BHARATI INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH & DEVELOPMENT (BIJMRD)

(Open Access Peer-Reviewed International Journal)

DOI Link : https://doi.org/10.70798/Bijmrd/04090004

Available Online: www.bijmrd.com | BIJMRD Volume: 4 | Issue: 09 | September 2026 | e-ISSN: 2584-1890

Promoting Inclusiveness in Science Education through Inquiry Based Laboratory Instructions (IBLI): An Equity Oriented Approach

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Abstract: *Science education needs a pedagogical approach which promotes scientific reasoning, practical skills, meaningful participation and equitable learning opportunities with conceptual understanding. However, present laboratory teaching method based on predetermined procedures, examination oriented practical works and teacher centered approach which may restrict learners' opportunities to investigate phenomena, formulate questions, make decisions, interpret evidence and communicate scientific explanations. The present conceptual study examines Inquiry Based Laboratory Instructions (IBLI) as equity oriented pedagogical approach for promoting inclusiveness in science education. The study adopt a qualitative literature based conceptual methodology combining relevant theoretical perspectives, scholarly literature on inquiry based learning, empirical studies, laboratory instructions, science education and educational inclusion. This study focus on perspective of constructivism learning theory, social constructivism learning theory, experiential learning theory, inquiry based science education, equity, inclusion and also this paper develops a conceptual framework linking inquiry oriented laboratory processes with inclusive science learning. The framework identifies twelve dimensions of inclusiveness: equitable access, active participation, meaningful engagement, differentiated support, learner agency, collaborative learning, equitable role distribution, accessibility and flexibility, voice and expression, scientific competency development, inclusive assessment and sense of belonging and confidence. This study shows that IBLI can promote inclusiveness through accessible resources, collaborative participation, differentiated scaffolding and responsive instructional design.*

Keywords: *Inquiry Based Laboratory Instructions (IBLI), Laboratory Learning, Inclusiveness, Scientific Competencies, Educational Equity.*

1. Introduction: Science education is foundational to the developing scientific understating, problem solving skill, reasoning, practical skill, collaboration and ability to apply scientific knowledge. Science education in the present context requires a shift from the transmission and memorization of scientific facts towards learning experiences in which students actively formulates questions, investigate problems, observe phenomena, analyze evidence, construct explanations and communicate their findings. Scientific inquiry methods facilitates an important foundation for this transformation because it provides learners to understand both scientific concepts and the processes through which scientific knowledge is developed. The laboratory

offers a particularly valuable context for inquiry oriented science education because it allows learners to interact directly with materials, instruments, phenomena, evidence and to connect theoretical knowledge with practical scientific experiences. However, the use of laboratory activities alone may be insufficient to promote meaningful and inclusive science learning. Conventional laboratory methods often relies on predetermined procedures, teacher demonstrations, prescribed experiments, recording of observations and examination oriented practical work. Conventional laboratory methods may least opportunities for learners to analyze evidence, construct scientific explanations, make investigative decisions. Consequently, it is very important that how to design laboratory activities for enhancing real scientific queries experienced by learners. This concern also becomes important when science education considered from the perspective of inclusiveness, when learner entered in laboratory with different mindset, previous laboratory experiences, confidence, learning needs and access to educational resources. These differences can influence who participates actively, who handles equipment, whose ideas are heard, who receives support and who has opportunities to demonstrate scientific competence. Thus, inclusive science education extends beyond physical access to laboratories and requires meaningful participation, recognition of learner diversity, removal of barriers and equitable opportunities for learning. In this context, equity provides an important foundation for promoting inclusiveness. Equality may involve providing learners with the same resources and opportunities whereas equity recognises that learners may require different forms and levels of support to participate meaningfully and achieve educational outcomes. An equity oriented approach therefore requires attention to differentiated support, accessibility, learner participation, collaboration and appropriate teacher guidance. These principles are particularly relevant to laboratory learning where differences in experience and confidence may otherwise result in unequal participation. Inquiry Based Laboratory Instructions (IBLI) provides a potential pedagogical approach for connecting inquiry, laboratory learning, inclusiveness and equity. In this paper, IBLI refers to laboratory instructions in which learners actively participate in questioning, planning investigations, experimentation, observation, evidence analysis, explanation, communication and reflection. The main proposition advanced in this paper is that IBLI can be understood not merely as an approach to improving laboratory learning, but as an equity-oriented approach to promoting inclusiveness in science education**.** The paper addresses the limited conceptual integration between inquiries based laboratory instructions and educational equity by examining how laboratory inquiry can be deliberately designed to reduce barriers and broaden participation. Drawing on constructivism, social constructivism, experiential learning and inquiry based science education and also equity and inclusion perspectives, the paper develops a conceptual framework connecting inquiry oriented laboratory processes with inclusive science learning achievements. The proposed framework identifies twelve dimensions through which IBLI may promote inclusiveness: equitable access, active participation, meaningful engagement, differentiated support, learner agency, collaborative learning, equitable role distribution, accessibility and flexibility, voice and expression, scientific competency development, inclusive assessment, sense of belonging and confidence**.** Through these dimensions, the paper positions inquiry based laboratory learning at the intersection of science education, inclusion and equity. Accordingly, the contribution of the paper lies in conceptualizing IBLI as an equity oriented pedagogical framework that seeks to create meaningful opportunities for diverse learners to participate in, contribute to, and benefit from scientific inquiry.

2. Need for the Study

2.1 Limitations of Conventional Science Instruction: Traditional laboratory method focused on fixed procedures, teacher explanations, memorization and examination oriented practical works. While IBLI encourages active investigation, decision making, evidence based reasoning and scientific explanation, thereby connecting laboratory activities with authentic scientific practices (Hofstein & Lunetta, 2004).

2.2 Need for Inclusive Science Education: Inclusive science education develops further beyond physical access to classrooms and laboratories. It focuses meaningful participation, recognition of learner diversity, removal of barriers and equitable opportunities for learning. Ainscow (2020) explain that contextual barriers

of learners restrict learning participation and progress. These barriers may be limited resources, limited experience, language difficulties, insufficient support, unequal participation can disproportionately affect marginalized students.

3. Literature review: Inquiry Based Laboratory Instructions (IBLI) is a learner centered approach while conventional laboratory approach is a teacher centered in which many activates are based on predetermined procedures. IBLI encourages students to ask questions, conduct experiments, make predictions, develop explanations and analyses evidence. Orosz et al. (2023) highlighted guided inquiry supported Grade 9 students when adequate scaffolding was provided, although challenges remained in hypothesis development and evidence evaluation but the relationship between inquiry and laboratory based Chemistry learning has also been explored through technologically supported activities Similarly, Wang et al. (2025) expalin the application of inquiry based learning in technologically supported analytical Chemistry laboratory activities, through a laboratory activity involving photoelectric technology and cerium analysis . Such approaches illustrate how laboratory instruction can move beyond routine experimentation by engaging students with authentic scientific problems and contemporary laboratory techniques. Similarly, Twizeyimana and Shiramunda (2026) through a meta-analysis of empirical studies conducted between 2018 and 2024, reported a positive effect of inquiry based Chemistry laboratory instruction on conceptual understanding. Their findings indicate that the effectiveness of inquiry laboratories may nevertheless differ according to educational level, instructional design and implementation conditions. Earlier research also provides evidence concerning the role of inquiry in supporting learners from diverse backgrounds. Kantor and Konstantopoulos (2009) reported that inquiry oriented curricula supported by appropriate teacher knowledge and instructional practices could contribute to improved science achievement among minority students. Blanchard et al. (2010) similarly found that guided inquiry laboratory activities produced stronger learning and retention of scientific concepts than conventional verification oriented laboratory work. These findings are relevant to an equity oriented perspective because meaningful laboratory participation can provide learners with opportunities that are often restricted when science teaching is dominated by explanation, demonstration and memorization. Research involving prospective teachers further strengthens the relevance of inquiry based laboratory instruction. Ozgelen et al. (2013) reported that structured and reflective inquiry supported prospective teachers' understanding of the nature of science, whereas Yakar and Baykara (2013) identified improvements in scientific process skills, creative thinking and attitudes towards experimentation. Irwanto et al. (2019) also found positive changes in the critical thinking abilities of prospective teachers. In addition, Eymur (2018) associated Argument-Driven Inquiry with improvements in laboratory skills and self-efficacy. These studies indicate that teacher preparation is an important component of successful inquiry-based science instruction because teachers require both conceptual knowledge and practical competence to facilitate inquiry effectively. The importance of guidance has been further established through broader research on inquiry based science education. Furtak et al. (2012) a meta-analysis of 37 experimental and quasi-experimental studies, reported positive effects of inquiry based science teaching while emphasizing that inquiry differs according to the nature and degree of teacher and learner involvement. Lazonder and Harmsen (2016) based on a meta-analysis of 72 studies; similarly found that instructional guidance can improve learning activities, task performance and learning outcomes. These findings are particularly significant for inclusive education because learners enter science classrooms with differences in prior knowledge, confidence, language, resources and laboratory experience. A flexible level of scaffolding can therefore help reduce barriers to participation. Technology supported inquiry has expanded the possibilities for inclusive laboratory learning. Virtual and online laboratory environments have been associated with opportunities for conceptual learning, scientific reasoning and experimentation (Nedungadi et al., 2015; Mutlu & Şeşen, 2020; Lai et al., 2021). However, technology by itself does not guarantee equitable learning. The educational value effect curricular alignment, accessibility, learner characteristics, teacher support and the quality of instructional design. Some studies focused the importance of reflection,

teacher facilitation, appropriate guidance and supportive learning environments (Gericke et al., 2022; Orosz et al., 2023; Denton & Kulesza, 2024; Mekonnen, 2025). Participation of student is very important dimension of laboratory reform. Nicol et al. (2022) expain the importance of considering students' experiences when redesigning laboratory education and reported a preference for learning environments that provide greater opportunities for participation, interaction and independence. Overall, the literature indicates that the effectiveness of inquiry based laboratory learning depends on the interaction of pedagogical design, teacher guidance, laboratory resources, learner characteristics and educational context**.** Existing research has largely concentrated on conceptual achievement, scientific reasoning, laboratory skills and learner attitudes. Comparatively less attention has been given to the deliberate use of laboratory inquiry as equity oriented strategy for promoting inclusiveness in science education particularly for learners who experience educational or social disadvantages. This gap provides a strong rationale for examining Inquiry Based Laboratory Instructions (IBLI) as an approach for promoting inclusiveness in science education through equitable participation, appropriate scaffolding and meaningful laboratory experiences.

4. Research Gap: Existing literature indicates that inquiry based and laboratory oriented science instruction can strengthen conceptual understanding, scientific practices, active participation, collaboration and learner engagement (Furtak et al., 2012; Hofstein & Lunetta, 2004; Lazonder & Harmsen, 2016). Similarly, inclusive education research emphasizes equitable access, participation, differentiated support, accessibility and barrier removal (UNESCO, 2020). However, these research strands have largely developed separately with limited conceptual integration of Inquiry Based Laboratory Instructions (IBLI) with equity and inclusiveness in science education. Existing studies primarily examine inquiry based laboratory practices in relation to achievement, conceptual understanding, scientific process skills and inquiry competencies while comparatively less attention is given to access, participation, learner agency, voice and belonging. Moreover, inclusive science education literature provides limited guidance on structuring laboratory pedagogy to address these dimensions. Therefore, this paper conceptualises IBLI as an equity oriented pedagogical approach and proposes twelve dimensions for promoting accessible, participatory, supportive, and inclusive science learning among diverse learners.

5. Theoretical Foundation: The theoretical foundation of Inquiry Based Laboratory Instructions (IBLI) is informe by constructivist learning theory, social constructivism learning theory, experiential learning, inquiry based science education and the equity and inclusion perspective. Together, these perspectives provide a comprehensive basis for understanding how laboratory instruction can promote active learning, scientific reasoning, meaningful participation and equitable learning opportunities. It has been shown that learners as active knowledge constructors who develop understanding through investigation, collaboration, reflection, and evidence based reasoning. Scaffolding supports diverse learners, while inquiry promotes meaningful participation, practical competence, scientific thinking, and equitable access to science learning experiences.

6. Conceptual Framework: The conceptual framework of the present study on Inquiry Based Laboratory Instructions (IBLI) as an equity oriented pedagogical approach for promoting inclusiveness in science education. It hypothesizes that the educational value of laboratory learning depends not only on providing practical activities but also on how inquiry experiences are designed, facilitated, and made accessible to diverse learners. IBLI involves interconnected inquiry processes, including questioning, planning, experimentation, observation, evidence analysis, explanation, communication, and reflection, enabling learners to construct scientific understanding through active participation. These processes can become more inclusive when supported by equity oriented practices, such as accessible laboratory resources, differentiated scaffolding, collaborative learning, equitable role distribution, learner agency, inclusive assessment, and responsive teacher support. Such practices may contribute to intermediate outcomes including active participation, meaningful engagement, confidence, scientific process skills, conceptual understanding,

scientific reasoning, and scientific communication. These outcomes may, in turn, support broader inclusive outcomes, including equitable participation, reduced learning barriers, stronger scientific competencies, learner agency, sense of belonging, and engagement with science. The framework also recognizes contextual influences, including teacher competence, laboratory resources, class size, school culture, curriculum requirements, learner characteristics, and institutional support. Thus, IBLI is conceptualised as a dynamic process linking inquiry practices, equity-oriented support, learner participation, and contextual conditions.

7. Research Methodology: The present study is based on qualitative and literature based conceptual research methodology to examine promoting Inclusiveness in Science Education through Inquiry Based Laboratory Instructions (IBLI). The study does not involve primary data collection or experimental intervention; rather, it systematically examines and synthesizes relevant theoretical perspectives, empirical studies and scholarly literature related to inquiry based learning, laboratory instruction, scientific inquiry and innovative pedagogical practices. Such an approach is appropriate for developing theoretical and conceptual understanding and for identifying relationships and gaps within an existing body of research.

8. Objectives of the Study: The paper has the following objectives:

1. To conceptualise Inquiry Based Laboratory Instructions (IBLI) as an approach to science teaching.
2. To examine the relationship between inquiry based laboratory learning and inclusive science education.
3. To analyse the equity oriented dimensions of IBLI.
4. To identify pedagogical mechanisms through which IBLI may promote equitable participation.
5. To propose a conceptual framework connecting IBLI with inclusive science learning outcomes.
6. To identify implications and future research directions for implementing IBLI in diverse educational contexts.

9. Significance of the Study: The present conceptual study is significant because it positions Inquiry-Based Laboratory Instructions (IBLI) as an equity oriented pedagogical approach for promoting inclusiveness in science education. Conventional laboratory instruction may provide unequal opportunities for participation because learners differ in their prior knowledge, confidence, socioeconomic circumstances, learning needs, and access to educational resources. IBLI can provide a structured framework through which learners actively engage in questioning, experimentation, observation, collaboration, evidence-based reasoning, and scientific explanation.

The study is significant in the following ways:

1. **Promoting Inclusive Science Education:** The study conceptualizes IBLI as a means of creating meaningful learning opportunities for diverse learners, including students who may experience barriers to participation in science education.
2. **Advancing Educational Equity:** It emphasizes equitable access, participation, engagement, learner agency, and differentiated support rather than focusing only on academic achievement.
3. **Strengthening Laboratory Pedagogy:** The study provides a conceptual basis for moving from teacher-directed laboratory activities toward more student-centred, inquiry-oriented, and participatory laboratory experiences.
4. **Supporting Teachers:** The proposed approach can help science teachers understand how inquiry-based

laboratory activities can be designed to accommodate learners with different abilities, backgrounds, prior experiences, and learning needs.

5. **Integrating Theory and Practice:** The study connects constructivism, experiential learning, inquiry-based learning, and inclusive education to develop a coherent conceptual understanding of equity-oriented laboratory instruction.

6. **Contribution to Research:** The study addresses the limited conceptual integration of inquiry-based laboratory instruction, inclusiveness, and educational equity and provides a foundation for future empirical research.

7. **Policy and Educational Relevance:** The approach is consistent with contemporary educational priorities that emphasize experiential, competency-based, inclusive, and learner centred science education

10. Dimensions of Inclusiveness through Inquiry-Based Laboratory Instruction (IBLI): The dimensions of inclusiveness through IBLI demonstrate how inquiry based laboratory instructions can create equitable, participatory, accessible and learner centered science learning environments**.** By emphasizing access, active participation, differentiated support, learner agency, collaboration, inclusive assessment, scientific competency and a sense of belonging, IBLI can provide diverse learners with meaningful opportunities to engage in scientific inquiry and develop their potential.

Sr. No.	Dimension of Inclusiveness	How IBLI Promotes Inclusiveness
1.	**Equitable Access**	Provides meaningful opportunities for diverse learners to access laboratory activities, materials, equipment and scientific experiences.
2.	**Active Participation**	Involves every learner in questioning, experimentation, observation, measurement, discussion and conclusion drawing rather than allowing only a few students to perform practical tasks.
3.	**Meaningful Engagement**	Connects laboratory investigations with learners' experiences, interests, questions and real life contexts, encouraging sustained involvement in science learning.
4.	**Differentiated Support**	Allows teachers to provide different levels of scaffolding, guidance, resources and assistance according to learners' prior knowledge, abilities and learning needs.
5.	**Learner Agency**	Gives students opportunities to formulate questions, make decisions, plan investigations, select procedures, interpret evidence and construct explanations
6.	**Collaborative Learning**	Promotes peer interaction and cooperative investigation, enabling learners to share ideas, responsibilities, resources and scientific reasoning.
7.	**Equitable Role Distribution**	Ensures that laboratory roles such as experimenter, observer, recorder, material manager and presenter are distributed fairly among learners.
8.	**Accessibility and Flexibility**	Encourages adaptation of laboratory activities, instructions, materials and procedures to accommodate different learning needs and levels of laboratory experience.

9.	**Voice and Expression**	Provides opportunities for learners to express questions, observations, explanations, interpretations and alternative ideas without fear of exclusion or dismissal.
10.	**Scientific Competency Development**	Enables diverse learners to develop conceptual understanding, scientific process skills, problem solving, reasoning and evidence-based decision-making.
11.	**Inclusive Assessment**	Uses multiple forms of assessment, including observation, practical performance, questioning, laboratory records, explanation and reflection, rather than relying exclusively on written examinations.
12.	**Sense of Belonging and Confidence**	Creates a supportive laboratory environment in which learners perceive themselves as capable and legitimate participants in scientific inquiry.

11. Discussion: The dimensions presented in the table provide a conceptual basis for understanding Inquiry Based Laboratory Instructions (IBLI) as equity oriented approach to promoting inclusiveness in science education. Rather than treating laboratory work only as a means of developing practical skills, IBLI emphasizes whether all learners receive meaningful opportunities to access, participate in, engage with, and benefit from scientific inquiry. Equitable access provides learners to have opportunities to use laboratory materials, equipment, and scientific resources, accompanied by appropriate guidance. Active participation engaging learners questioning, experimentation, observation, measurement, discussion, and conclusion drawing, ensuring that practical experiences are not limited to confident or high-achieving students. Meaningful engagement connects investigations with learners' experiences, interests, questions, and real life contexts. Differentiated support enables teachers to adapt scaffolding, instructions, resources, questioning, and feedback according to learners' prior knowledge and learning needs without lowering academic expectations. IBLI also promotes learner agency by enabling students to formulate questions, make decisions, plan investigations, interpret evidence, and construct explanations. Collaborative learning facilitates peer interaction, shared problem solving, and collective knowledge construction, while equitable role distribution ensures that students rotate responsibilities such as experimentation, observation, recording, and presentation. Accessibility and flexibility allow activities and resources to be adapted to diverse needs, including contexts with limited laboratory facilities. Furthermore, voice and expression, inclusive assessment, and opportunities for scientific competency development enable learners to demonstrate conceptual understanding, practical skills, reasoning, and evidence based decision making. Collectively, these dimensions position IBLI as an inclusive pedagogical framework that reduces participation barriers and promotes equitable engagement in science education.

12. Conclusion: Inquiry Based Laboratory Instructions (IBLI) provides an inclusive and equity oriented approach for transforming laboratory learning beyond predetermined procedures. It engages learners to formulate questions, plan investigations, conduct experiments, analyze evidence, construct explanations, communicate findings, and reflect on learning. The framework integrates inquiry based learning with educational equity by emphasizing equitable resource access, differentiated scaffolding, teacher guidance, collaboration, learner agency, role distribution, accessibility, and inclusive assessment. The twelve dimensions identified in the framework further demonstrate that inclusiveness involves more than physical access to laboratory facilities. It encompasses active participation, meaningful engagement, voice and

expression, scientific competency development, and a sense of belonging and confidence. The reviewed literature suggests that the effectiveness of inquiry-oriented laboratory learning depends on the quality of pedagogical design, teacher facilitation, level of guidance, learner characteristics, available resources, and educational context. Therefore, IBLI should not be regarded as unstructured discovery learning; rather, the level of support should be adapted to learners' prior knowledge, experience, and learning needs. The major contribution of this paper is the conceptual integration of IBLI with inclusiveness and educational equity. It provides a framework for understanding how laboratory pedagogy can address barriers to participation while supporting scientific competencies and learner agency. However, because the study is conceptual and literature-based, the proposed relationships cannot be considered causal and require empirical validation. Future research should therefore examine the framework through quantitative, qualitative, mixed-methods, and longitudinal studies, particularly across diverse learner groups and educational contexts. Overall, IBLI can be understood not merely as a laboratory teaching strategy, but as an equity-oriented pedagogical framework for creating meaningful opportunities for diverse learners to participate in and learn through scientific inquiry.

13. Scope for Future Research: Future research should empirically examine the proposed IBLI framework through quantitative, qualitative, and mixed-methods approaches. Experimental and quasi-experimental studies can compare IBLI with conventional laboratory instruction in relation to conceptual understanding, scientific reasoning, inquiry skills, achievement, and laboratory competence. Qualitative studies can examine learners' experiences of participation, agency, voice, confidence, and belonging during inquiry-based laboratory activities. Particular attention should be given to learners who experience educational or social disadvantage, including students with disabilities and learners from different socioeconomic, linguistic, rural, and urban contexts. Further research should investigate how teacher scaffolding, differentiated support, and different levels of inquiry-structured, guided, and open influence equitable participation. Future research should investigate low cost, physical, and virtual laboratory models in resource constrained settings. Researchers should also develop and validate equity oriented tools assessing access, participation, learner agency, engagement, scientific competencies, and belonging. Longitudinal studies can examine sustained outcomes. Overall, IBLI represents an equity oriented pedagogical framework whose proposed relationships require empirical validation across diverse educational contexts.

14. Limitations of the Study: This study is conceptual and literature based and not an empirical intervention. Therefore, it does not claim that IBLI has independently demonstrated causal effects on inclusiveness. The proposed relationships among IBLI, equity oriented pedagogical processes, and inclusive outcomes require empirical testing. Furthermore, inclusion and equity are context dependent therefore; strategy that addresses barriers in one educational setting may not have the same effect in another. Consequently, future research should consider institutional, cultural, socioeconomic, linguistic, technological and learner specific factors.

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Citation: **Kumar. M., Mohanty. P. & Ekka. R.,** (2026) "Promoting Inclusiveness in Science Education through Inquiry Based Laboratory Instructions (IBLI): An Equity Oriented Approach", *Bharati International Journal of Multidisciplinary Research & Development (BIJMRD)*, Vol-4, Issue-09, September-2026.