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Priming physics teachers to embrace an inquiry stance

Eilish McLoughlin0000-0001-7991-7134,1, Stephen Gammell0009-0005-2610-3029,1, Paul Grimes0000-0001-6705-9566,2 and James Lovatt0000-0001-7360-5834,2

[1]Centre for Advancement of STEM Teaching and Learning & School of Physical Sciences, Dublin City University, Dublin 9, Ireland.
[2]Centre for Advancement of STEM Teaching and Learning & School of STEM Education Innovation and Global Studies, DCU Institute of Education, Dublin City University, Dublin 9, Ireland.

eilish.mcloughlin@dcu.ie

Abstract. Physics teachers often consider the influence of their teaching methods and strategies on their students' learning, motivations, and achievements. However, teachers often report that they lack the ability or time to systematically examine their own professional practice. The objective of this research is to support physics teachers in embracing an inquiry stance towards designing, facilitating and reflecting on classroom practices. This study presents data from 57 physics teachers, who were completing a teacher upskilling programme and discusses their understanding of the role Inquiry Based Learning (IBL) in physics education. The teachers identified several benefits from using IBL in physics education, e.g. positive influence on students' attitudes, motivation and self-regulating skills, along with development of students' scientific and experimental skills. However, teachers identified that using IBL requires more time for planning and were less confident about the role of IBL in developing students' conceptual understanding.

1. Introduction

Physics teachers regularly contemplate on the influence of their teaching methods and strategies on student learning, motivations, and achievements. However, teachers generally report that they lack the ability or time to systematically examine their own professional practice. Over the past two decades, science teachers have been encouraged to adopt inquiry based science education (IBSE) in their classroom practices. In 2006, the European Commission tasked a group of experts to examine the alarming decline in young people's interest for key science studies and mathematics. The Rocard Report [1] published by this expert group concluded that "*"A reversal of school science-teaching pedagogy from mainly deductive to inquiry based methods provide the means to increase interest in science"* and recommended that IBSE should be widely adopted by schools. The report highlighted the important role that teachers play in the renewal of science education and the importance of providing opportunities for teachers to be part of a network in improving the quality of their teaching and supporting their motivation.

While psychologists and educational scientists generally agree that student involvement is critical to successful learning, there has been much debate on how students should be facilitated in the learning process [2]:

> "*Based on a century of education research, consensus has settled on a fundamental mechanism of teaching and learning, which suggests that knowledge is developed within a learner through constructive processes and that team-based guided scientific inquiry is an effective method for promoting deep learning of content knowledge as well as developing high-end cognitive abilities.*"

Inquiry based learning (IBL) promotes holistic student development by activating all three domains of learning: cognitive, psychomotor, and affective – in one inquiry process [3]. Categorizing inquiry activities into cognitive domains was first proposed by Duschl (2008) who suggested three integrated domains "*the epistemic domain, which is about how scientific knowledge is developed and evaluated; the conceptual domain, which concerns constructing an understanding of the concepts of science and reasoning scientifically; and the social domain, which is about communication and argumentation in scientific knowledge-building*" [4]. An IBL approach (cycle) provides a structured approach to scientific investigations: a problem or phenomenon is presented to students, a tentative explanation(s) for the features of the phenomenon is(are) formed, experiments that test the explanation are suggested, and based on the experimental results, the tentative explanation is pursued or discarded. This process is supported by a teacher, who takes the role of a mentor/facilitator, steering the students' learning through questions and prompts. Investigations are usually carried out by small groups of students, which fosters students' collaboration and communication skills, as well as developing their confidence in taking and sharing responsibility [5].

However, teachers need to be provided with opportunities to develop their pedagogical skills to facilitate students learning through IBL and to be confident in evaluating the influence of IBL on their students' learning [6,7]. A systematic review of 142 empirical articles on inquiry based science education (IBSE) in teacher education between 2000 and 2022 concluded that IBSE is used for pre-service teachers (PSTs) to learn science concepts and processes and how to teach science through inquiry; however, few studies highlight the transition between these [8]. This review categorised the studies in terms of six cognitive domains (epistemic, procedural, conceptual, social, pedagogical and affective) to examine differences between IBL (PSTs conduct inquiry as learners) and IBT (PSTs implement and/or reflect on inquiry in the teacher role) experiences [8]. The review concluded that to support PSTs in transitioning from IBL to IBT, teacher educators should use explicit modelling to provide and discuss examples of how to orchestrate IBSE in the classroom. The review recommended that PSTs should first conduct inquiry in the role as learners and then reflect on, critique, and modify IBT resources, preferably scaffolded by a teacher educator – so they acquire the skills and confidence needed to design and conduct inquiry based activities themselves [8].

Teacher engagement in continual professional learning and reflection on their own practices is widely considered as the most crucial factor for improving the quality of student learning [2]. However, there is much debate about how best to support teachers. In this study we adopt the notion of "inquiry as stance" which is reported to have positive impacts on educational outcomes and contexts [9]. Teachers are supported to engage in Practitioner Inquiry (PI) - a form of teacher professional learning defined as the systematic intentional study by teachers on their own practice Teachers (= practitioners) engage in systematic reflection and act for change by asking questions ("inquiries"), analysing the data, making evidence-informed changes in their practice, and sharing their learnings with others [10]. Nancy Dana [11] highlights the importance of teacher inquiry as a

> "*Continual cycle that all educators spiral through throughout their professional lifetimes—a professional positioning or stance, owned by the teacher, where questioning, systematically studying, and subsequently improving one's own practice becomes a necessary and natural part of a teacher's work*".

There are many variations on how a PI should be carried out, but they all tend to have several recurring characteristics: it is intentional, it is about improving classroom practice, and it is part of the teachers' role. A PI must be carried out systematically and involve the students in the PI process [11]. Conducting a PI can be done by teachers on their own, but several studies have reported that the impact on students' learning is greater if it is done collaboratively. Forming professional learning communities

(PLCs) of teachers, who meet regularly to share and learn from each other's practice through structured dialogue and engagement in continuous cycles of inquiry has been strongly recommended [11].

This research study examines teachers' engagement in IBL activities and reports on their reflections of these experiences. The research question of this study is: *What are physics teachers' understanding of the role of inquiry based learning in physics education?*

2. Methodology

The participants in this study were 57 (30 female, 27 male) in-service teachers completing a two-year, upskilling programme to gain qualification for teaching physics up to Leaving-Certificate level in Ireland, known as the Professional Diploma in Teaching Physics (PDITP) programme [12]. The PDITP programme is delivered as a blended learning programme over a two-year period where teachers complete 15 ECTS of physics pedagogy alongside 60 ECTS of physics lecture and laboratory modules. The goals of the PDITP programme are that teachers: (1) Acquire the theoretical and experimental knowledge of physics as well as pedagogical content knowledge that is necessary for effective physics teaching at second level; (2) Demonstrate an ability to connect physics content modules with the school physics curriculum; (3) Develop a high standard of practical competence in physics teaching as reflective practitioners.

During a week-long, online summer school at the end of year one, teachers are introduced to the concepts of (1) Inquiry Based learning (IBL), (2) Practitioner Inquiry (PI), and (3) Professional Learning Communities (PLCs). Teachers are facilitated to carry out a range of IBL activities, where the teacher educators (authors) model practice and describe how IBL can be used in classroom practice. Teachers are supported to interrogate each concept in terms of their purpose, how they are carried out and their relevance to their practice and learning. As part of this process, teachers complete reflective diaries on their experiences and learning of IBL, PI and PLCs, which are submitted within one month of completing the summer school.

In this study we report on an analysis of content of teachers' reflective diaries related to their understanding of IBL only and the analysis of their understanding of PI and PLCs will be addressed in a future study. In completing their IBL reflections, teachers were asked to consider how they can design IBL activities to support students' learning across the domains of knowledge, skills, attitudes, and values. Teachers' responses are examined through four questions.

- What do teachers want their students to learn through IBL?
- How do teachers design IBL activities to support students' learning?
- What are the roles of teachers and students in an IBL classroom?
- How can IBL be used effectively in my classroom practice?

To gain insights into teachers' understanding of IBL, an inductive approach was used to analyse their IBL reflections. Each teacher's responses were analysed separately, and a two-cycle approach was used to code the data, first by assigning small descriptions (codes) to relevant segments and then grouping these into categories [13]. Categories were identified by finding commonalities between codes, as shown in Tables 1-4. The identified categories provide insights into teachers' understanding of different aspects of IBL and became the main themes discussed in the findings section.

3. Findings and Discussion

This study presents findings from teacher's reflections of their understanding of Inquiry Based Learning (IBL). The codes and categories emerging from this analysis, along with excerpts from teachers' reflective diaries, are presented in Tables 1-4.

3.1 What do teachers want their students to learn through IBL?

Table 1 summarises teachers' reflections on what teachers want their students to learn through IBL. All teachers strongly identified the role of IBL in developing students' attitudes and motivation for learning physics. Teachers reflected on the importance of the role of IBL in developing students' physics and experimental skills e.g. raising questions, collecting and analysing data, making observations and drawing conclusions. They also identified students' development of 21st century skills, e.g. teamwork, critical thinking, communication and problem-solving. Most of the teachers highlighted the role of IBL in developing students' self-regulating factors, e.g. ownership of learning, resilience, curiosity and metacognition. Teachers reflected on the importance of students being "*actively engaged with the content of the lesson because it helps them develop a deeper understanding, become critical thinkers and improve their problem-solving skills*". Only a small number of teachers commented on the influence of IBL in supporting students to develop knowledge and conceptual understanding: "*IBL really looks to get students to delve deep to understand causal explanations for what they are observing*". A review of empirical research on scientific inquiry activities identified a lack of studies presenting evidence of the interrelation between scientific inquiry, scientific knowledge and the nature of science [14]. Other studies have reported on the positive benefits that IBSE can have on student learning but caution that this is only when specific criteria are met, e.g. the importance of linking the explanations of the outcomes of investigations to related concepts [15]. While the teachers in this study clearly identified knowledge and skills that could be developed by students, they did not make links between scientific inquiry, scientific knowledge and the nature of science.

Table 1. Teachers' reflections on what they want their students to learn through IBL.

Category	Code	Quote from teacher
Student development of physics/scientific skills and knowledge	• Questioning skills • Experimental skills • Hypothesis formation • Critical thinking • Investigating a problem • Searching for solutions • Making observations • Recording results • Data analysis • Extract understanding from experimentation • Writing causal explanations concisely in their own words and linking it back to their observations • Conceptual understanding and learning	• *IBL is a process that involves several important activities for students, including asking their own questions, investigating multiple sources of information, thinking critically to make sense of information they've found, communicating what has been learned and proposing new questions to be answered.* • *I want students to be actively engaged with the content of the lesson because it helps them develop a deeper understanding, become critical thinkers and improve their problem-solving skills.* • *IBL really looks to get students to delve deep to understand causal explanations for what they are observing.*
Student development of self-regulating factors	• Taking ownership of their own learning • Justifying claims and explanations • Assuming nothing prove everything • Challenge what they think they know • Improving metacognition • Thinking about the bigger picture • Identity and inclusion in physics/science. • Resilience • Curiosity • Motivation	• *IBL gives students ownership of their work and motivates them to guide their own inquiry.* • *Discussion with peers encourages self-directed learning, attitudes and values.* • *I want students who are currently excluded from mainstream education to see science in general and physics in particular as an option for them.* • *IBL can ignite a fire inside students for science through letting the students have autonomy of their work, finding their own answers to questions about the real world.*

3.2 How do teachers design IBL activities to support students' learning?

Table 2 presents teachers' considerations for designing IBL activities. All teachers reflected on the planning and design process and the importance of creating a positive learning environment in their classrooms. Teachers commented on a shift in focus in their planning towards designing lessons that guide and deepen student learning and facilitate students to reflect on and evaluate their own learning. Teachers also commented on the importance of creating a positive classroom learning environment that supports the diverse needs of learners and promotes equity and inclusion. It is evident from teachers' reflections that they have deepened their understanding of how to design and use IBL activities to support their student learning.

Similarly, Crawford and Capps (2018) propose that teachers must "*orchestrate a dance between school-wide curricular standards, expectations of parents and community, pressures from high stakes testing and teacher accountability, and perhaps, most importantly, students who may resist taking ownership of their learnin*g" [16]. These findings highlight the need for explicit modelling of IBL activities with teachers and the importance of providing and discussing examples of how to orchestrate IBSE in the classroom.

Table 2. Teacher's reflections on how they design IBL activities.

Category	Code	Quote from teacher
Planning and design	• Design probing/ prompting questions to guide students learning. • Determine students' prior knowledge. • Challenge misconceptions. • Design IBL activities at various levels – guided, structed, open • Get students thinking about how to investigate in science and what is an investigable question. • Allow students some freedom in how they investigate the question, yet also enough structure to provide some guidance.	• *Design lessons that support student learning, giving them an opportunity to evaluate, apply knowledge, make connections and understand the relevance of physics.* • *It is important to focus on the questioning, investigating and discussing hypotheses and results as it will allow students to reflect and evaluate their learning.* • *It is important to make sure that the IBL activities are well planned in advance, as without planning, there may not be clear pathways to outcomes for both students and teachers.* • *The inquiry cycle drives the planning stage to help create effective activities which will inform my teaching going forward.*
Classroom learning environment	• Students should be excited to know more about something they are interested in rather than scared of getting it wrong. • Use language that the students understand. • Develop a culture of questioning within the class among peers. • IBL must be engaging to all levels of learner. • Facilitate students working independently. • Presenting information to students to support differentiation in the classroom.	• *I want to work on ensuring my classroom is a place where students feel safe to fail and attempt questions or experiments.* • *if there were more than one way to carry out an experiment, then the teacher could provide students with suitable opportunity to reach the goal by more than one way.* • *The teacher must expose the students to some problem-solving strategies while also allowing students to learn how to work independently.* • *The use of causal explanation using storyboards is a great idea and would be particularly useful for SEN students. It would also provide an opportunity for students to elaborate on their initial observations and modify their explanations over time.*

3.3 What are the roles of teachers and students in an IBL classroom?

Table 3 illustrates teachers' perceptions of the different roles that teachers and students have in an IBL classroom. They identified that the teacher's role is to facilitate and not direct student learning and to provide different levels of support aligned with the goals of the activity. They emphasised the importance of asking and responding to students' questions and providing appropriate feedback to drive student learning. The teachers' responses suggest that they consider students' role in an IBL classroom is to construct their own learning, act autonomously and complete investigations to answer their inquiry questions. These findings align with early classifications of inquiry versus traditional teaching, e.g. Anderson (2002) who proposed that in traditional teaching the role of the teacher is as dispenser of knowledge while the role of the student is as passive receiver. In inquiry based approaches, teachers act as coaches/facilitators and students adopt the role of self-directed learner [17]. However, adjusting to these shifts in roles for teachers and students takes careful consideration and planning and highlights the need for explicit modelling of IBL activities with teachers to support their professional learning. Adopting an IBL approach places new demands on teachers' knowledge and skills, e.g. teachers need to identify and diagnose students' prior knowledge which differs for every student, and strong communication skills are essential in eliciting students' ideas [18].

Table 3. Teachers' reflections on the roles of teachers and students in an IBL classroom.

Category	Code	Quote from teacher
Teacher role in IBL classroom	• Change the focus to the students. • Facilitate the activity and scaffold where necessary. • Guide students' development to make their own understanding and enable students to take responsibility for their own learning. • Support IBL by asking questions, recording student questions, making sure groups are working well together. • Support students to conduct research and apply to everyday examples. • Create opportunities for students to contemplate socio-scientific issues. • Engage students and promote critical thinking and problem solving in lessons. • Ensure that there is an environment that is conducive to learning, where the students are comfortable sharing their ideas and debating their opinions. • Ensure that the language used is accessible to students to support their learning.	• *It is important to decide what level of support to provide to students both in terms of providing knowledge and with assistance during inquiry activities.* • *The role of the teacher in this model is to facilitate, not direct, student learning—to ask questions to prompt thinking, to provide feedback that can move thinking forward, and to connect students to appropriate resources while also giving them enough room to make choices on their own.* • *Student learning is facilitated through reasoning, asking questions, conducting experiments, weighing up evidence and considering alternative hypotheses using "science skills" to promote scientific thinking and inquiry in the classroom.*
Student role in IBL classroom	• Use their curiosity and formulate questions which they can investigate. • Experiment, investigate, test to try to gather data to answer questions. • Take responsibility for their learning and engage in the lesson. • Construct their own learning and act autonomously.	• *IBL can ignite a fire inside students for science through letting the students have autonomy of their work, finding their own answers to questions about the real world.*

3.4 How can IBL be used effectively in classroom practice?

Teachers recognised the importance of IBL in providing a scaffold to support student learning and teacher professional learning, shown in Table 4. They valued the use an inquiry cycle as a framework for planning and implementing activities. However, they identified the need to balance the use of IBL with other methodologies for teaching physics and expressed concern that IBL could only be used once students had developed mathematical skills relevant to physics. Recent studies report that physics teachers faced both intrinsic (lack of experience and lack of pedagogical content knowledge) and extrinsic challenges (students' lack of self-efficacy in using IBL, time restrictions, and limited resources) in using IBL to teach Physics [18]. While the teachers report that planning and using IBL is time consuming, they also strongly recognise its value, e.g. *"I definitely think IBL could be used to teach any aspect of physics; however, I don't think it would be optimal for every part of the course".* Teachers emphasised the need to maintain a balance between using teacher-directed instruction, IBL and other pedagogies *"to ensure all aspects of the curriculum are sufficiently covered*".

Table 4. Teacher's reflections on how IBL can be used effectively in classroom practice.

Category	Code	Quote from teacher
Use of IBL	• Provides a scaffolded approach that gives student autonomy to explore and make conclusions for themselves but also gave the teacher sufficient control to keep the student on task. • Adopt the inquiry cycle as a framework for planning and implementing activities. • Requires a lot for planning. • Require times for student thinking, and idea generation. • Supports teacher professional learning. • Provides a strong focus on student learning. • Enables students and teachers to engage in feedback and reflection.	• *The Inquiry Cycle provides guidance to both teachers and students on the series of steps to be taken during IBL and informs us of the purpose of each step. This framework is crucial if facilitating and/or participating in IBL is to become a habit of practice in the classroom.* • *IBL keeps me growing as a teacher, learning about different methodologies, how my students think and what has the most positive impact on their learning.* • *It is crucial that students are not left completely in the dark about how to proceed. I feel that a completely open-ended approach will not serve the lower-ability students well as they are more likely to opt out of the learning process completely.*
IBL for teaching physics	• Need a balance between IBL and other methodologies. • Promotes an inquiry mindset which is relevant in physics. • Students need to have prior knowledge. • Students need to have developed mathematical skills.	• *While IBL could potentially be used to teach most aspects of physics, a balance would need to be sustained between teacher-directed instruction, IBL and other pedagogies to ensure all aspects of the curriculum are sufficiently covered.* • *Science is about questioning things, and I think it's important to encourage an inquiry mindset as it makes them stronger and more rounded independent learners* • *Once students have a basic knowledge and have developed mathematical skills within physics, I believe IBL would be very effective for students making connections and deepening understanding.*

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Teachers expressed concerns about their student preparedness to engage in IBL in physics education, e.g. "*Students need a certain level of knowledge and skills in physics to progress in it*". This concern has also been identified in literature, e.g. "*Successful IBL requires students to have extensive content knowledge*" [19]. Teachers were cautious about the suitability of IBL approaches for all their learners, e.g. "*It is crucial that students are not left completely in the dark about how to proceed. I feel that a completely open-ended approach will not serve the lower-ability students well as they are more likely to opt out of the learning process completely*". Other studies have raised similar concerns about implementation of IBL, e.g. "*IBL is not effective with lower-achieving students*" [19]. Gholam identified four indicators relating to student readiness that hindered teachers use of IBL practices, i.e. "*Students don't like IBL"; "Students are not able to do inquiry"; "I worry about my students getting lost and frustrated in their learning in IBL lessons";* and *"IBL is too difficult for many students"* [20]. This study highlights the importance of providing appropriate teacher professional learning to model, reflect and share IBL practices to address teachers concerns and perceptions about using IBL practices.

4. Conclusions

This study discusses teachers' reflections on the role and importance of IBL in the physics classroom. The teachers identified several benefits from using IBL in physics education, e.g. positive influence on students' attitudes, motivation and self-regulating skills, along with development of student's scientific and experimental skills. Research highlights that IBL "*creates a culture of deep and transferable learning and strengthens student engagement and IBL allows for differentiation and empowers student voice and choice"* [20]. It is evident from teachers' reflections in this study that they have heightened awareness in listening to the student voice and focussing on developing student learning in the affective domain. Teachers were less confident about the role of IBL in developing student conceptual understanding. Research highlights the negative implications of teachers equating inquiry to using "hands-on" activities or that inquiry can be devoid of science content [16]. Rönnebeck et al. (2016) argue that it is not enough for students to carry out inquiry based activities they must also make connections with scientific concepts [14]. Furtak et al. (2012) report that IBSE has the greatest effect on learning when students are actively involved in developing and justifying explanations, presenting and discussing their explanations and the teacher actively supports learning by linking prior knowledge and concepts [15]. An important aspect of IBSE is that it enables students to understand how science is conducted and that science itself is in constant development [16].

Several factors have been identified that hinder teachers implementing IBL in their classroom practices, with time being the most prominent challenge identified by the teachers in this and other studies, e.g. "*The curriculum does not encourage IBL", "There is not enough time in the curriculum"* [19]. The teachers in this study recognised that adopting IBL in their classroom practices required a shift in their approaches to designing and facilitating student learning and identified the need to develop their skills in asking questions and providing formative feedback to support student learning. One study surmises that effective implementation of IBL requires *"a skilled teacher who is willing to teach, reteach, and model patterns of thinking, then students will be involved in a classroom culture that reinforces collaboration, problem solving, reflection, differentiation, motivation, and above all, transfer of knowledge and skills to new situations in and beyond the classroom*" [20]. The authors further caution that IBL needs to be valued by the education system, e.g. "*IBL needs to be highly valued at all academic levels starting from early stages and across all disciplines"* [20].

Research emphasises the importance of supporting teacher professional learning, with both pre-service and in-service teachers, so they can engage in IBL as a learner and be supported to reflect on these experiences [16]. Teacher engagement in professional learning is essential – "*with continuous professional development, collaboration with experienced inquiry based educators, and with careful planning and gradual implementation of IBL units, students can reap the benefits of inquiry in the classroom*" [18]. This study examines teachers understanding of the role and importance of IBL in physics education through engaging them as learners in IBL activities and supporting them to reflect and discuss their experiences. The findings from this study offer rich insights for teacher educators to design appropriate IBL experiences for teachers and recommends that more needs to be done to demonstrate how IBL can be used support student learning across the six cognitive domains [8]. Greater emphasis needs to be placed on how IBL can be used to support the development of student conceptual understanding in physics education.

References

[1] European Commission 2006 *Science Education Now: A new pedagogy for the future of Europe* https://www.eesc.europa.eu/en/documents/rocard-report-science-education-now-new-pedagogy-future-europe
[2] Bao L and Koenig K 2019 Physics education research for 21st century learning, *Disciplinary and Interdisciplinary Science Education Research* **1** https://doi.org/10.1186/s43031-019-0007-8
[3] McLoughlin E and Sokolowska D 2022 Inquiry Approaches in Physics Education in *Connecting Research in Physics Education with Teacher Education* (vol.3), ed J Guisasola and E McLoughlin (An ICPE Book) pp 209-221 https://zenodo.org/records/5792968
[4] Duschl R 2008 Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals *Review of Research in Education*, **32**(1) 268-291 https://doi.org/10.3102/0091732X07309371
[5] European Commission: Strengthening Teaching in Europe 2015 *New evidence from teachers compiled by Eurydice and CRELL*. http://ec.europa.eu/education/library/policy/teaching-profession-practices_en.pdf
[6] Sokolowska D 2020 Inquiry Based Learning to enhance teaching: Theory, tools and examples in *3DIPhE. Volume 1* ed Sokolowska D and Čepič M (University of Ljubljana, Faculty of Education) https://www.3diphe.si/e-book/
[7] McLoughlin E and Sokolowska D 2023 Physics Teacher Professional Learning in *The International Hand-book of Physics Education Research: Teaching Physics* ed MF Taşar and RPL Heron (AIP Publishing LLC) https://doi.org/10.1063/9780735425712_015
[8] Strat T T S, Henriksen E K and Jegstad K M 2023 Inquiry-based science education in science teacher education: a systematic review. *Studies in Science Education*, **60** pp 191–249 https://doi.org/10.1080/03057267.2023.2207148
[9] Cochran-Smith M and Lytle S L 1993 *Inside/outside: Teacher research and knowledge.* (Teachers College Press)
[10] Dana N F 2015 Understanding Inquiry as Stance: Illustration and Analysis of One Teacher Researcher's Work. *Learning Landscapes* **8** pp 161-171 https://www.learninglandscapes.ca/index.php/learnland/article/view/Understanding-Inquiry-a-Stance-Illustrationand-Analysis-of-One-Teacher-Researcher-s-Work/702
[11] Dana N F and Yendol-Hoppey D 2019 *The reflective educator's guide to classroom research: Learning to teach and teaching to learn through practitioner inquiry (*Corwin)
[12] McLoughlin E 2025 Remaking physics teacher professional learning: A national upskilling programme for physics teachers. *In Advancing Physics Education – Innovations from Early Learning to Higher Education,* ed Z Jeskova, Z and J Hanc, J (Springer)
[13] Miles M B, Huberman A M and Saldana J 2014 *Qualitative data analysis: A methods sourcebook 3rd ed.* (SAGE Publications)
[14] Rönnebeck S, Bernholt S and Ropohl M 2016 Searching for a common ground – A literature review of empirical research on scientific inquiry activities *Studies in Science Education* **52**(2) pp 161-197 https://doi.org/10.1080/03057267.2016.1206351
[15] Furtak E M Seidel T Iverson H & Briggs D C 2012 Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research* **82**(3) pp 300-329 https://doi.org/10.3102/0034654312457206
[16] Crawford B A and Capps D K 2018 Teacher cognition of engaging children in scientific practices. In *Cognition, metacognition, and culture in STEM education,* ed Y J Dori, Z R Mevarech, and D R Baker pp 9-32 (Springer)

[17] Anderson R D 2002 Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education* **13** (1) pp 1–12. https://doi.org/10.1023/A:1015171124982
[18] Roslan A, Phang F, Pusppanathan J and Nawi N 2023 Challenges in implementing inquiry -based learning in physics classroom. *AIP Conference Proceedings,* **2569** 050003 https://doi.org/10.1063/5.0117509
[19] Silm G, Tiitsaar K, Pedaste M, Zacharia Z C and Papaevripidou M 2017 Teachers' Readiness to Use Inquiry-Based Learning: An Investigation of Teachers' Sense of Efficacy and Attitudes toward Inquiry-Based Learning. *Science Education International, 28*, pp 315-325 https://files.eric.ed.gov/fulltext/EJ1161535.pdf
[20] Gholam A P 2019 Inquiry-Based Learning: Student Teachers' Challenges and Perceptions *Journal of Inquiry and Action in Education* **10** https://digitalcommons.buffalostate.edu/jiae/vol10/iss2/6