitive tools that make inquiry effective.

However, the success of IBL in nurturing SPS depends heavily on the learning environment and teacher support. Guerrero and Bautista (2023) identify two critical factors for effective implementation: well-structured inquiry guidance and a classroom culture that values curiosity, collaboration, and reflection. When these conditions are met, students gain both the competence and confidence to conduct meaningful investigations. Conversely, challenges such as large class sizes, limited resources, and insufficient teacher training can hinder the full realization of IBL's potential to develop SPS (Bioco & Echaure, 2021).

Thus, IBL serves as the fertile ground where SPS take root and flourish. Together, they form the cornerstone of scientific literacy, which enable learners to not only acquire scientific knowledge but also develop the intellectual curiosity and critical skills necessary to understand and shape the world around them. However, its success is affected by contextual challenges which remain critical areas for ongoing support and research.

## MATERIALS AND METHODS

This study utilized the systematic literature review (SLR) method to examine how inquiry-based learning (IBL) significantly affects the development of science process skills (SPS) among students in different areas of science. The review procedure followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page, 2021). Article selection was carried out according to the four major phases outlined in the PRISMA flowchart: identification, screening, assessment of eligibility, and final inclusion. In the identification stage, relevant literature was identified from the search engine Google Scholar using the search terms "science education," "inquiry-based," and "science process skills." In the screening stage, the identified relevant literature was screened by selecting journal articles published in 2020-2025. In the eligibility stage, the selected journal articles were screened further by excluding review papers and non-experimental studies. In the inclusion stage, articles that meet the following inclusion criteria were included in the study: publication timeline is 2020-2025, record type is original research article, and the research design is quasi-experimental study on the effect of using IBL methods on the development of SPS conducted among students in the secondary level. Articles who met the inclusion criteria were analyzed using selected content analysis.

## RESULTS AND DISCUSSION

Based on the literature search on Google Scholar, eleven (11) studies that met the established inclusion criteria were identified, all examining the impact of inquiry-based learning (IBL) methods on students' science process skills (SPS). These studies were carried out across several countries, specifically Indonesia (3 studies), the Philippines (3 studies), Turkey (3 studies), Ethiopia (1 study), and Pakistan (1 study).

**Table 1:** Review of literature on the effects of IBL methods on students' SPS

Author (Year Published)	Country	Field of Study (Level)	Method	Key Findings
Rapi et al. (2025)	Indonesia	Physics (Junior High School – Grade 10)	Inquiry-based learning with project-based assessment	Students who were guided using the IBL approach combined with project-based assessment demonstrated a notable increase in their SPS compared to those taught through the conventional learning method. Students in the experimental group have high level of SPS, particularly in terms of observing, formulating hypothesis, investigating, interpreting findings, and making conclusions.
Tahya and Saija (2023)	Indonesia	Chemistry (Senior High School – Grade 11)	Ethnoscience-based inquiry learning	Students' SPS showed a significant improvement following the implementation of the ethnoscience-based inquiry learning model. Integrating culture into learning science (ethnoscience) and the inquiry process improved students' SPS.
Katauhi et al. (2022)	Indonesia	Science (Junior High School – Grade 8)	E-module based on guided inquiry with flipped classroom strategy	There is a significant increase in students' SPS after the implementation of a guided inquiry-based science e-module with a flipped classroom strategy. Students demonstrated the highest aspect achievement in the post-test results on SPS, particularly in the indicators on observing, formulating the problem, structuring hypothesis, interpreting data, and making conclusions.
Belga (2022)	Philippines	Physics (Junior High School – Grade 10)	Argument-Driven-Inquiry (ADI) laboratory method	Students in the experimental group, who was exposed to ADI laboratory method, had better gains in SPS than those in the control group. The experimental group demonstrated high proficiency across the five integrated SPS: identifying and controlling variables, generating hypothesis, defining operationally, interpreting data, and experimenting. Incorporating argumentation (using evidence to support conclusions or claims) into laboratory activities proves more effective in promoting the development of students' SPS than traditional laboratory approaches.

Idul and Caro (2022)	Philippines	Earth Science and Chemistry (Junior High School – Grade 10)	Process-oriented guided inquiry learning (POGIL)	<p>A significant difference was observed in the SPS of students in POGIL classes compared to those in non-POGIL classes.</p> <p>Students who were exposed to POGIL reached Moving Towards Mastery level in their basic SPS in terms of observing, measuring, inferring, and predicting, Nearing Mastery level in terms of communicating, and Mastered level in terms of classifying.</p> <p>POGIL provided students with greater opportunities to develop and strengthen their SPS by engaging them in small-group work, with the teacher serving as a facilitator.</p>
Tan et al. (2020)	Philippines	B i o l o g y (Junior High School – Grade 9)	Inquiry-based learning with flipped classroom strategy	<p>Students in both the flipped inquiry and non-flipped inquiry groups demonstrated significant improvements in their SPS.</p> <p>No significant difference was found in the SPS of students taught through flipped IBL compared to those taught using the non-flipped approach</p>
Erkacmaz et al. (2023)	Turkey	B i o l o g y (Junior High School – Grade 9)	Inquiry-based laboratory approach	<p>Students taught using inquiry-based laboratory approach demonstrated higher gain in their SPS as compared to those in the traditional inquiry.</p> <p>The integration of laboratory approach in IBL, where scientific principles, concepts, and generalizations are learned through the experiments the students plan, is more effective than the traditional inquiry.</p>
Tekin and Mustu (2021)	Turkey	P h y s i c s (Junior High School – Grade 7)	Inquiry-based laboratory approach Research-inquiry based activities	<p>Engaging in experiments and completing activities under research-inquiry based instruction led to an improvement in students' SPS.</p> <p>Research-inquiry based learning, which presents students with problems to solve through the scientific process and facilitates knowledge construction, effectively enhances their SPS.</p>
Sahintepe et al. (2020)	Turkey	C h e m i s t r y (Junior High School – Grade 7)	Inquiry-based learning approach	<p>Students taught using IBL showed significant improvement in their basic and integrated SPS as compared to those who were not taught using IBL.</p> <p>It was also observed that students had positive attitude and better motivation to learn science as a result of using IBL.</p>

Chengere et al. (2025)	Ethiopia	B i o l o g y (Junior High School – Grade 10)	I n q u i r y - b a s e d laboratory activities	Students who received instruction through the Guided Inquiry-Based Laboratory Experiments Enriched Instructional (GIBLEI) approach demonstrated a significant improvement in their SPS compared to those taught using the Traditional Laboratory Experiments Enriched Instructional (TLEI) method. GIBLEI-based instruction, emphasizing inquiry-driven laboratory activities that engage students in investigation,
Majeed et al. (2023)	Pakistan	S c i e n c e (Junior High School – Grade 8)	I n q u i r y - b a s e d learning approach	Students instructed using the 5E inquiry-based learning model demonstrated better SPS compared to those in the control group who received traditional instruction. Using the 5E model of IBL, the students improved their basic SPS (observing, measuring, classifying, predicting, and communicating) and integrated SPS (controlling variables, hypothesizing, experimenting, and interpreting data).

The synthesis of eleven (11) studies across five countries reveals a consistent and compelling pattern: inquiry-based learning (IBL) methods significantly enhance students' science process skills (SPS) across various scientific disciplines and educational levels. Regardless of the variation in instructional methods, whether through ethnoscience integration, argument-driven inquiry, process-oriented guided inquiry, flipped classroom integration, laboratory approach integration, or research integration, students exposed to IBL approaches consistently demonstrated greater mastery of both basic and integrated SPS compared to those taught through traditional, teacher-centered instruction.

A notable trend across the studies is the effectiveness of IBL in fostering active engagement and scientific reasoning. For instance, Rapi *et al.* (2025) and Katauhi *et al.* (2022) in Indonesia reported substantial gains in observation, hypothesis formulation, and interpretation of data when learners participated in guided or project-based inquiry. These findings reinforce Dewey's notion of experiential learning, wherein students construct understanding by directly engaging with phenomena. The use of guided inquiry e-modules and project-based assessments not only encouraged self-directed exploration but also nurtured reflective thinking, which are key aspects of higher-order SPS.

Cultural and contextual adaptations of IBL also surfaced as valuable enhancers of learning outcomes. The ethnoscience-based inquiry model of Tahya and Saija (2023) effectively bridged scientific and cultural knowledge, allowing students to connect scientific investigation with local experiences. This contextual relevance made inquiry more meaningful and authentic,

echoing Vygotsky's idea of learning as a socially and culturally mediated process. Such culturally responsive inquiry not only improved students' SPS but also heightened their motivation and sense of ownership in the learning process.

In the Philippine context, studies by Belga (2022), Idul and Caro (2022), and Tan *et al.* (2020) underscore the transformative potential of IBL in developing both basic and integrated SPS among Filipino learners. Belga's (2022) integration of the Argument-Driven Inquiry (ADI) laboratory method demonstrated that when students are required to justify claims with evidence, their ability to analyze, interpret, and communicate scientific information improves substantially. This aligns with the view that argumentation fosters deeper cognitive processing and metacognition, critical for mastering integrated SPS. Similarly, the Process-Oriented Guided Inquiry Learning (POGIL) approach used by Idul and Caro (2022) cultivated collaboration and reflection as students worked in small groups with teacher facilitation, leading to mastery in classifying and communication skills. Tan *et al.* (2020), meanwhile, revealed that both flipped and non-flipped inquiry models are effective, suggesting that the core of IBL success lies in active inquiry itself rather than the specific delivery format.

Research from Turkey, Ethiopia, and Pakistan reinforces the global validity of IBL's effectiveness. Studies by Sahintepe *et al.* (2020), Tekin and Mustu (2021), and Erkacmaz *et al.* (2023) demonstrate that structured inquiry laboratory approaches significantly boost students' ability to observe, control variables, and interpret data, which are the skills central to scientific investigation. In Ethiopia, Chengere *et al.* (2025) found

that the Guided Inquiry-Based Laboratory Enriched Instruction (GIBLEI) model produced higher SPS gains than traditional methods, highlighting the importance of structured scaffolding within inquiry environments. Likewise, Majeed *et al.* (2023) in Pakistan showed that the 5E IBL model effectively promoted both basic and integrated SPS, underscoring how inquiry cycles that emphasize engagement, exploration, and explanation cultivate the full range of scientific skills.

Taken together, these studies illustrate that the common denominator of using IBL across contexts is the shift from passive reception of knowledge to active construction through questioning, experimentation, and reflection. Students exposed to IBL were not merely learning science content. They were learning how to think scientifically, observe systematically, test ideas logically, and interpret evidence critically.

Moreover, the results highlight the dual importance of teacher facilitation and learner autonomy. In all reviewed studies, successful implementation depended on teachers who guided inquiry without dominating it, which emphasizes the importance of balancing structure with freedom. This confirms Guerrero and Bautista's (2023) assertion that effective IBL thrives in classrooms where curiosity, collaboration, and reflection are nurtured. When learners are supported yet empowered to take ownership of their investigations, their SPS develop most effectively. The overall evidence points toward IBL as a transformative pedagogy that not only strengthens scientific skills but also cultivates curiosity, confidence, and lifelong engagement with science.

## CONCLUSION

This review reveals that inquiry-based learning methods have a significant positive effect on students' science process skills (SPS) across different educational contexts, grade levels, and fields of science. Students who were taught using inquiry-based approaches consistently outperformed those in traditional classrooms, showing higher levels in their SPS such as observing, hypothesizing, experimenting, interpreting data, and drawing conclusions. These outcomes highlight that IBL effectively nurtures both basic and integrated science process skills, allowing learners to engage more actively and meaningfully in scientific investigations.

The findings also reveal that variations in IBL, such as project-based inquiry, ethnoscience integration, flipped classroom strategies, argument-driven inquiry, and guided laboratory instruction, are all effective when they encourage students to explore, test ideas, and communicate findings. This suggests that the strength of IBL lies not in a single model but in its shared emphasis on student-centered exploration and evidence-based learning. When students are given opportunities to investigate and reflect, they develop scientific reasoning that extends beyond content recall to authentic problem-solving and analytical thinking.

While the studies collectively affirm the effectiveness

of IBL, they also point to limitations related to context. Most of the reviewed research was conducted within controlled or small-scale classroom settings, where teachers received guidance or resources for implementation. Hence, broader application may face challenges in larger, resource-constrained classrooms where inquiry activities are difficult to manage. These limitations suggest the need for further studies that examine long-term effects and the sustainability of IBL practices under varied school conditions.

The overall findings affirm the relevance of IBL as a transformative approach in science education, one that equips learners with the cognitive and practical tools needed to think and act scientifically. Its consistent success across different cultural and disciplinary contexts underscores its adaptability and pedagogical value. To maximize its impact, science educators are encouraged to integrate inquiry strategies into regular classroom instruction, provide structured yet flexible guidance, and cultivate environments that value curiosity and collaboration. With continued support, training, and adaptation to local needs, IBL can serve as a grounding pedagogical approach for developing scientifically literate learners.

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