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Inquiry Project Laboratory: The Collaborative Problem Solving and Critical Thinking on Laboratory

Hendri Saputra[1*], Juli Firmansyah[2], Ahmad Ihsan[3]

[1] Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Samudra, Kota Langsa, Aceh, Indonesia.
[2] Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Serambi Mekkah, Kota Aceh, Aceh, Indonesia
[3] Program Studi Informatika, Fakultas Teknik, Universitas Samudra, Kota Langsa Aceh, Indonesia.

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Corresponding Author:
Hendri Saputra
hendri_physics@unsam.ac.id

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Abstract: Collaborative problem-solving is one of the important soft skills in project-based laboratory activities to equip students with critical thinking skills. A study that systematically reviews literature relevant to the successful implementation of the Inquiry Project Laboratory (IPro-Lab) which is carried out in 5 main stages. A systematic review of relevant qualitative research findings using an integrative approach to gain a deeper understanding (meta-synthesis) through summarization techniques (meta-aggregation). The review stage begins with extracting relevant studies, identifying important findings, categorizing findings, and developing a conceptual framework. The studies and reviews are focused on the success of the IPro-Lab practicum in equipping critical thinking, creative, collaboration and communication skills. In addition, it was also found that the successful track record of the IPro-Lab practicum has been tested and valid to support the formation of scientific thinking, solving complex problems and the needs of the 21st century. IPro-Lab also provides opportunities for the self-development of teachers so that they are more innovative, creative and structured.

Keywords: Collaborative; Critical Thinking; Inquiry-Project; Laboratory; Problem Solving

Introduction

Highlighting the needs of the industry and the challenges of the world of work in the era of society 5.0, it is very necessary to equip the younger generation, in this case, college-level students (PT), with various soft skills by the recommendations of the world economic forum (Narvaez Rojas et al., 2021). Soft skills that are currently popular in the industrial world are detailed as Communication skills (CS) 95%, skills to work in teams (WT) 94%, Argumentation Skills (AT) 91%, Cognitive Flexibility (CF) 90%, Critical Thinking (CT)) 89%, Time management (TM) 83%, Creativity (C) 80%, and Emotional intelligence (EI) 72%. (Dingot, n.d.). The modern world shows the effectiveness of using high technology and its development processes dynamically. Therefore, the resources that are most in demand are those who have specialists and can make changes quickly and flexibly.

Professional practice in the modern world and industry is also associated with the need to continuously improve themselves, including their adaptation to ever-changing conditions to maintain competitiveness (Farida & Setiawan, 2022; Javaid et al., 2022). Today, specialists with a flexible, systematic, and critical mind, and most importantly able to apply their skills creatively, to be able to solve problems in several ways are urgently needed (Ritter & Mostert, 2017). Higher education is currently faced with the responsibility to shape students by not only developing professional competencies (hard skills) but also cultivating soft skills that enable them to be able to quickly respond to changes in the professional environment and quickly adapt to them (Singh et al., 2021). This includes communication skills, skills in working collaboratively in teams, as well as the capacity to manage information effectively (choose what is most relevant and organize it

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well) and make decisions independently (Darling-Hammond et al., 2020).

Preparing professional resources for such challenges, one which can be achieved by providing them during the study period of Higher Education. The debriefing in question can be in the form of preparing learning models and practicums whose learning stages facilitate students' thinking skills (Coman et al., 2020; Stehle & Peters-Burton, 2019). Different versions of the innovation model have been executed to enhance the capacity of students as future educators in formulating efficient educational methods for use in school settings (Panadero, 2017). Instructional approaches concentrate on elevating knowledge dimensions as well as cognitive aptitude and scholarly engagement. Consequently, the interaction between instructors and learners becomes exceedingly crucial during the educational journey (Serdyukov, 2017). The professional rapport established between students and educators is molded by encounters and thus demonstrates noteworthy professional development, empowerment, and amplified self-assurance.

Universities that prepare graduate teacher candidates or Education Personnel Education Institutions (LPTK) have a big responsibility to equip their graduates with complete mastery of concepts, adequate skills, and of course attitudes that grow during learning (Wijayanti et al., 2020). Particularly in preparing prospective Physics teacher graduates, many learning models and practicums have been introduced. Experience that has been owned can be applied through a learning process that facilitates the ability to think and work independently in completing tasks. One way to increase scientific achievement is to adopt an enabling assignment approach, and one way is through project-focused learning and practicum (Keiler, 2018). These assignments can facilitate students to be independent and work creatively and critically in solving problems (Albay, 2019; M. Fan & Cai, 2022).

Implementing project-based learning or Lab, does not just refer to project assignments to students. A quality project has the ability to stimulate and build student understanding according to the discipline being studied (Coman et al., 2020; Darling-Hammond et al., 2020). Hence, it is important to regulate the projects assigned to students by emphasizing an approach centered around inquiry-based learning and Lab (Pedaste et al., 2015; Shariff et al., 2013).

Utilizing inquiry-based learning and Labs is especially suitable when used in the realm of science because it effectively cultivates students' scientific talents (Saputra et al., 2019). Therefore, the integration of project-based learning and practicum with an inquiry approach can be realized effectively through the application of the Inquiry-Project Lab (IPro-Lab) (Firmansyah et al., 2022a; Zhang & Ma, 2023).

The IPro-Lab serves as a carefully designed instructional framework to optimize the improvement of scientific thinking and attitudes as well as practical skills. This approach incorporates the principles of Project-Based Practicum and Inquiry by ensuring a scientific component to the practicum process. This blend of instructional methodologies aims to enhance the overall educational experience and outcomes, which include acquisition of knowledge, attitudes, and refinement of scientific skills.

In education, as an effort to improve the quality of graduates, it is known as the achievement of hard skills and soft skills. Hard skills are called professional competencies that can be presented, measured and evaluated which are essential for carrying out certain professional activities. Meanwhile, soft skills refer to a series of studies that consider situations where students are faced with making independent decisions (Ten Cate & Schumacher, 2022). Soft competence is universal knowledge that can be applied in various professions. Possessing these types of skills enables students to deal with rapid change, ambiguous situations, and uncertainty in today's world. Some examples of soft skills are competencies related to the ability to work in teams, innovate, have an entrepreneurial spirit, overcome challenges in tense situations, have insight into the future, and make accurate predictions (Lamri & Lubart, 2023).

Furthermore, flexible skills are a series of soft skills that play a role in achieving success while carrying out professional activities, guaranteeing high productivity, and at the same time not being tied to a specific field of study (Ra et al., 2019). Researchers commonly delineate two approaches for fostering flexible skills. Firstly, through the learning process by incorporating specific courses and collaborative practicum involvement in laboratory activities. Secondly, by leveraging the potential of the subjects studied in connection with extracurricular educational endeavors (De Prada Creo et al., 2020).

Many laboratory activities have been introduced to facilitate student soft skills, referring to the Inquiry-Based Practicum and projects (Firmansyah et al., 2022b; Guo et al., 2020; Hastuti et al., 2018). IPro-Lab serves as an educational framework aimed at fostering systematic thinking, particularly in problem-solving within the realm of science or physics. Research findings show that IPro-Lab learning has a positive effect on students' ability in project-based work, although there are some minor notes of adjustment in some learning stages (Vedi et al., 2022). Consequently, if researchers plan to integrate the IPro-Lab into teaching, they must be prepared to offer customized assistance to their students. The main objective of this research effort at the IPro-Lab is to describe the distinctive features of the IPro-Lab and to ascertain the benefits associated with its application, particularly for students and educators operating in the natural sciences domain. Figure 1 shows the soft skill development relationship framework in IPro-Lab.

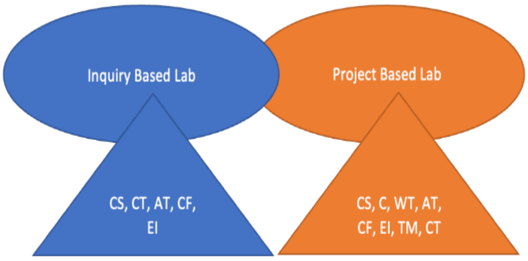

Figure 1. Soft skill relationship in the Inquiry and Project practicum stages

The Inquiry Project or IPro-Lab practicum stages are designed from the two practicum stages. At each of these stages, it is ensured that there are stages that have been tested to be able to equip the required soft skills, develop attitudes and of course strengthen concepts.

Method

The research employs a systematic review methodology, a rigorous approach aimed at identifying, assessing, and comprehending all pertinent research findings associated with specific subject matters (Mengist et al., 2020). A systematic review of relevant qualitative research findings using an integrative approach to gain deeper understanding (meta-synthesis) through summarization techniques (meta-aggregation) (Hannes et al., 2018). The summary is carried out on scientific articles that discuss the topic of Inquiry lab and lab projects in Physics learning, which will later produce a conceptual framework.

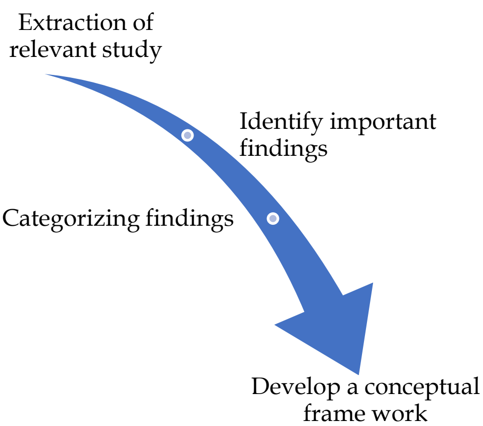

Figure 1. The visual representation of the synthesis process

The research was carried out in 5 main stages, starting with exploring studies and theories relevant to inquiry-based practicum activities and projects. Relevant studies and theories are then identified as important findings that support and are closest to the criteria determined by the categories that have been prepared.

Result and Discussion

IPro-Lab is a laboratory approach designed with the aim of providing authentic experiences to students in understanding investigative methods in the context of science education. As a result, students become skilled in carrying out investigations and applying logical thinking to scientific concepts (Hamed & Aljanazrah, 2020; Khishfe, 2022). An analysis of the articles related to IPro-Lab yields some compelling insights, which can be clearly organized around several core dimensions: improvement of students' cognitive skills, creation of effective teaching designs for educators, and evaluation processes related to student engagement and assignment implementation (Smiderle et al., 2020).

Some important findings in inquiry-based practicums are that students get the opportunity to learn with direct experience in the process (Rahayu & Sari, 2023) of discovering concepts, clarifying, confirming and verifying relationships of magnitudes and concepts like young scientists in solving problems collaboratively (Firmansyah et al., 2022b, 2022a; Tong et al., 2021). The inquiry practicum stages have also proven successful in facilitating students' thinking skills (Saputra et al., 2019).

Since the pre-lab stage, students practice argumentation skills and critical thinking to be able to find relationships between quantities to be able to formulate problems (Van Peppen et al., 2021). Furthermore, in the investigation stage, students are trained in teamwork, time management and hone their creativity in problem solving (Le et al., 2018). In the final stage, students are skilled in communication skills to report the findings of the investigation (Reith-Hall & Montgomery, 2022). Unfortunately, the findings and conclusions they produce have not been applied to a real product of student work.

Another important finding in project-based practicum is that the designed stages are a continuation of the findings and the inquiry investigation steps (J.-Y. Fan & Ye, 2022). Students develop a hypothesis, how the formulation of the findings of the concept, if applied in a product of student work (Oh, 2010). In the project-based practicum stage, it begins with an introduction to the project and presentation of guiding questions to students so they can understand and discover the physics concepts involved in a project (Firmansyah et al., 2022b). Thus, students are trained in argumentation, critical thinking and flexible scientific understanding (Sellars et al., 2018). Furthermore, students are trained in time management, working in collaborative teams, creative in strengthening concepts before students finally apply these concepts to the specified project product (Raymundo, 2020).

Before implementing the IPro-Lab practice, the teacher needs to prepare an activity plan that will be carried out according to the relevant material. Prepare practicum tools such as tools and materials to prepare projects, inquiry investigation needs, and all other supporting needs (Kim et al., 2019). Table 1 shows the types of physics materials that have been tested in the IPro-Lab application. The concepts that are relevant to the characteristics of the IPro-Lab practicum lie in the project assignments given, which are applied concepts or applications of physics material.

Table 1. The Physics Material's IPro-Lab

Project	Main Concept	Additional Concepts
Submarine	Archimedes Law	Newton Law
Drone	Principe Bernoulli	Newton Law
Hydram Pump	Hydrostatic Pressure	Pascal Law
Smart Home	Semiconductors	AC/DC Current

Assessments can focus on a student's technical and cognitive aspects or even a combination of both. IPro-Lab has different assessment methods, namely individual assessment and group assessment (Forsell et al., 2020). Individual assessments can be carried out, for example by assigning assignments to review material provided by the teacher, or by preparing interesting ideas from the implementation of class material and discussing them in the form of a "study diary" at the next meeting, discussion, and presentation of learning activities for group assessment.

In general, the assessments conducted do not differ significantly from other learning assessments. However, assessment needs to emphasize students' understanding of the material and engagement with each stage of learning (Darling-Hammond et al., 2020; Lodge et al., 2018). Therefore, each student needs to establish a "project board" so that the teacher can easily view the completion of each student's learning indicators.

In training soft skills, several research results show the success of soft skills training in IPro-Lab practice (Firmansyah et al., 2022b; Kozlowski & Ilgen, 2006; Saputra et al., 2019). Table 2 explains how the IPro-Lab stages can facilitate soft skills that support the needs of the 21st century.

Table 2. Soft Skills trained in the IPRO-Lab stages

Stage of IPRO-Lab	Main Activity	Soft Skills Facilities
Lab Orientation Project	Launching the Project	Cognitive Flexibility
	Project Assignment	Critical Thinking, Argumentations Skills
	Case Study	Creative Thinking
	Formulate problems	Critical and Creative Thinking Skills
	Hypothesis submission	Argumentations,
Lab Concept Reinforcement	Design Investigative Activities	
	perform Data Analysis	
	Conclusions	Time Management, Collaboration, Communication, Critical Thinking, Creative Thinking, Working with The Team, Emotional Intelligence
Real Word Project Lab	Project Design	
	Project work	
Project Testing Lab	Product Testing	
	Report Preparation	
Dissemination Project Lab	Project Presentation	
	Writing the Articles	

Based on table 2, explains the stages of skills development in IPro_lab practicum activities, starting with the launching of the project stage. In this stage, students are presented with an explanation of the application of physics concepts in a product that will be used as a project assignment in the practicum, students study and explore carefully the relationship between quantities and concepts contained in the prepared project assignment, then analyze the data and information presented in the project assignment. This activity is closely related to cognitive flexibility skills. Students are trained to have multiple perspectives and can think about several different concepts simultaneously.

The Project Assignment stage allows students to analyze information, instructions, data, or facts about criteria or working principles as a basis for determining equipment and materials in practical activities to strengthen concepts before making project assignments. Here, students will be trained in critical thinking and argumentation. The case study stages, formulating problems and proposing hypotheses in IPro-Lab, enable students to practice critical, creative, and argumentation thinking skills.

In the project stage, students are allowed to design inquiry investigations and discover physics concepts in practical experiences so that they can support project completion at the next stage, namely the real-world project lab. The next stage is to carry out project testing with previously designed product testing equipment until students evaluate the product and prepare a project report to be submitted at the project dissemination stage. Here students are skilled in communication and argumentation, working in teams, and practicing critical and creative thinking skills. In the end, students write an article as a final report, from the IPro-Lab stage. This allows students to practice presentation, communication, and collaboration skills.

IPro-Lab is a development of the inquiry-based practicum and project-based practicum models. It is still very possible for IPro-lab to add information technology integration in line with the era of Industrial Revolution 4.0 and Indonesian Society 5.0 to support the provision of 21st-century skills and the profile of Pancasila students in secondary education. This means that, according to the implementation stages of IPro-Lab, this model is very suitable to be introduced at the middle and upper education levels, in addition to higher education.

The implementation stages of IPro-Lab are very easy to integrate with technology, and students will find it easier to take part in practicums and be actively involved in activities that support practicing critical thinking skills through collaborative problem-solving.

The results of this research also strengthen previous research which stated that assessing 21st century skills is not easily measured only by verification practicum. The study used an online-based innovation practicum to assess individuals' complex problem-solving and collaboration skills and level of inquiry (Khishfe, 2022). Apart from that, critical and creative thinking skills can also be trained in the project-based practicum stage. Therefore, 21st-century skills need to be taught in laboratory activities to help students acquire the knowledge, abilities, and attitudes that will help them become successful individuals, productive members of society, and engaged citizens (Suradika et al., 2023).

Based on the results of the literature study, several recommendations for conclusions are as IPro-Lab can be implemented in a practicum process at the tertiary level by prioritizing the quality of students' skills in the field of science. IPro-Lab can facilitate the formation of understanding of concepts, skills, and attitudes of students individually and collaboratively, maximizing thinking skills and optimizing student contributions in the lab. IPro-Lab also provides an environment for innovative, creative, and structured ways. In the end, results still depend on the commitment of teachers and students to deliver teaching according to priority needs.

Conclusion

This literature review focuses on studies identifying the characteristics and effectiveness of applying the IPro-Lab learning design in the context of learning, teaching, and assessment for science learners. The summary results of the literature review discussing project-based labs and inquiry-based labs in the sciences show that they are highly effective in implementation, especially when they can be collaborative as provided by IPro-Lab. The IPro-Lab can be implemented in five steps (1) Lab Orientation Project, (2) Lab Concept Reinforcement (3) Real Word Project Lab (4) Project Testing Lab (5) Dissemination Project Lab.

Author Contributions

The author is involved in the overall making of this article. The authors collaborate in reviewing the literature and developing frameworks so that the articles are well structured.

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Conflicts of Interest

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

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