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Innovation of Mobile Science Laboratories as a Solution to Access to Practical Learning in Schools: A Case Study at an Education Quality Assurance Center in Banten, Indonesia

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Abstract

Inequality of access to laboratory facilities is one of the main challenges in science learning in schools, especially in areas with limited infrastructure. This study aimed to describe and analyze the innovation of the Mobile Science Laboratory implemented by an Education Quality Assurance Center in Banten, Indonesia as an alternative solution in expanding access to practical learning. This study used a qualitative approach with a case study type. Data collection techniques were carried out through interviews with program managers and documentation analysis. The results of the study indicate that the mobile science laboratory program contributes to expanding access to practical work for students in schools that do not have laboratory facilities, increasing student engagement in science learning, and strengthening teachers' pedagogical capacity. The main challenges in implementation include time constraints, school facility conditions, teacher readiness, and logistics. Supporting factors for the success of the program include the institutional commitment of an Education Quality Assurance Center, adaptive program design, and enthusiasm from target schools. This study recommends integrating the program with teacher training, regional policy support, and developing a replication model in other provinces.

Keywords: Mobile Laboratory, Practical Learning, Educational Innovation, Access to Education

INTRODUCTION

Science learning is an important foundation in forming scientific thinking, logical reasoning skills, and data-based problem solving. In the constructivist approach, science is not enough to be studied theoretically, but must involve direct interaction with objects and phenomena through practical activities. Practical work provides real learning experiences (hands-on learning) that allow students to develop science process skills such as observing, measuring, interpreting data, and concluding (Abrahams & Millar, 2008; Hofstein & Lunetta, 2004).

According to Kolb (1984), learning will be meaningful if students experience it directly and reflect on the experience. In the context of science learning, practical experience is a critical stage for building deep and applicable conceptual understanding. Research by Kotsis (2024); Ningtyas et al., (2024); Zhang & Ma, (2023) also shows that student involvement in science experiments can increase learning interest, material retention, and critical thinking skills. In addition, research conducted by Lozano & Solbes (2021); Marshall et al., (2017) in junior high schools shows that the integration of inquiry-based practical work significantly improves science learning outcomes and students' active participation in class.

Although the importance of practicums has been widely recognized, the reality on the ground shows a serious gap in access to laboratory facilities, especially in schools in disadvantaged, frontier, and outermost (3T) areas. Data from the Ministry of Education, Culture, Research, and Technology (2022) states that more than 55% of elementary and junior high schools in Indonesia do not have laboratory space, and most schools in the 3T area do not even have basic practicum equipment.

Studies by Khaerunnisah et al. (2022) and Yanto (2023) show that practical activities are only conducted demonstratively by teachers in many rural areas, or verbal explanations are used only to replace explanations. This directly impacts students' poor understanding of scientific concepts and science process skills. Tikly et al. (2020) conducted a global study that found that a lack of laboratory facilities is one indicator of poor science education quality in developing countries.

These infrastructure limitations are exacerbated by a lack of teacher training in managing experiment-based learning in confined environments. Furthermore, local governments do not provide budgetary support for the purchase of teaching aids and laboratory materials (Salsyabella & Sundari, 2025; Utsman et al., 2022).

The mobile science laboratory model is one of many learning innovations developed to address the issue of limited access. This mobility-based innovation allows for the gradual provision of experimental tools and activities to target schools. Mobile laboratories have been used in many countries, such as South Africa and India, to address the issues of limited facilities and geographical differences (Beyers et al., 2012; Patel et al., 2024).

Mobile laboratories can provide practical, elementary science experiments for students in schools and are designed to be contextual and portable. According to research conducted by the Science Adventure Lab program at the Seattle Children's Research Institute Roden at al. (2018), mobile laboratories enable schools with limited resources to provide hands-on experiences in science learning, increase student interest in STEM, and reduce the school's logistical burden. Additional findings from Jones & Stapleton's Mobile Lab (2017) indicate that mobile laboratories provide hands-on experiences in science learning.

One type of educational innovation known as mobile science laboratories aims to provide hands-on science experiments to schools that lack permanent laboratories. Developing countries have used this model as a solution to mobilize limited resources equitably and efficiently. For example, the Agastya Foundation's Mobile Science Laboratory program has reached thousands of rural schools in India using mobile vehicles equipped with experimental equipment (Patel et al., 2024). Evaluation results have shown significant increases in students' interest in science and their understanding of basic concepts. A study in South Africa (Beyers et al., 2012) demonstrated that the use of mobile laboratories can increase students' motivation to learn and enhance their participation in education.

Mobile laboratory models are typically adaptable, with portable lab equipment and a curriculum that can be tailored to the local environment. This model has the significant advantage of being accessible to remote areas at a relatively lower operational cost compared to building a permanent laboratory.

The Education Quality Assurance Center in Banten, Indonesia has implemented the innovative mobile science laboratory as part of its learning transformation program. Since 2005, Education Quality Assurance Center in Banten, Indonesia has provided mobile science laboratory services to elementary and junior high schools in Indonesia that lack adequate laboratory facilities. In addition to providing lab equipment, this program provides assistants and lab modules tailored to the curriculum.

As a technical implementing agency of the Ministry of Education, Culture, Research and Technology, an Education Quality Assurance Center has the capacity to design and implement innovations based on regional data, as well as build partnerships with the Education Office and education units. This study focuses on examining in depth how the innovations are designed, implemented, and their impact on access and quality of practical learning in target schools. In addition, this study aims to identify challenges faced and formulate recommendations for development based on field evidence.

With a qualitative case study approach, this article is expected to contribute to the development of science education innovation models in the regions, as well as become a reference for educational policies based on equal access and quality improvement.

METHOD

This study uses a qualitative approach with an exploratory case study type. The qualitative approach was chosen because the main focus of the study is to deeply understand the meaning, process, and experience related to the implementation of the Mobile Science Laboratory innovation by an Education Quality Assurance Center in Banten, Indonesia in a real-world context. This study does not attempt to quantitatively measure the effectiveness of the program, but rather explores how the innovation is implemented, accepted, and its impact is felt by stakeholders, especially teachers, students, and program managers.

In this context, an Education Quality Assurance Center in Banten, Indonesia is used as a single case unit because it is the initiator and main implementer of the mobile laboratory innovation. The focus of exploration is directed at how the program was designed, mobilized, implemented, and how the perceptions and experiences of target schools are towards the services provided. The selection of this single case study can be justified because this innovation is unique and strategic, so that an in-depth study of one case can provide valuable insights for the development of similar policies and practices in other areas (Creswell, 2015).

The subjects in this study consisted of stakeholders who were directly involved in the planning, implementation, and acceptance of benefits from the Mobile Science Laboratory innovation by an Education Quality Assurance Center in Banten, Indonesia. In accordance with the characteristics of qualitative research, the selection of subjects was carried out purposively, namely based on the criteria of relevance, experience, and knowledge of the subjects towards the phenomenon being studied Creswell (2015) . The main subjects were: Program Managers at an Education Quality Assurance Center in Banten, Indonesia, which included the mobile laboratory program coordinator and the technical implementation team responsible for the design, logistics, implementation, and monitoring of activities.

The selection of this subject considers the principle of triangulation of data sources to increase the validity of the findings Welch & Patton (1992). By combining perspectives from implementers, facilitators, and beneficiaries, this study can explore information holistically and in depth.

The location of this research was determined in Banten Province, with a focus on schools that were the targets of the Mobile Science Laboratory program organized by an Education Quality Assurance Center in Banten, Indonesia

The data collection techniques used in this research are:

1. In-depth Interview (In-depth Interview)

   Interviews were conducted semi-structured with program managers at an Education Quality Assurance Center in Banten, Indonesia, teachers, and principals. The purpose of the interviews was to explore the planning process, technical constraints, program benefits, and perceptions of the impact of innovation on learning.

2. Documentation and Archive Studies

   Documentary data is obtained from program implementation reports, service schedules, practicum module designs, target school data recaps, and photos or videos of activities. Documentation studies are useful for understanding the program context chronologically and operationally.

Data analysis in this study was conducted qualitatively using a model (Miles Matthew et al., 2014), which includes three main steps:

1. Data Reduction

   The process of selecting, simplifying, and organizing data from interviews, documentation, and observations. Irrelevant data is filtered out, while important data is given an initial coding.
2. Data Presentation

   Data is arranged in the form of descriptive narratives, matrices, or thematic tables to show patterns, relationships between information, and dynamics of program implementation. This stage facilitates initial interpretation.
3. Drawing Conclusions and Verification

   Researchers draw tentative conclusions, which are then verified by comparing data sources (triangulation) to ensure consistency. This process is carried out iteratively to produce valid and contextual understanding.

RESULTS AND DISCUSSION

Description of the Mobile Science Laboratory Innovation

The Mobile Science Laboratory Innovation initiated by an Education Quality Assurance Center in Banten, Indonesia is a concrete response to the inequality of access to science practicum facilities in elementary and junior high schools, especially in areas that do not have permanent laboratories. This program is an example of a mobility-based educational service that provides hands-on practical experiences to schools in a flexible and adaptable manner.

The primary goal of the Mobile Science Laboratory innovation is to make science practical learning more accessible in schools that previously lacked laboratories, encourage students to actively participate in experiments, and enhance teachers' abilities to support students in practical-based science learning. Furthermore, in accordance with the mandate of the National Education Standards and the learning transformation agenda within the Merdeka Belajar (Freedom to Learn) framework, this program aims to achieve equitable distribution of educational services.

This program is also intended as an innovation-based educational service model that brings resources closer to students in a fair and adaptive manner, according to interviews with program managers at an Education Quality Assurance Center in Banten, Indonesia (Rosyid & Mubin, 2024). This goal aligns with the principles of inclusivity and equity in science education (Tikly et al., 2021) and the notion that local relevance and needs significantly influence the successful diffusion of innovation (Fatmawati, 2018; Rogers et al., 2019; Sinaga & Fauzi, 2024).

The Mobile Science Laboratory at an Education Quality Assurance Center in Banten, Indonesia is designed as a mobile service that brings a set of experimental equipment to target schools using official operational vehicles or functionally modified rental vehicles. This service includes several forms of activities, namely: regular visits to schools that have been surveyed and prioritized based on facility needs; direct implementation of practicums in schools involving students, science teachers, and facilitators from an Education Quality Assurance Center; technical and pedagogical assistance to teachers regarding the use of equipment, management of experiments, and integration of practicum results in learning; and provision of practicum modules that are arranged in line with learning outcomes in the *Merdeka* Curriculum.

This service model emphasizes service mobility, contextualization of materials, and collaboration with schools. This service is temporary but structured, with the aim of equipping schools to be able to carry out simple science practices independently in the future.

The experiments carried out in the Mobile Science Laboratory program were selected based on three main considerations: (1) suitability to the learning outcomes of junior high school science for grades VII and VIII, such as acid-base material, changes in state of matter, and electrical circuits; (2) potential to encourage active student involvement through direct observation activities and group discussions; and (3) ease of operation, namely tools and materials that are portable, safe, and easy to assemble in schools with limited facilities. This approach ensures that the experiments are relevant, participatory, and can be implemented evenly.

(1) conducting experiments with changes in state of matter and heat such as evaporation, freezing, and condensation; (2) conducting acid-base solution tests with red cabbage extract as a natural indicator; (3) conducting capillarity experiments to see how plant stems absorb water; (4) making simple electrical circuits with batteries and LED lights; and (5) conducting microscopic examinations of plant cells, such as these experiments were chosen because they are easy to do, relevant to the teaching material, and able to encourage active, experience-based learning.

This experiment is simple, based on local materials, and aims to enhance conceptual understanding and observation skills (Hofstein & Lunetta, 2004). Allowing students to experience the cycle of observation, hypothesis, experimentation, and conclusion, this practice is intended to enhance inquiry-based learning.

The equipment is packaged in a durable, water-resistant *mobile laboratory kit* that can be transported to schools with challenging environments. Daily logistics planning ensures the equipment distribution system. This includes vehicle routes, implementation times, and coordination with schools. To ensure the completeness and condition of the equipment before and after use, an Education Quality Assurance Center also created a *logistics checklist form*.

Mobile laboratory logistics depend not only on equipment; coordination, training of the facilitator team, and responsiveness to local contexts are also crucial (Beyers et al., 2012). The Education Quality Assurance Center in Banten, Indonesia program demonstrates the implementation of adaptive educational innovation strategies with institutional support in this regard.

The Mobile Science Laboratory innovation created by an Education Quality Assurance Center in Banten, Indonesia demonstrates that educational programs must be tailored to local needs. According to the diffusion of innovation theory (Rogers et al., 2019), this program possesses many innovative features. These include being better than learning without practical work, being less complex because the tools are easy to use, being testable through direct teacher and student engagement, and being recordable because the results can be discussed and observed. These features enhance the program's potential for adoption and replication in other areas.

Therefore, there is a strong likelihood that this innovation will be replicated and adapted elsewhere. However, its success is largely determined by the collaboration between program designers, schools, and existing institutional support in the area.

Implementation in Target Schools

The Mobile Science Laboratory program is implemented in target schools in a structured and scheduled manner through a collaborative approach between the implementation team and the schools. The implementation process begins with data collection and identification of target schools, especially schools located in areas with limited science laboratory facilities. The determination of schools is based on Dapodik data, results of education quality supervision, and recommendations from the Regency/City Education Office.

The implementation stages of the Mobile Science Laboratory program include four main steps. First, initial socialization and coordination between Education Quality Assurance Center and target schools to agree on the schedule, location readiness, and number of participants. Second, distribution and arrangement of practicum equipment by the mobile laboratory team before the activity begins. Third, implementation of science practicums facilitated by the Education Quality Assurance Center team together with science teachers. Fourth, documentation and reporting of activities, including brief reflections from teachers and students as part of the program evaluation and development.

The implementation of the activity generally takes place in one full day, including two practical sessions for different groups of students. This format is designed so that students get direct experience in conducting experiments with tools and materials that have not been available in their schools.

The success of the program implementation is highly dependent on technical readiness and good communication between Education Quality Assurance Center and the school. In some cases, activities must be adjusted to geographical conditions, such as distance and limited communication networks, especially in areas such as Cibaliung District (Pandeglang Regency) and Sobang District (Lebak Regency).

The implementation of practicums through mobile laboratories places teachers as facilitators and active partners of the implementation team. In this activity, science teachers play an important role in several aspects, including: delivering an introduction to the theory before the experiment begins, guiding students to understand the practicum worksheet (LKP), helping to explain the experimental procedures directly, and integrating the results of the practicum into class discussions after the activity takes place. This role not only ensures smooth operation but also strengthens the connection between students' lab experiences and their conceptual understanding.

The program also builds teachers' capacity, as they were previously unfamiliar with conducting labs with portable equipment or simple, local experiments. Teachers' involvement in the mobile laboratory program also boosted their confidence and innovation in developing alternative experiments after the team's visit, according to Yuliati et al. (2020).

For students, practical activities through mobile laboratories provide interactive, concrete, and meaningful learning experiences. They become more active in directly observing scientific phenomena, recording data and measurement results, discussing with group members about experimental findings, and drawing conclusions based on experimental results. This direct involvement helps strengthen conceptual understanding and forms scientific thinking skills more naturally.

Most students showed high enthusiasm during the activity. Observation results showed that students find it easier to understand abstract concepts such as changes in matter or electrical systems when they can see and touch the objects directly (Abrahams & Millar, 2008) . This kind of activity strengthens the learning experience based on the theory *of experiential learning.* (Kolb, 1984).

One example of a successful implementation is the practical activity carried out at SMP Negeri 4 Sobang, Lebak Regency, in October 2023. This school previously did not have a laboratory and only relied on simple picture or simulation media in teaching science.

Through the Mobile Science Laboratory program, an Education Quality Assurance Center in Banten, Indonesia team brought a set of experimental tools for experiments on the properties of acid and base solutions, including natural indicators from red cabbage, litmus paper, vinegar solution, soapy water, and lemon juice. Students were divided into small groups and asked to test various solutions, then record the color changes of the indicators.

During the activity, the science teacher also accompanied and explained the concept of acidity. After the experiment was completed, the teacher led a class discussion to compare the results of the experiment between groups. From the post-activity interview, students stated that they found it easier to understand the concept of acids and bases because they could directly see the color changes, rather than just reading about it in a book.

Another similar example was also found in SMP Negeri 1 Sumur, Pandeglang Regency, which successfully modified the mobile laboratory activity into a routine mini-experiment activity using used equipment donated by an Education Quality Assurance Center after the activity was completed. This practice shows the sustainability of the activity if supported by teacher creativity and the support of the principal.

The implementation of the Mobile Science Laboratory program in target schools reflects the real application of a local needs-based innovation diffusion approach. (Fatmawati, 2018; Rogers et al., 2019; Sinaga & Fauzi, 2024) . In this context, the role of teachers as agents of change is very significant, especially in adopting and adapting new practices into existing learning systems (Fullan, 2016) . Furthermore, student involvement in experimental activities shows that the program is able to bridge the gap between theoretical learning and real practice, in line with research findings Hofstein & Lunetta (2004) that emphasize the importance of laboratory experiences in developing students' science skills.

Overall, the implementation of this program not only provides technical solutions to the limitations of laboratory facilities, but also contributes to a paradigm shift in science learning in schools that previously had minimal practical experience.

Impact on Access and Quality of Practical Learning

The Mobile Science Laboratory Innovation by an Education Quality Assurance Center in Banten, Indonesia has shown a real contribution in expanding access to practical learning while improving the quality of science teaching and learning processes in schools that previously did not have permanent laboratories. The impact of the program can be analyzed through the following three main aspects:

1. Access to Practical Activities

   One of the main achievements of this program is the opening of access to science practicum activities for students in schools that have previously experienced limited facilities. Based on field data, around 70% of target schools do not have a science laboratory space, and practicums were almost never carried out directly before the program intervention.

   With the Mobile Science Laboratory service, students in remote areas such as Cigeulis (Pandeglang) and Sobang (Lebak) Districts can now experience firsthand the experience of conducting experiments, which they previously only learned through textbooks or verbal explanations from teachers.

   This program proves that physical barriers to laboratories can be bridged through resource mobilization. This is in line with studies that Beyers et al. (2012)state that mobile laboratories are effective in addressing the inequality of access to practical work in rural Africa, and is also supported by the findings Jones & Stapleton, (2017); Roden et al., (2018)that mobile labs can improve the equality of science education services.

2. Increasing Student Engagement and Conceptual Understanding

   The implementation of the program showed that the hands-on lab experience had a positive impact on student engagement in learning. The results of teacher observations and reflections showed an increase in student enthusiasm, curiosity, and active participation during the mobile laboratory activities. Students appeared more focused, actively discussed in groups, and were able to follow experimental procedures independently with little direction.

   This kind of involvement is essential in science learning, as emphasized by Hofstein & Lunetta (2004), that laboratory activities provide students with opportunities to build concepts through real-life experiences and social interactions. In addition, simple, visual and manipulative experimental activities have been shown to help students understand abstract concepts, such as changes in state of matter, chemical reactions, and electrical systems.

   Based on the analysis of the Practical Worksheet (LKP) and the results of teacher interviews, most students were able to re-explain the procedures and results of the experiment, and draw simple conclusions that showed conceptual understanding. Teachers also reported an increase in formative assessment scores after the practical activities took place, although no systematic quantitative evaluation was conducted in this study.

3. Strengthening Teacher Capacity

In addition to having an impact on students, the Mobile Science Laboratory program also made a significant contribution to strengthening teacher capacity in practicum-based learning. Many teachers in target schools admitted that they previously felt less confident in facilitating science experiments due to limited tools and training. The presence of an Education Quality Assurance Center team to accompany and provide direct examples has been a valuable learning experience.

Teachers are actively involved in activities ranging from introducing materials, mentoring students, to discussing experimental results. This process opens teachers' insights into how experiments can be carried out with simple tools and local materials. In addition, several teachers are motivated to develop independent mini-experimental activities outside the mobile laboratory program, by utilizing materials that are easily available in the surrounding environment.

According to Fullan (2016) , sustainable educational innovation relies heavily on strengthening the capacity of teachers as agents of change. This program, although temporary, has provided initial *scaffolding* for teachers to explore active and experiential learning approaches.

Furthermore, teacher involvement in the program also contributed to increased professional collaboration, as science teachers from various schools shared experiences and ideas through post-program reflection forums facilitated by an Education Quality Assurance Center.

The above findings confirm that the Mobile Science Laboratory innovation not only serves as a technical solution to overcome limited facilities, but also as a transformative instrument that builds a more active, inclusive, and meaningful science learning ecosystem. Physical access to experimental equipment is not enough; the program has succeeded in encouraging changes in attitudes and pedagogical approaches to science learning.

Within the framework of the diffusion of innovation theory Rogers et al. (2019), the success of this program is also seen in the adoption of new behavior by early adopters, namely teachers in target schools who began to integrate experiments into their learning routines.

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However, to ensure the sustainability of the impact, systemic support is needed in the form of further training, provision of basic experimental equipment in schools, and post-implementation monitoring mechanisms. Such interventions should be seen as an initial step towards independent laboratory practices in marginal schools.

Field Implementation Challenges

The Mobile Science Laboratory Program is generally designed as a one-day visit to each school. Although this approach allows for equal distribution of services to many schools, the limited time makes it difficult to carry out in-depth experiments. In one day, only one to two types of experiments can be carried out alternately by several groups of students.

Teachers reported that they did not have enough time to have in-depth discussions, review experimental results, or develop comprehensive follow-up learning. This made the learning experience fragmentary and difficult to form a complete conceptual understanding.

Research by Hofstein & Lunetta (2004) confirms that meaningful science experiments require sufficient time for exploration, reflection, and discussion, not just brief procedures.

Another challenge is the logistics and distribution of experimental equipment to target schools. Some schools are located in difficult-to-reach locations, such as hilly areas, coastal areas, or areas that can only be accessed via narrow and damaged roads. The implementation team from an Education Quality Assurance Center in Banten, Indonesia reported that delays in equipment delivery and damage during travel were recurring problems.

In addition, not all portable equipment brought is suitable for field conditions. For example, experiments that require temperature stability or flat surfaces are difficult to perform optimally in open spaces. This problem suggests that the program's logistics design needs to take into account local geographic conditions and infrastructure in more detail (Beyers et al., 2012).

Another challenge that emerged was the difference in the level of science literacy of students in the target schools. Many students showed limitations in basic skills such as reading experimental procedures, recording observations, and drawing conclusions based on data.

Students from schools in 3T areas are generally not accustomed to inquiry-based learning methods or direct exploration. This makes it difficult for some students to follow the flow of the practicum even though it has been simplified. Low scientific literacy causes some students to only imitate instructions without really understanding the meaning behind the activities carried out.

As explained by Bybee (2010) , scientific literacy includes the ability to understand concepts, use scientific processes, and make evidence-based decisions. Low scientific literacy is an obstacle in making practicums a learning process that forms students' scientific thinking skills.

These challenges show that while the Mobile Science Laboratory innovation has a positive impact, its success is largely determined by the readiness of the education system at the school level. Innovation cannot just come from outside; it requires active involvement and increased internal capacity of schools, including teachers, infrastructure, and student readiness.

CONCLUSION

This study shows that the Mobile Science Laboratory innovation initiated by an Education Quality Assurance Center in Banten, Indonesia is a strategic breakthrough in addressing the issue of inequality of access to science practical learning in schools that do not have permanent laboratories, especially in disadvantaged, outermost, and remote areas (3T). This innovation is designed based on the real needs of schools with a mobility approach, tool portability, and partnership with teachers as learning facilitators.

The Mobile Science Laboratory program has increased students' access to hands-on experimental activities previously unavailable in their schools; encouraged active student participation and enhanced their understanding of science concepts through hands-on learning experiences; and strengthened science teachers' ability to design, implement, and reflect on practical learning using readily accessible tools and materials.

However, implementation in the field faces numerous challenges. These include limited school infrastructure and facilities, limited time, challenging logistics, the readiness of diverse teachers, and variations in scientific literacy among students. These challenges demonstrate that innovation does not rely solely on creative ideas; systems must be prepared and sustainably supported.

Therefore, the Mobile Science Laboratory innovation is not merely a temporary solution to limited facilities; it symbolizes a paradigm shift in educational services: from centralized to decentralized, from passive to active, and from facility-centric to centered on quality and equitable access. This innovation demonstrates that educational progress is not solely determined by technological advancements, but also by sensitivity to reality and the courage to create new models tailored to the needs of the context.

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