

Chemistry Learning Outcomes through Project-Based Learning with Themed Electrolyte Test Kits

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ABSTRACT

This study describes the implementation of project-based learning (PjBL) integrated with Google Sites for teaching the electrical conductivity of electrolyte and non-electrolyte solutions during a blended distance-learning and limited face-to-face period. The participants were 66 Grade X science students at SMAN 1 Giri in the 2021/2022 academic year, comprising 33 students in Class X MIPA 4 and 33 in Class X MIPA 5. Students worked in small groups to design, construct, test, document, and present themed electrolyte test kits made from accessible materials, while Google Sites functioned as a digital portfolio for project evidence. The study used a descriptive qualitative approach supported by project scores, post-test results, student responses, and documentation. The mean project scores were 89.06 for X MIPA 4 and 89.84 for X MIPA 5. Mean post-test scores were 82.58 and 81.29, with mastery rates of 93.94% and 84.85%, respectively. The learning design enabled students to continue practical chemistry activities during distance learning while exercising voice, choice, ownership, collaboration, and creativity. However, because the study did not report a pretest or comparison group, the findings should be interpreted as evidence of successful implementation and high post-intervention attainment rather than as a causal estimate of improvement. The results support the use of low-cost project work and digital portfolios as complementary strategies for contextual chemistry learning.

Keywords: chemistry education; electrolyte test kit; Google Sites; learning outcomes; project-based learning

INTRODUCTION

The COVID-19 pandemic required schools to redesign laboratory-based science learning when students could not always access school facilities. At SMAN 1 Giri, chemistry instruction combined distance learning (Pembelajaran Jarak Jauh/PJJ) with limited face-to-face learning (Pembelajaran Tatap Muka Terbatas/PTMT). This arrangement created a practical challenge for the Grade X topic of electrolyte and non-electrolyte solutions because students were expected not only to understand conductivity concepts but also to design and conduct an experiment. Similar disruptions worldwide accelerated the use of blended and digitally supported science instruction and highlighted the need for learning designs that preserve active experimentation and interaction (Rapanta et al., 2020; Trust & Whalen, 2020; König et al., 2020; Baber, 2021).

Project-based learning (PjBL) offers a relevant response because students investigate an authentic task over time and create a tangible product. In science and chemistry education, project work can integrate conceptual understanding, inquiry, collaboration, problem solving, communication, and practical skills. Recent reviews and empirical studies indicate that PjBL can support achievement, engagement, science-process skills, and conceptual understanding when projects are structured around clear learning goals and teacher scaffolding (Almulla, 2020; Guo et al., 2020; Muliaman & Mellyzar, 2020; Nuha et al., 2020; Munawwarah & Side, 2025; Aslam et al., 2025).

The intervention in this study centered on a themed electrolyte test kit. Students constructed a simple conductivity tester from inexpensive materials available in their surroundings, tested different solutions, documented observations, and developed conclusions about strong electrolytes, weak electrolytes, and non-electrolytes. The project was designed to maintain hands-on practical work even when students were learning from home. Contextual and inquiry-oriented laboratory activities are important in chemistry because macroscopic observations must be connected to submicroscopic particle explanations and symbolic representations (Taber, 2019; Seery, 2020; Bretz, 2019).

Google Sites was integrated as an e-portfolio platform. Each group uploaded project documentation, experimental evidence, explanations, and reflections to a site that could be accessed by peers and teachers. Digital portfolios can make learning processes visible, support reflection, and preserve artifacts across time, while blended-learning research emphasizes the value of combining digital resources with purposeful teacher-student interaction (Rapanta et al., 2020; Martin et al., 2020; Müller & Mildemberger, 2021; Heilporn et al., 2021).

The study therefore aimed to describe student learning outcomes and project performance after the implementation of PjBL using themed electrolyte test kits integrated with Google Sites in Classes X MIPA 4 and X MIPA 5 at SMAN 1 Giri. It also documented how the project was implemented across PJJ and PTMT and how student voice, choice, ownership, and peer support were manifested during the learning process.

LITERATURE REVIEW

Project-Based Learning in Chemistry Education

PjBL organizes learning around an extended problem or challenge that culminates in a product, presentation, or public artifact. Its core features include a meaningful driving question, sustained inquiry, learner decision making, collaboration, revision, and reflection. In contemporary research, PjBL is associated with active and student-centered learning because learners must integrate knowledge and action rather than reproduce isolated information (Almulla, 2020; Guo et al., 2020; Markula & Aksela, 2022).

Chemistry is well suited to project work when abstract concepts can be linked to observable phenomena and designed products. Studies in chemistry education have reported positive outcomes for

achievement, collaboration, science-process skills, and conceptual understanding, although effects depend on project quality, assessment, time, resources, and teacher guidance (Nuha et al., 2020; Berutu, 2022; Munawwarah & Side, 2025; Aslam et al., 2025).

Electrolyte Conductivity and Low-Cost Practical Work

Electrolyte conductivity provides an accessible context for connecting macroscopic evidence with particle-level explanations. A strong electrolyte produces many mobile ions in solution, a weak electrolyte ionizes only partially, and a non-electrolyte produces essentially no ions. In a simple tester, differences can be inferred from lamp brightness and gas bubbles at the electrodes. Practical work can support conceptual learning when students are explicitly guided to interpret observations rather than merely follow procedures (Seery, 2020; Bretz, 2019).

Low-cost apparatus is especially useful when access to conventional laboratory equipment is restricted. In the present study, students repurposed materials such as carbon electrodes from used batteries, nails, cardboard, fabric, and ice-cream sticks. This approach positioned the home environment as a learning resource and made repeated prototyping possible.

Digital Portfolios and Blended Learning

Digital portfolios collect evidence of learning in forms such as text, images, videos, and reflective commentary. When embedded in a learning sequence, they can document process as well as product and provide a space for feedback, revision, and learner ownership. Google Sites offers a simple web-based environment for organizing such artifacts without requiring advanced programming skills.

Blended learning combines online and face-to-face experiences in ways that should be pedagogically integrated rather than merely juxtaposed. Research during and after the pandemic has emphasized teacher presence, purposeful interaction, accessible resources, and alignment between synchronous, asynchronous, and assessment activities (Rapanta et al., 2020; Müller & Mildemberger, 2021; Heilporn et al., 2021; Singh et al., 2021).

METHODS

Research Design, Setting, and Participants

The source study used a descriptive qualitative design. It was conducted at SMAN 1 Giri, Banyuwangi, East Java, Indonesia. Project activities during PJJ took place from 7 to 18 March 2022, followed by PTMT presentation, reflection, and evaluation activities from 21 to 25 March 2022. Data analysis and report preparation continued through April 2022. Participants were selected purposively and consisted of 66 Grade X students: 33 students in X MIPA 4 and 33 students in X MIPA 5.

Project Procedure

Following the PjBL sequence, students first determined a theme for their group electrolyte tester, planned the required tools and materials, constructed and tested the apparatus at home, and documented their work through video. Groups reported project progress through video calls or WhatsApp and were allowed to redesign unsuccessful prototypes. Experimental observations and conclusions were uploaded to each group's Google Sites portfolio. Group presentations, reflection, conceptual clarification, and evaluation were conducted during PTMT.

Data Sources and Analysis

Data included student responses, photographs of project products and learning activities, project assessment scores, and post-test learning outcomes. The project rubric covered design, creativity, reliability during testing, and thematic appropriateness. The original study reports descriptive statistics only; no pretest, inferential test, reliability coefficient, or comparison group is provided. Accordingly, the analysis in this English version preserves the original descriptive design and does not infer causal effectiveness from post-test scores alone.

RESULTS AND DISCUSSION

Implementation of the Electrolyte Test-Kit Project

Students completed the major construction and experimentation stages from home during PJJ. They selected themes, sourced materials, assembled circuits, tested solutions, recorded evidence, and revised their designs when initial attempts failed. During PTMT, groups presented their work and the teacher corrected conceptual errors identified in some conclusions. The implementation therefore combined hands-on experimentation, iterative design, peer collaboration, teacher feedback, and digital documentation.

Table 1. Group project scores for the themed electrolyte test kits

Group	X MIPA 4	X MIPA 5
1	87.50	87.50
2	93.75	93.75
3	93.75	75.00
4	100.00	87.50
5	100.00	87.50
6	87.50	93.75
7	75.00	100.00
8	75.00	93.75
Mean	89.06	89.84

Note. Scores are reproduced from the original study. Project assessment covered design, creativity, reliability of the tester, and fit with the selected theme.

The average project score was 89.06 in X MIPA 4 and 89.84 in X MIPA 5. The group-level results show generally high product performance, but they also reveal variation across groups, particularly in X MIPA 5 where scores ranged from 75 to 100. Iterative construction was a meaningful feature of the learning process: students whose first design did not work were expected to troubleshoot and rebuild. Such revision is consistent with PjBL principles that treat feedback and product refinement as part of learning rather than as post-task correction (Guo et al., 2020; Markula & Aksela, 2022).



Figure 1. Examples of themed electrolyte test kits produced by students



. DASAR TEORI

- Larutan elektrolit adalah larutan yang dapat menghantarkan listrik. Larutan elektrolit terbentuk dari zat elektrolit, seperti asam, basa, dan garam yang terlarut dalam pelarut air. Larutan nonelektrolit adalah larutan dalam pelarut air yang tidak memiliki kemampuan untuk menghantarkan arus listrik. Larutan non elektrolit sebagian besar terdiri dari zat-zat organik.
- Penghantaran listrik ini disebabkan karena zat-zat elektrolit dalam larutan atau leburannya terurai (terionisasi) menjadi ion positif dan ion

Figure 2. Example of a student Google Sites digital portfolio for the electrolyte project

Learning Outcomes

Table 2. Post-test outcomes and mastery rates

Class	Students	Mean post-test	Mastery (%)
X MIPA 4	33	82.58	93.94
X MIPA 5	33	81.29	84.85

Note. The source article reports post-test results only; no pretest scores are available for estimating learning gain.

Both classes achieved mean post-test scores above 80, and the reported mastery rate exceeded 80% in each class. These outcomes indicate that most students met the classroom criterion after participating in the project. However, the absence of baseline and comparison data means that the results cannot establish how much learning changed because of PjBL or whether the project outperformed another instructional approach. The findings are therefore best interpreted as strong post-intervention attainment within the observed classes.

Student Agency, Collaboration, and Digital Documentation

The project gave students substantial voice, choice, and ownership. Groups chose peers based partly on nearby residence, selected the theme and appearance of their test kit, decided how to use available materials, and designed their Google Sites pages. Several groups needed multiple trials before their devices worked, creating opportunities for persistence and responsibility for the final product. These features align with student-centered PjBL in which learners make consequential decisions while teachers provide structure and feedback (Almulla, 2020; Guo et al., 2020).

One implementation barrier was unequal device access. A group that lacked a sufficiently capable smartphone could not initially upload its work to Google Sites. Peers assisted the group with uploading, creating an unplanned peer-tutoring opportunity. This episode also illustrates a continuing digital-equity issue in technology-supported learning: access to devices and connectivity can determine whether students can participate fully in digital portfolio tasks (Bond et al., 2021; Hammerstein et al., 2021).

The digital portfolio extended the visibility of the project beyond the classroom. Students could organize text, photographs, and videos in one location and retain the site for subsequent projects. From an instructional perspective, the value of the platform lies less in the specific application than in the learning function it serves: documenting process, supporting reflection, enabling sharing, and preserving evidence for assessment.

Limitations

The study is limited by its descriptive design, purposive selection of two classes, absence of pretest and control-group data, and lack of reported psychometric evidence for the post-test and project rubric. Student responses are mentioned as a data source but are not reported systematically in the source manuscript. In addition, the study was conducted during a specific pandemic-era blended-learning arrangement, which may limit transferability to fully face-to-face settings. Future studies should employ validated instruments, pretest-posttest measures, clearer qualitative coding procedures, and comparative or quasi-experimental designs.

CONCLUSION AND RECOMMENDATIONS

Project-based chemistry learning using student-designed electrolyte test kits and Google Sites was successfully implemented across distance and limited face-to-face learning at SMAN 1 Giri. Students produced high-scoring project artifacts, with mean project scores of 89.06 in X MIPA 4 and 89.84 in X MIPA 5. Post-test means were 82.58 and 81.29, with mastery rates of 93.94% and 84.85%, respectively. The project also created opportunities for practical experimentation, collaboration, creativity, iterative problem solving, and student ownership. Google Sites functioned as a digital portfolio for preserving and sharing evidence of learning. Teachers may adapt this model to other chemistry topics and interdisciplinary projects, but future research should use stronger designs to quantify learning gains and distinguish the effects of PjBL, practical work, and digital portfolio use.

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