

Exploring the Investigative Science Learning Environment (ISLE) Approach in Physics Education: A Systematic Literature Review

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Article Info	Abstract
Article history: Received: May 28, 2025 Accepted: July 2, 2025 Published: July 20, 2025 Keywords: Investigative science Learning environment Physics learning Systematic literature review This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License © 2025 Berkala ilmiah Pendidikan Fisika	The Investigative Science Learning Environment (ISLE) approach is designed to represent the scientific thinking process. This study aims to examine the implementation characteristics, contributions, and challenges of the ISLE approach through the systematic literature review (SLR) method. Articles were collected through the Scopus and Google Scholar databases, using the following inclusion criteria for the years 2015–2025, and analyzed using the PRISMA method. A total of 17 articles that met the criteria were reviewed to identify implementation trends, methodological designs, physics topics, and learning impacts. The results show that ISLE has been applied flexibly at various levels of education and topics, with a dominance of mechanics and waves. This approach has been shown to improve conceptual understanding, critical thinking skills, and collaboration. Implementation challenges include instructor readiness, time constraints, group dynamics, and the need for process-based assessment. ISLE has the potential to be a transformative pedagogical approach in 21st-century physics learning, provided that it is supported by teacher training and contextual learning design. These findings underscore the importance of designing physics learning that supports holistic scientific inquiry, as well as the need to strengthen teacher capacity and develop evaluation systems that are in line with ISLE principles to encourage more meaningful learning transformation.
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INTRODUCTION

Physics is a branch of natural science that makes a major contribution to understanding natural phenomena. Physics learning in secondary schools and universities should be designed to encourage mastery of physics concepts ([Banda & Nzabahimana, 2021](#); [Novitasari et al., 2021](#)). Conceptual understanding is a crucial foundation for the development of students' metacognition, which encompasses high-level thinking skills that enable them to control their thinking and learning processes actively ([Mills, 2016](#)). This mastery is not only important for the development of science but also for equipping students to think critically and solve problems logically. The increasingly competitive global challenges require students to take on an active role, especially in problem-solving ([Etkina et al., 2019](#)).

However, the reality of physics learning in the classroom is often far from these expectations. Various studies have reported that physics is considered a difficult, abstract,

and irrelevant subject by most students ([Akhter et al., 2019](#); [Bøe et al., 2018](#); [Chala et al., 2020](#)). The main difficulties include poor mathematical skills, lack of problem understanding, and inability to plan solutions ([Reddy & Panacharoensawad, 2017](#); [Sartika & Humairah, 2018](#)). In addition, in practical activities, students can collect and present data but often struggle to interpret and analyze it more deeply. Therefore, it is necessary to develop skills to enhance the results of practical work ([Pols et al., 2021](#)).

In response to these challenges, various innovative learning approaches and models have been developed, such as problem-based learning (PBL), inquiry-based learning (IBL), and project-based learning (PjBL). PBL can improve conceptual understanding, motivation, and critical thinking skills in the field of physics ([Shishigu et al., 2017](#)). It is also stated that the PBL model can develop critical thinking skills and real problem-solving, but limits the in-depth understanding of physics theory, resulting in shallow analysis in reports and presentations ([Marcinauskas et al., 2024](#); [Samadun & Dwikoranto, 2022](#)). Meanwhile, the inquiry model encourages students to experiment and observe but still faces obstacles in analyzing data and drawing in-depth conclusions ([Wen et al., 2020](#)). In addition, the inquiry model has not fully encouraged independence, because students still rely on teacher guidance in designing experiments ([Blanchard et al., 2009](#)). Therefore, a learning approach is needed that can overcome these limitations while encouraging deeper conceptual understanding. One approach that has the potential to meet this need is the Investigative Science Learning Environment (ISLE). ISLE is designed to engage students directly in the scientific process, to develop deep conceptual understanding, and to reflect on the learning process ([Etkina et al., 2006](#)).

The ISLE approach is an effective solution for learning physics, as it engages students in a process that mirrors the process used by physicists to develop new knowledge ([Faletič & Planinšič, 2020](#)). ISLE encourages the development of hypothetico-deductive reasoning skills ([Buggé et al., 2023](#)) and scientific abilities through the revision of lab reports ([Buggé, 2023](#)). This approach has been successfully adapted for students with diverse mathematical backgrounds, showing significant improvements in conceptual understanding and practical physics concepts ([Wilson et al., 2020](#)). ISLE-based learning has shown positive results in exam performance, laboratory notebook quality, and student engagement ([Wilson et al., 2020](#)). Furthermore, ISLE is effective in teaching electrostatics using innovative experiments ([Faletič & Planinšič, 2020](#)). ISLE is explicitly designed to mimic the thinking and working processes of scientists by placing students in a cycle involving observation of phenomena, modeling, prediction, testing predictions through experiments, and reflection to revise their models or scientific beliefs ([Etkina et al., 2019](#)).

Although the ISLE approach has demonstrated effectiveness in enhancing students' conceptual understanding and scientific skills, its implementation in various educational contexts still faces several challenges. [Rutberg et al. \(2023\)](#) emphasized that this approach requires intensive training for instructors, especially those unfamiliar with student-centered learning, as its implementation is more complex than traditional teaching. Various studies have reported successes and obstacles in implementing ISLE; however, these findings are still scattered and have not been thoroughly analyzed. Until now, there has been no comprehensive synthesis that systematically examines the global pattern of ISLE implementation, the variety of pedagogical strategies used, and the factors that influence its success in various educational contexts. This gap is the basis for the urgency of this study, as it aims to gain a comprehensive understanding of the strengths and limitations of the ISLE approach in physics learning.

This study aims to conduct a systematic review of empirical studies that implement the ISLE approach in physics learning. Specifically, the objectives of this study include (1) identifying general characteristics of studies, including educational level, research design, physics topics studied, and geographic and institutional contexts; (2) analyzing the implementation of the ISLE approach in learning practices; (3) evaluating the contribution

of the ISLE approach to physics learning; and (4) identifying challenges reported in the implementation of ISLE. Thus, the results of this study are expected to provide a comprehensive mapping of the effectiveness, dynamics of implementation, and recommendations for the development of ISLE-based physics learning in various educational contexts.

METHODS

The research method used is a Systematic Literature Review (SLR). SLR is a method used to collect, evaluate, and analyze previous studies in a comprehensive and structured manner in a particular field ([Torres-Carrión et al., 2018](#)). The method used is PRISMA, with the aim of systematically and transparently identifying, selecting, evaluating, and synthesizing scientific articles relevant to the research topic ([Moher et al., 2015](#)). The PRISMA stage scheme can be shown in Figure 1.

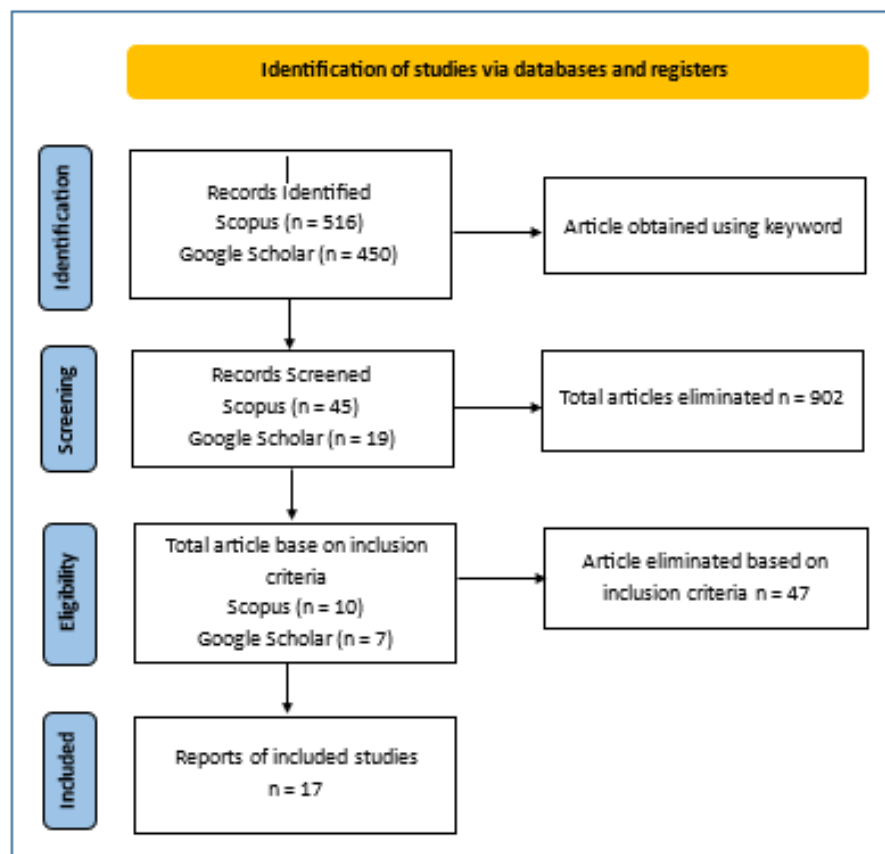


Figure 1 The PRISMA stage scheme

The first stage of identification involves searching for relevant scientific articles using Publish or Perish (PoP), with the databases used focusing on Scopus and Google Scholar. The keywords used in the search include "Investigative Science Learning Environment," "ISLE-Approach," "ISLE-Based Learning." Furthermore, at the screening stage, the collected articles are filtered based on titles and abstracts relevant to the research topic. Articles that do not match the keywords, are duplicated, or are not available in full-text form will be eliminated. Meanwhile, at the eligibility stage, articles that pass the screening will be reviewed in depth for their entire contents to assess the suitability of the research focus. These criteria include the substance of the topic, year of publication, accessibility, and form of scientific publication. Details of the criteria can be presented in Table 1.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion Criteria
Articles explicitly discussing the ISLE approach	Articles not discussing ISLE
Published between 2015-2025	Published outside the 2015-2025 period
Articles available in full text and open access	Articles not available in full-text and closed access
Publication not in the form of a seminar or conference	Publication in the form of seminars or conferences

The last stage of inclusion contains articles that meet all the criteria and are worthy of further analysis. The articles are then analyzed systematically to identify research trends, the context of ISLE implementation, the learning strategies used, and the space for further development of the ISLE approach in science education.

RESULTS AND DISCUSSION

What are the general characteristics of studies that apply the ISLE approach to physics learning?

The distribution of ISLE article publications from 2015-2025 is shown in Figure 2.

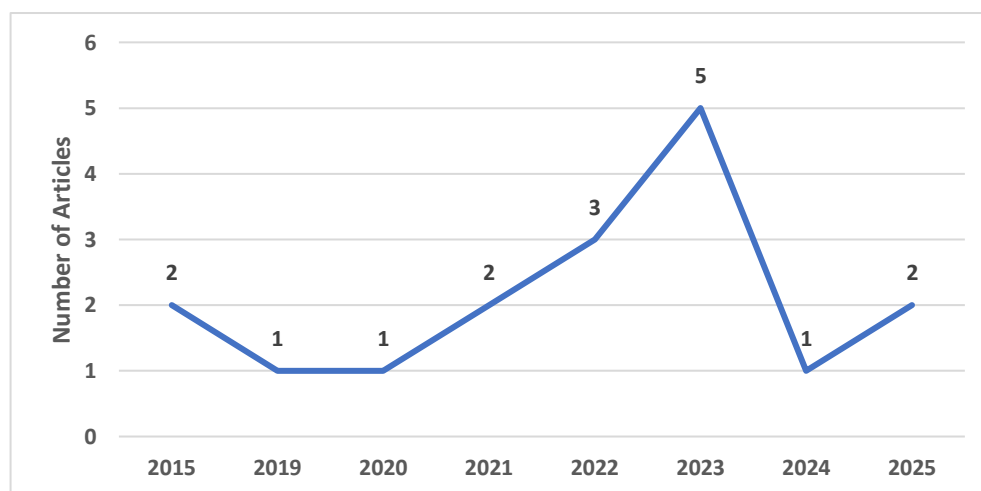


Figure 2 Distribution of ISLE article publications 2015-2025

Based on the 17 articles analyzed, the distribution of publication years is shown in Figure 2, indicating that most research on the Investigative Science Learning Environment (ISLE) Approach was published between 2015 and 2025. In 2015, two articles (11.76%) were published, followed by one article each (5.88%) in 2019 and 2020, indicating a continued interest. The year 2021 experienced a slight increase with two articles (11.76%), marking the beginning of the widespread implementation of ISLE in higher education and secondary school classrooms and laboratories. A more significant trend emerged in 2022, with three articles (17.65%) beginning to emphasize the integration of ISLE with modern learning media and assessments of student scientific reasoning.

The peak occurred in 2023, with five articles (29.41%), making that year the highest point of scientific productivity related to ISLE implementation. The increase in article publications from 2020 to 2023 can be correlated with the transition to learning after the pandemic. Although the article does not mention this, the ISLE approach is integrated with technology that is able to adapt to the needs of the times. This is supported by research conducted by [Brookes et al. \(2023\)](#), which implemented video-based experimental investigations using the ISLE approach, suitable for online distance learning. In 2024, there

was only 1 article (5.88%), while 2025 showed indications of sustainability through 2 articles (11.76%), indicating that ISLE remains a relevant and actively developed approach.

The increase in interest in the ISLE approach over time is also reflected in the various research methods used to evaluate its effectiveness and identify challenges to its implementation. The distribution of research methods used in the ISLE approach is illustrated in Figure 3.

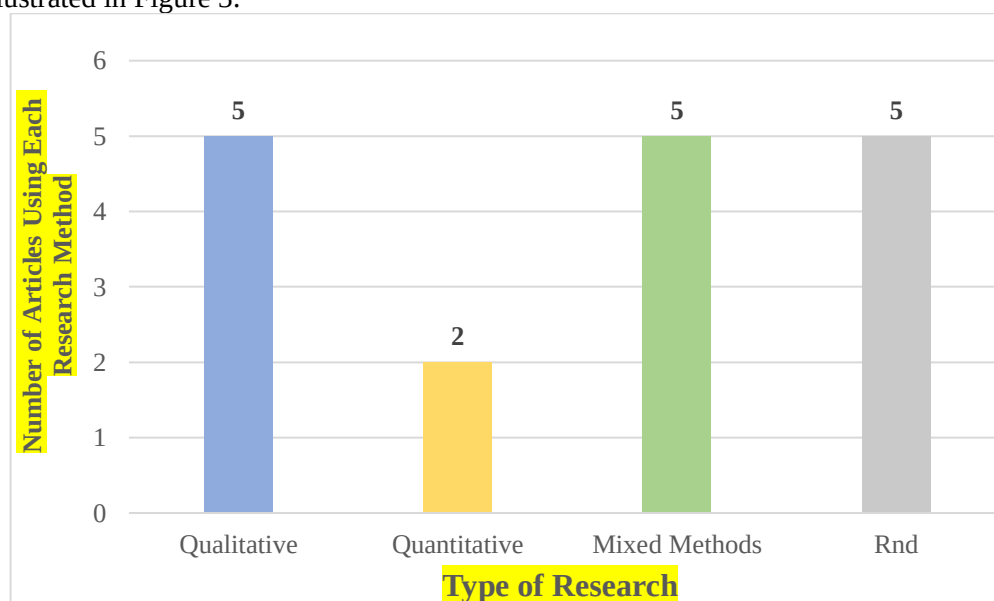


Figure 3 Distribution of research methods used in ISLE-based physics education

In terms of research design, the distribution of methodological studies offers valuable insights into the diverse approaches used in ISLE approach research in physics learning. The 17 articles reviewed showed that mixed methods, research and development (R&D), and qualitative methods were used proportionally, each in 5 articles (29.41%). While the pure quantitative approach was only used in 2 articles (11.76%). The dominance of these three main methods indicates that ISLE research does not only focus on learning outcomes but further explores the complexity of the learning process, both in terms of device design, scientific thinking dynamics, and social interactions involved in it.

The mixed methods method was chosen to provide a comprehensive view of the implementation of the ISLE approach by capturing quantitative data from tests (pre-post), scientific ability rubrics, Reformed Teaching Observation Protocol (RTOP), questionnaires, and qualitative data from interviews, observations, video analysis, and analysis of practicum report results ([Brookes et al., 2020](#); [Buggé, 2023](#); [Buggé et al., 2023](#); [Yanti et al., 2025](#)). This approach fits the cyclical, reflective, and exploratory character of ISLE - where learning success is not only seen from the final results but also from how students build, test ideas, and revise reports.

Meanwhile, the study R&D shows that ISLE is not just a conceptual approach but also a basis for innovation of contextual teaching tools, such as ISLE-STEM-based the student worksheet ([Nufus et al., 2022](#)), ISLE the student worksheet assisted by PhET ([Rafika et al., 2023](#)), ISLE-based the student worksheet to improve creative thinking ([Wahyuni et al., 2021](#)), resonance teaching aids to visualize the concept of stationary waves ([Mirza et al., 2022](#)), and IoT media for environmental issues ([Hamid et al., 2022](#)). This R&D research positions ISLE as the foundation of authentic and technology-integrated instructional design.

The qualitative methods in five articles explore the cognitive and social aspects of ISLE learning, including students' thinking patterns in building models, the role of small group dynamics in the effectiveness of scientific work, and obstacles in developing data-based

explanations. The findings from this approach highlight that the success of ISLE implementation is highly dependent on the quality of interactions, the role of the facilitator, and the collaborative structure established in the classroom ([Brookes et al., 2021](#)). The five articles provide an overview of the understanding of the effectiveness of the ISLE approach in various dimensions: cognitive, social, visual, and contextual. They show that ISLE is not only effective as an inquiry-based learning model but also as a cross-disciplinary approach that can improve the understanding of complex and deep physics concepts. On the other hand, the quantitative approach is only employed in two articles, focusing on quasi-experimental design research that compares student understanding through video-based experimental investigations, physical experiments, and their combinations ([Brookes et al., 2023](#)). While other studies with a one-group pretest-posttest design test and analyze the effect of ISLE-STEM-based physics learning on students' understanding of physics concepts. The variation of this research approach is also closely related to the characteristics of the research subjects, which include the students' backgrounds and their learning context. The following can be seen in Figure 4 for the distribution of research subjects used in the ISLE approach.

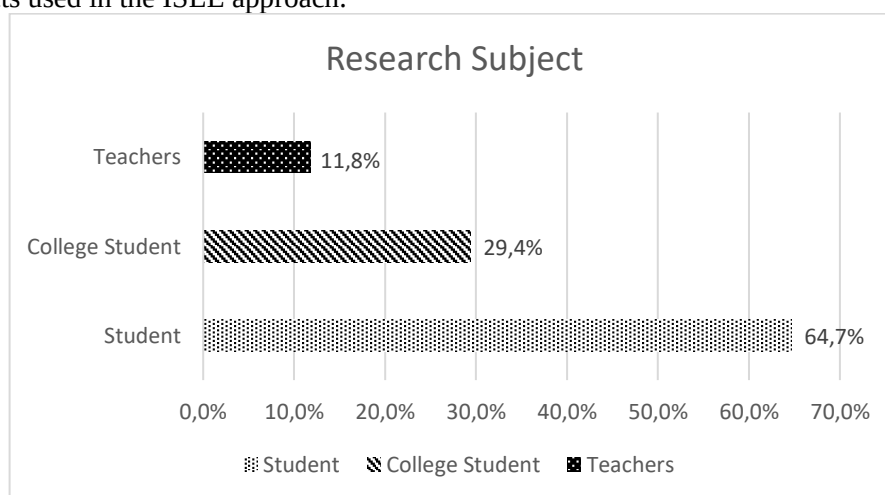


Figure 4. Distribution of research subjects

Based on the 17 articles analyzed, the distribution of research subjects was found to show diversity in terms of educational level. The majority of studies, around 64.7% (11 of 17 articles), involved high school students as research subjects. Student involvement is focused on understanding physics concepts through the ISLE approach, which incorporates observational experiment activities, formulating hypotheses, making predictions, testing those predictions, reflecting on the results, and applying the experiments. In implementing the ISLE approach, it has been proven to be able to improve critical and creative thinking skills, increase learning activities, and foster scientific awareness in dealing with real phenomena ([Mirza et al., 2022](#); [Sari et al., 2024](#); [Wahyuni et al., 2021](#)). Furthermore, 29.4% (5 of 17 articles) used physics education students and general students as research subjects. Student subjects are focused on developing advanced scientific skills such as hypothesis-deductive reasoning ([Buggé et al., 2023](#)), the ability to design experiments, and analysis of the role of group work in building social dynamics that provide meaning through discussion ([Brookes et al., 2021](#)). This shows that the ISLE approach is very relevant to be applied at the tertiary level to form a scientific mindset and reflective attitude towards phenomena in physics.

Finally, around 11.8% (2 of 17 articles) focused on novice teachers and instructors as research subjects. This study emphasizes the importance of ongoing training and support for teachers to be able to implement the ISLE approach effectively. According to research conducted by [Rutberg et al. \(2023\)](#) involving four postgraduate teaching assistants as

novice instructors in conducting teaching practices, research conducted by [Nufus et al. \(2022\)](#) involved pre-service teachers and physics teachers to develop professionalism in terms of pedagogy and scientific skills.

The diversity of research subjects illustrates that the ISLE approach is flexible and cross-level, with the potential to be applied in physics learning in the context of formal, informal learning, and professional training. In addition, it is able to strengthen ISLE's position as an approach that can integrate cognition, collaboration, and reflection between physics phenomena and real practice in the classroom. Finally, the ISLE approach is a transformational framework for students and teachers to be actively involved and think like physics scientists.

The physics material used in the articles studied can be seen in Table 2 as follows.

Table 2 Physics materials in ISLE research

Physics Topics	f	%
Motion & Kinematics	6	35%
Newton's Laws & Forces	5	29%
Vibration & Waves	4	24%
Direct Current (DC) Electricity	2	12%
Optics & Geometric Optics	2	12%
Electromagnetism	2	12%
Modern/ Quantum Physics	2	12%
Energy & Particle Systems	2	12%
Global Warming	2	12%

Note: Some articles address more than one topic, so the total frequency exceeds 17.

From the Table 2, the physics material from the 17 articles that is most frequently discussed is basic mechanics, especially the topics of motion and kinematics, with a percentage of 35%, and Newton's laws and forces, with a percentage of 29%. This dominance reflects that the topics chosen are compatible with the characteristics of ISLE, which focuses on observing concrete phenomena, developing models, and testing predictions. In addition, the topic of vibrations and waves, which discusses superposition and stationary waves, accounts for 24% of the content, indicating that this topic is considered appropriate for exploration that demands data-based visualization and modeling. Some topics that are rarely addressed in the ISLE approach include modern physics, particularly in the context of learning abstract concepts through analogy and representation. Likewise, the topics of direct current electricity and geometric optics only appear at 12%, even though both have the potential to conduct direct experiments. Finally, the ISLE approach integrates real-world issues related to global warming, indicating that it not only focuses on understanding concepts but also fosters contextual scientific awareness ([Hamid et al., 2022](#); [Sari et al., 2024](#)). Overall, the implementation of ISLE in physics topics focuses on concrete materials and direct experiments, so it is necessary to enrich the coverage of other materials.

Thus, based on the dimensions of the year of publication, research methods, subjects, and topics of physics materials, it can be concluded that the ISLE approach has become a focus of research that is developing progressively and multidimensionally. The general characteristics identified indicate that ISLE is not only flexible and adaptive to various contexts but also has the potential as a pedagogical solution to the challenges of physics learning in the future.

How is the implementation of the ISLE approach in physics learning reported in the reviewed studies?

The implementation of the Investigative Science Learning Environment approach in physics learning consistently states that it can improve students' understanding of physics concepts, scientific thinking skills, and motivation and self-confidence. ISLE is designed

to position students as practicing scientists, with the stages carried out, namely observing phenomena, developing explanations, making predictions, testing experiments, and applying experiments that emphasize students revising and reflecting at each stage ([Etkina et al., 2019](#)). Learning activities are conducted in groups to foster independent exploration of ideas and solutions among students, rather than simply receiving knowledge from teachers ([Etkina et al., 2020](#)). The learning cycle of the approach is illustrated in Figure 5.

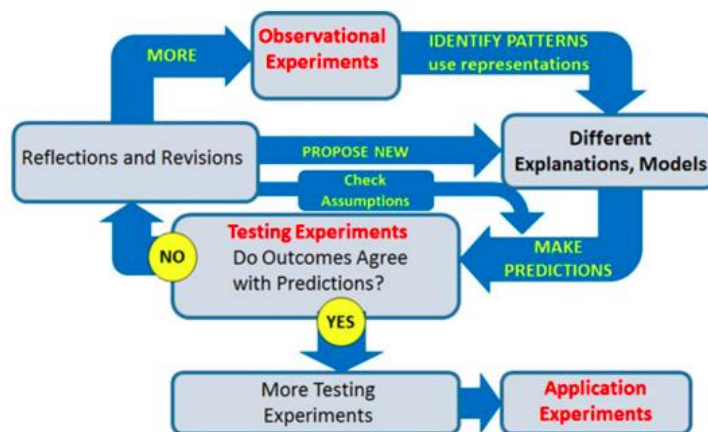


Figure 5 ISLE learning cycle ([Etkina et al., 2019](#))

Physics learning based on ISLE begins with activities to observe real physics phenomena. This initial stage aims to build students' cognitive engagement, activate prerequisite knowledge, and arouse curiosity and scientific questions. Through these observations, students are encouraged to identify emerging patterns and formulate questions that can be used as a basis for further investigation ([Planinsic & Etkina, 2019](#)). After the observation phase, students work in small groups to develop initial explanations or hypotheses regarding the observed phenomena ([Rutberg et al., 2023](#)). In this process, students link previous experiences and knowledge to formulate initial scientific conjectures. The role of the teacher at this stage is that of a facilitator, who directs and stimulates discussion, rather than providing answers. Thus, interactions within the group take place in a dialogic and exploratory manner.

The next stage involves designing and implementing experiments to test the hypotheses or explanations that have been formulated. Students use simple tools, media, or available props to take measurements, record data, and analyze experimental results. This process emphasizes the development of basic scientific skills, including systematic observation, quantitative data processing, and drawing conclusions based on empirical evidence. Trial experiments can utilize worksheets provided by [Etkina et al. \(2019\)](#), which are either real-based or online. This is in line with research conducted by [Brookes et al. \(2023\)](#) using videos in trial activities to facilitate independent and online learning. After the experiment is carried out, students compare the test results with previously made predictions. If there is a discrepancy between the experimental results and the initial predictions, students are asked to revise the model or explanation that has been prepared and then retest it through further experiments ([Etkina et al., 2019](#)).

This process is cyclical and can be repeated until students gain a conceptual understanding that is consistent with applicable physics principles. Throughout the learning process, students actively document the results of observations, experiments, and group discussions using media such as worksheets, mini whiteboards, or presentation cardboard ([Brookes et al., 2021](#); [Mirza et al., 2022](#); [Yanti et al., 2025](#)). The results of the group's work are then presented to the class to open up a wider discussion space and facilitate an exchange of ideas among groups. The teacher plays a role in directing the discussion

towards conceptual reflection, emphasizing how scientific knowledge is constructed, why one explanation is more appropriate than another, and how the concepts learned can be applied in real-life contexts.

What are the potential contributions of the ISLE approach to physics learning according to the findings of the reviewed studies?

The Investigative Science Learning Environment approach opens up various strategic opportunities in physics learning that are oriented towards strengthening 21st-century skills. One significant opportunity is to increase students' involvement and active participation in the learning process through the scientific cycle, which involves direct observation, identifying patterns, formulating hypotheses, and testing predictions through application experiments linked to real phenomena. This finding is in line with research stating that students are able to build a deep understanding of complex and abstract physics concepts, such as the characteristics of LEDs and fluorescence ([Planinšič & Etkina, 2015](#)). Students also experienced an increase in making hypotheses in quantum superposition material ([Faletič, 2025](#)), as well as an improvement in learning outcomes after the implementation of web-based R-STEM (Remote STEM Laboratory) in ISLE-based magnetic induction learning on magnetic induction ([Yanti et al., 2025](#)).

This approach explicitly encourages students to think and act like scientists through a learning process based on inquiry, reflection, and knowledge construction ([Planinsic & Etkina, 2019](#); [Planinšič & Etkina, 2015](#)). In addition, this approach makes a real contribution to strengthening scientific skills and critical thinking, as shown in various studies where students are trained to analyze experimental data, draw conclusions, and reflect on their understanding. Finally, ISLE-based physics learning also strengthens collaborative skills through meaningful group interactions, with findings that groups with equal distribution of social positions show more effective learning outcomes ([Brookes et al., 2021](#)). Overall, the ISLE approach shows high flexibility because it can be applied at various levels of education, physics topics, and learning media, including direct experiments, videos, simulations, and Internet of Things (IoT)-based technologies ([Hamid et al., 2022](#); [Mirza et al., 2022](#); [Nufus et al., 2022](#); [Rafika et al., 2023](#)). Thus, ISLE acts as a pedagogical approach that is able to answer the challenges of 21st-century physics learning comprehensively.

What are the challenges reported in implementing the ISLE approach in physics learning?

Although several articles on the ISLE approach mention the advantages of its implementation, there are challenges in implementing it in terms of technique, pedagogy, and social and structural factors. The most dominant challenge is the readiness of instructors to learn and apply the ISLE approach, especially for teachers who are accustomed to implementing traditional learning models, who will have difficulty understanding the cycle in ISLE and building constructive feedback in the learning ([Buggé, 2023](#); [Buggé et al., 2023](#); [Nufus et al., 2022](#); [Rutberg et al., 2023](#)). This is evident; teachers or instructors reject whiteboard discussions with student activities, predicting and revising models as less efficient activities ([Rutberg et al., 2023](#)). A comparison of laboratory report scores between the two groups at the beginning of the second semester of ISLE implementation shows that instructor effectiveness plays an important role in developing students' scientific skills. These findings indicate that instructors who have experience and a deep understanding of the ISLE approach are better able to facilitate students' scientific processes optimally.

Next, the challenges from the students' perspective, where students are not used to thinking scientifically, which results in frustration if they do not produce the correct answer at the beginning of the ISLE cycle ([Brookes et al., 2020](#); [Buggé et al., 2023](#); [Čančula et al.,](#)

2015), the challenges in group dynamics in social relationships can result in a lack of learning effectiveness, which is characterized by the dominance of only one group member in collaboration, so it is necessary to build a sense of responsibility for each group member by working equally (Buggé, 2023). Finally, there are limitations in time management because the ISLE approach involves several cycles, including observation experiments, testing and application experiments, and revisions, which can take a considerable amount of time (Rutberg et al., 2023).

Furthermore, students' ability to formulate testable hypotheses and make logical predictions is often a major obstacle. Even with the help of visual analogies, many students still misunderstand complex concepts such as superposition or force interaction (Faletič, 2025). Finally, the success of ISLE also requires changes in the assessment system. Since ISLE emphasizes the scientific thinking process, teachers need to implement process-based assessments, such as scientific abilities rubrics and experimental reports, rather than simply relying on final answers (Brookes et al., 2020; Buggé, 2023). Therefore, effective ISLE implementation requires ongoing teacher training, infrastructure readiness, and careful lesson planning.

CONCLUSION

Based on the results of a systematic review of 17 relevant scientific articles, the following conclusions were obtained:

1. The general characteristics of studies implementing ISLE show diversity in terms of educational level (high school, college students, and teachers), research methods (mixed methods, R&D, qualitative, and quantitative), and physics topics studied (dominant in mechanics and waves). This indicates that the ISLE approach is flexible, adaptive, and has the potential to be applied in various educational contexts and physics materials that are concrete and exploratory.
2. The implementation of the ISLE approach in physics learning emphasizes the active involvement of students in the scientific thinking process through a learning cycle that includes observation of phenomena, formulation of hypotheses, prediction of outcomes, testing of experiments, application of experiments, and self-assessment. This approach encourages students to build conceptual understanding reflectively and train collaborative skills and decision-making based on empirical evidence.
3. The contribution of the ISLE approach to physics learning appears significant in improving conceptual understanding, developing critical and scientific thinking skills, and increasing student motivation and involvement. ISLE also shows its effectiveness in various learning media, including direct experiments, videos, simulations, and technology integration (IoT), making it a pedagogical approach that is relevant to the demands of 21st-century learning.
4. Challenges in implementing the ISLE approach include instructor readiness in understanding the ISLE learning cycle, limited implementation time, uneven group work dynamics, and the need for an assessment system that evaluates the entire scientific thinking process. Therefore, the implementation of ISLE requires ongoing teacher training, contextual learning design, and the development of process-based evaluations.

This study has limitations, namely, not exploring in depth the integration of the assessment system in the ISLE approach and its relationship to other variables such as critical thinking, problem-solving, collaboration, and others. Therefore, further studies are recommended to expand the scope of the analysis and gain a more comprehensive understanding of the effectiveness and implementation of ISLE in the context of authentic and transformative physics learning.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTION

The conceptualization and design of this study were carried out by ID, SK, and S. The development of the methodology and ID and S. carried out systematic review design The data analysis and interpretation of findings were carried out by ID and H. Resource provision, including literature collection and reference management, was handled by ID. ID wrote the initial draft of the manuscript with substantial contributions from SK. All authors were actively involved in reviewing the manuscript's content and have approved the final version submitted for publication.

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