JPPIPA 12(2) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Ethnoscience Based Durian Acid Product Development for Sustainable Chemistry Education: A Project Based Study on Prospective Chemistry Teachers' Creativity

Maria Erna[1], Siti Nazhifah[1*], Sri Haryati[1], Putri Adita Wulandari[1], Muhammad Imam Rahmatullah[2]

[1] Chemistry Education Study Program, Faculty of Teacher Training and Education, Universitas Riau, Pekanbaru, Indonesia.
[2] Physical Education Health and Sports Study Program, Faculty of Teacher Training and Education, Universitas Riau, Indonesia.

Received: December 13, 2025
Revised: January 19, 2026
Accepted: February 25, 2026
Published: February 28, 2026

Corresponding Author:
Siti Nazhifah
siti.nazhifah@lecturer.unri.ac.id

DOI: 10.29303/jppipa.v12i2.13884

Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)

Abstract: This study aims to examine how an ethnoscience-based durian acid product-development project functions as a PCK-driven creative learning environment for prospective chemistry teachers and to analyze creativity across elaboration, originality, problem solving, and synthesis. A Classroom Action Research (CAR) design with an embedded mixed-methods approach was employed involving 68 fifth-semester pre-service chemistry teachers at the University of Riau. The intervention integrated Project-Based Learning (PjBL) stages—orientation, planning, implementation, and evaluation—within Plan–Act–Observe–Reflect cycles. Data were collected using creativity questionnaires, classroom observations, and interviews, and triangulated to validate findings. Results showed high agreement (74–93%) across creativity dimensions during orientation–implementation, supported by observed evidence of detailed planning, novel product ideas, and iterative troubleshooting. However, more neutral responses emerged during evaluation, indicating difficulties in evidence-based reflection and conceptual integration. The core chemistry concepts addressed included fermentation chemistry, pH interpretation, solution dilution, and acid strength comparisons. Triangulation was generally convergent, with partial divergence in originality during evaluation due to discrepancies between self-perceived novelty and observed pedagogical innovation. These findings suggest that ethnoscience-enriched PjBL effectively promotes creative PCK development, but requires structured scaffolding to strengthen data-driven justification and synthesis during reflective evaluation.

Keywords: Creativity; Durian acid; Ethnoscience; Project based learning; Prospective chemistry teacher

Introduction

Indonesia's rich biodiversity and indigenous knowledge systems provide not only cultural heritage but also strategic resources for achieving Sustainable Development Goal (SDG) 4 on Quality Education through contextualized science learning. In teacher education, the use of culturally embedded materials offers a powerful pathway to connect abstract chemistry concepts with students' lived experiences. However, the challenge in contemporary chemistry teacher education is not merely contextualization, but the development of Pedagogical Content Knowledge (PCK) that enables future teachers to transform such cultural-scientific knowledge into effective, innovative, and pedagogically sound learning designs.

One of the major challenges in chemistry learning is the dominance of abstract representations detached from students' cultural and environmental experiences, which often leads to low engagement and superficial understanding (Driel et al., 2002; Aydın & Akın, 2022). In response to this gap, ethnoscience has emerged as a

How to Cite:
Erna, M., Nazhifah, S., Sri Haryati, Wulandari, P. A., & Rahmatullah, M. I. (2026). Ethnoscience Based Durian Acid Product Development for Sustainable Chemistry Education: A Project Based Study on Prospective Chemistry Teachers' Creativity. *Jurnal Penelitian Pendidikan IPA*, *12*(2), 642-654. https://doi.org/10.29303/jppipa.v12i2.13884

pedagogical approach that bridges scientific concepts with indigenous and local knowledge, enabling learners to understand science as part of their lived reality rather than as isolated textbook knowledge (Dewi et al., 2021; Setyowati et al., 2023).

From a constructivist perspective, learning becomes meaningful when new concepts are anchored in prior cultural and experiential knowledge (Hmelo-Silver, 2004; Krajcik & Blumenfeld, 2006). Ethnoscience-based learning operationalizes this principle by positioning local practices as epistemic resources for scientific reasoning. This approach is particularly relevant in chemistry, where many key topics—such as acids, bases, fermentation, and reaction processes—naturally occur in traditional food processing, preservation, and local technologies. Therefore, ethnoscience is not merely cultural enrichment, but a cognitive scaffold that helps students conceptualize chemical phenomena through authentic contexts.

One culturally significant example in Sumatra and Aceh is durian acid (asam drien), a fermented durian product traditionally used as a food ingredient. Scientifically, durian acid represents a natural laboratory of biochemical and microbiological processes, where carbohydrate fermentation produces organic acids that directly relate to acid–base chemistry and microbial metabolism (Muzaifa et al., 2015; Zuraidah et al., 2024). Thus, durian acid offers a dual value: it preserves local cultural heritage while simultaneously embodying core chemical principles that are normally taught abstractly.

Within the framework of teacher education, ethnoscience does not function merely as contextual material, but as a PCK-building mechanism that supports teachers in selecting representations, examples, analogies, and instructional strategies grounded in local realities. According to PCK theory, effective teaching requires not only mastery of content, but the ability to reorganize that content in ways that are meaningful, teachable, and cognitively accessible to learners (Driel et al., 2002). Ethnoscience-based learning environments provide a fertile ground for this transformation process because they force pre-service teachers to negotiate between scientific explanations, cultural practices, and pedagogical intentions.

Previous studies have demonstrated that ethnoscience-based chemistry resources—such as e-modules and contextual teaching materials—are pedagogically valid, practical, and capable of enhancing scientific literacy and learning engagement (Januarti et al., 2024; Nurhayati et al., 2021; Mahbubah et al., 2025; Ismulyati et al., 2025). Moreover, studies using local products such as shrimp paste have shown that ethnoscience helps students connect chemistry concepts with everyday life and cultural identity (Nazhifah et al., 2025; Dewi et al., 2021). However, most of these studies have focused on learning outcomes, such as literacy, motivation, or feasibility of materials, rather than on how such contexts stimulate teacher creativity, which is a core competence in 21st-century science education.

Creativity is not an optional trait in chemistry teacher education; it is a core component of PCK development. When pre-service teachers design learning activities, develop teaching materials, or adapt local phenomena into classroom instruction, they must engage in creative processes such as generating representations, resolving instructional problems, and synthesizing scientific and cultural knowledge. Thus, creativity in this study is conceptualized as a functional dimension of PCK, rather than as a general personality trait. In ethnoscience-based learning, creativity determines how well future teachers can translate local practices—such as durian fermentation—into accurate, meaningful, and pedagogically powerful chemistry learning experiences.

Project-Based Learning (PjBL) is widely recognized as a powerful environment for developing creativity because it places learners in authentic problem-solving and product-design situations (Bell, 2010; Krajcik & Blumenfeld, 2006). Recent international studies confirm that Project-Based Learning environments significantly promote creative thinking, problem solving, and collaboration when students engage in authentic product development tasks (Li & Tu, 2024; Prokša et al., 2023; Piard et al., 2025). When combined with ethnoscience, PjBL becomes even more powerful, because students are not only solving technical problems but also transforming cultural knowledge into scientifically meaningful learning resources. Recent studies confirm that ethnoscience-enriched PjBL significantly enhances creative thinking, including elaboration, originality, problem solving, and synthesis (Christiana & Rohaeti, 2024; Sumarni et al., 2025; Bayani et al., 2024). The others studies also demonstrate that PjBL integrated with ethnoscience improves creativity and scientific literacy in chemistry learning (Wahyudiati et al., 2022; Dibyantini et al., 2023).

In chemistry teacher education, project-oriented learning has been shown to support pre-service teachers' pedagogical innovation, experimental design skills, and creative instructional planning (Prokša et al., 2023; Chu et al., 2023). Similar patterns were observed in Indonesian teacher education contexts, where ethnoscience-based modules strengthened creative lesson planning and contextual pedagogy (Utari, 2021; Yuliana et al., 2023). While previous studies have explored durian acid from chemical, microbiological, or cultural perspectives, and others have investigated ethnoscience-based learning outcomes such as scientific literacy or motivation, there remains a critical conceptual gap: very little is known about how pre-service teachers' PCK-driven creativity emerges, develops, and can be systematically measured during ethnoscience-based product development projects. Existing research tends to treat creativity as a general learning outcome, rather than as a pedagogically grounded competence embedded in instructional design and content transformation.

This gap is highly significant because teacher education programs are responsible not only for transmitting content knowledge, but also for preparing future teachers to become designers of culturally relevant and innovative learning environments. Without empirical evidence on how ethnoscience-based projects influence teacher creativity, curriculum developers lack a solid foundation for integrating local-wisdom-based innovation into chemistry teacher training. The novelty of this study does not lie in durian acid as a commodity, but in its conceptual and methodological contribution to chemistry teacher education. This research introduces an ethnoscience-based, product-oriented PCK–creativity framework, in which creativity is operationalized through four theoretically grounded dimensions—elaboration, originality, resolution, and synthesis—to capture how pre-service teachers transform local knowledge into pedagogically meaningful chemistry learning designs.

The inclusion of problem solving and synthesis as creativity dimensions is theoretically justified within both creativity theory and PCK theory. Problem solving reflects the teacher's ability to solve pedagogical and conceptual problems that arise when translating real-world phenomena into teachable chemistry content, aligning with the problem-solving core of PCK. Synthesis represents the ability to integrate scientific concepts, empirical data, cultural context, and instructional goals into coherent learning designs—an essential requirement for effective chemistry teaching. Together, these dimensions move beyond surface-level creativity (idea generation) toward deep pedagogical creativity, which is critical for sustainable teacher competence.

This research is therefore important because it addresses a strategic need in chemistry teacher education: to move from creativity as a vague outcome to creativity as a measurable, PCK-embedded professional competence. By situating creativity within an ethnoscience-based product development project, this study provides a model for how local knowledge can be transformed into sustainable, high-quality chemistry instruction, directly supporting SDG 4 (Quality Education) through culturally grounded science learning. Accordingly, this study aims to examine how an ethnoscience-based durian acid product development project functions as a PCK-driven creative learning environment for prospective chemistry teachers, and to analyze their creativity across the dimensions of elaboration, originality, problem solving, and synthesis as they design, implement, and evaluate culturally grounded chemistry learning resources.

Method

This study employed a Classroom Action Research (CAR) design with an embedded mixed-methods approach. The CAR framework was used to systematically improve and examine the implementation of an ethnoscience-based, project-based learning (PjBL) intervention, while quantitative questionnaire data and qualitative observational and interview data were integrated to capture multiple dimensions of pre-service teachers' creativity. The mixed-methods structure allowed numerical patterns (questionnaire percentages) to be triangulated with rich qualitative evidence (classroom actions, reflections, and interviews), ensuring methodological coherence and analytical depth.

The research participants consisted of 68 fifth-semester prospective chemistry teachers at the University of Riau, who were involved in developing the product and its use in chemistry teaching materials. Data were collected through classroom observation, interviews, and creativity questionnaires. The creativity questionnaire which covers four dimensions, namely elaboration, originality, problem solving, and synthesis. The research procedure of development of durian acid products was carried out based on the learning activities contained in the durian acid ethnoscience module with the PjBL stages: orientation, planning, implementation, and evaluation.

The CAR was conducted following the classical cyclical model of Plan–Act–Observe–Reflect, in which the PjBL stages functioned as the pedagogical intervention within each cycle. Specifically, plan corresponded to the orientation and planning stages, where the ethnoscience-based durian acid project and learning designs were prepared; act corresponded to the implementation stage, during which students developed the durian acid products and applied them in chemistry learning activities; observe involved systematic documentation through classroom observations, questionnaires, and student artifacts; and reflect corresponded to the evaluation stage, in which outcomes were analyzed and improvements were identified for future cycles. Thus, the CAR framework structured how the PjBL intervention was studied and refined. The overall research flow is illustrated as follows at Figure 1.

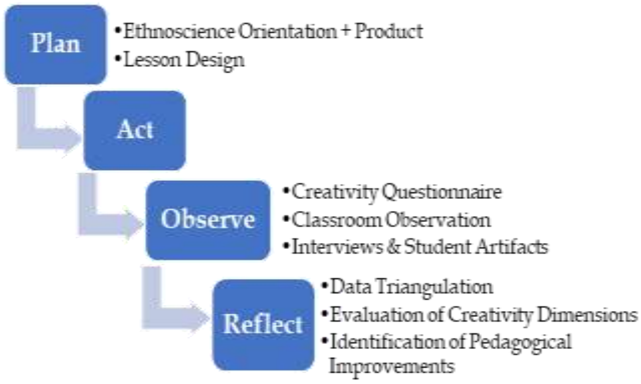

Figure 1. CAR Framework with PjBL Intervention

This cycle ensures that creativity is not only measured but examined as part of an iterative instructional improvement process. The creativity questionnaire was developed based on established creativity and educational psychology frameworks, particularly drawing from Torrance's theory of creative thinking (elaboration and originality) and problem-based learning and integrative learning theories (problem solving and synthesis) (Amabile, 1996; Hmelo-Silver, 2004; Krajcik & Blumenfeld, 2006). Elaboration measures the ability to expand and detail ideas, which reflects instructional planning depth in PCK; originality captures novelty in product and learning design; resolution (Problem Solving) represents the ability to address procedural, conceptual, and pedagogical challenges; and synthesis reflects the integration of chemical concepts, empirical data, cultural knowledge, and pedagogical goals into coherent learning designs. This four-dimension structure is particularly suitable for ethnoscience-based projects because it captures not only idea generation, but also pedagogically meaningful creativity, which is essential for teacher education. The data were analyzed using thematic analysis and triangulation techniques to ensure the validity of the findings, by comparing the results of observations, interviews, and questionnaires.

Result and Discussion

The ethnoscience-based durian acid project was implemented using a Classroom Action Research (CAR) framework integrated with Project-Based Learning (PjBL). The learning intervention followed four pedagogical stages—orientation, planning, implementation, and evaluation—which were embedded within the CAR cycles of Plan–Act–Observe–Reflect. This structure enabled systematic documentation of instructional improvement while simultaneously capturing quantitative creativity data and qualitative classroom evidence. The implementation process and product development were guided by the durian acid ethnoscience module (Figure 2).

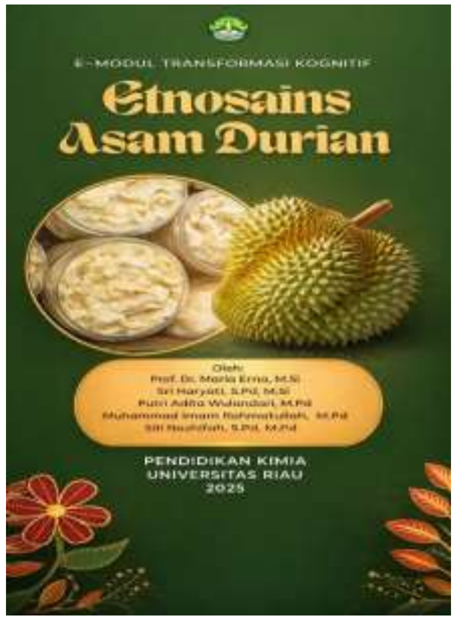

Figure 2. Module of durian acid ethnoscience

PjBL-CAR Orientation Stage (Plan Phase)

At the orientation stage, which corresponds to the plan phase of the CAR cycle, prospective chemistry teachers explored ethnoscience concepts and contextualized durian acid within local cultural practices and chemistry learning. The learning activities were based on the durian acid ethnoscience module (Figure 2), which introduces ethnoscience concepts, product examples, design procedures, classroom integration strategies, and reflection guidelines.

Through group discussions, prospective chemistry teachers built a shared understanding of how ethnoscience can explain natural phenomena and support chemistry learning, especially regarding fermentation and the emergence of acidic characteristics in durian-based processing. In addition, prospective chemistry teachers examined examples of durian acid products available in daily life and on the market, such as traditional foods and preservative applications (Suryana, 2020; Hartono, 2021). During this stage, many prospective chemistry teachers began linking observed products to chemistry concepts—particularly fermentation processes and possible chemical changes occurring during durian acid production.

PjBL-CAR Planning Stage (Plan Phase)

The planning stage also formed part of the plan phase in the CAR framework. At this stage, prospective chemistry teachers translated ethnoscience exploration into structured learning designs and product plans. Prospective chemistry teachers developed independent product ideas and translated them into concrete plans, including product objectives, ingredient selection, basic procedures, and the integration of relevant chemistry concepts. The proposed products included durian acid tonic, durian acid crisps, durian acid sauce, and durian acid essence. This stage emphasized not only product development but also pedagogical planning, ensuring that the products could function as contextual chemistry learning resources (Sutrisno & Dewi, 2022).

PjBL-CAR Implementation Stage (Act Phase)

The implementation stage represents the act phase of the CAR cycle, where the planned ethnoscience-based intervention was executed through hands-on product development and classroom integration. Prospective chemistry teachers produced durian acid products according to their designs. While several products demonstrated innovation, some groups faced technical constraints that required iterative revisions. Lecturer and peer feedback supported procedural refinement, reflecting the iterative nature of project-based product development (Ulrich & Eppinger, 2019). Implementation also included translating the product into learning practice. As summarized in Table 1, students designed learning activities such as pH measurement, chemical reaction demonstrations, solution preparation and dilution experiments, and acid strength comparisons.

Table 1. The Result of Implementation in Learning

Material	Implementation in learning
Application of the concept of acids and bases	The prospective chemistry teachers use durian acid products to demonstrate the properties of durian acid through ph measurement and comparison with other ingredients.
Use of chemical reactions	The prospective chemistry teachers design experiments that show the reaction of durian acid with other materials to produce a change in color or gas, teaching the concept of chemical reactions.
Solution preparation and dilution	The prospective chemistry teachers designed an experiment to prepare a solution with various concentrations of durian acid and measure its effect on pH.
Comparison with other materials	The prospective chemistry teachers designed a ph comparison experiment between durian acid and other chemicals to introduce the concept of differences in acid strength.

The variety of durian acid products and learning activities designed during the Act phase demonstrates the development of Pedagogical Content Knowledge (PCK). Prospective chemistry teachers transformed abstract chemistry concepts into observable learning representations such as fermentation-based acidity measurement, dilution experiments, and reaction demonstrations. This aligns with the PCK framework emphasizing the transformation of subject matter into pedagogically accessible forms (Driel et al., 2002).

PjBL-CAR Evaluation Stage (Reflect Phase)

The evaluation stage corresponds to the reflect phase of the CAR cycle, in which prospective chemistry teachers and instructors analyzed learning outcomes, identified weaknesses, and formulated improvement strategies for subsequent instructional refinement. Prospective chemistry teachers reflected on procedural challenges, product limitations, and learning integration issues. Many reported improved creative and critical thinking skills, particularly in linking cultural context with scientific explanation and instructional design (Stevenson & O'Brien, 2021).

The Data of Creativity Questionnaire (Observe Phase)

Creativity questionnaire data represent the observe phase of CAR, capturing quantitative patterns across four creativity dimensions: elaboration, originality, problem solving, and synthesis. Table 2 presents the distribution of student responses across PjBL stages.

Table 2. The Results of Creativity Questionnaire

Creativity indicator	PjBL stage	Percentage				
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Elaboration	1	0%	2%	10%	60%	28%
	2	1%	0%	5%	63%	31%
	3	0%	0%	12%	56%	32%
	4	0%	0%	26%	52%	22%
Originality	1	0%	0%	9%	53%	38%
	2	0%	1%	12%	55%	32%
	3	1%	0%	15%	44%	40%
	4	1%	1%	19%	54%	25%
Problem solving	1	2%	0%	5%	47%	46%
	2	0%	0%	20%	62%	18%

Creativity indicator	PjBL stage	Percentage				
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	3	0%	0%	20%	56%	24%
	4	0%	0%	21%	57%	22%
Synthesis	1	0%	0%	13%	46%	41%
	2	0%	1%	22%	65%	12%
	3	0%	0%	21%	57%	22%
	4	0%	1%	21%	50%	28%

As shown in Table 2, high levels of elaboration, originality, problem solving, and synthesis were observed during the orientation, planning, and implementation phases (agree + strongly agree = 74–93%). However, neutral responses increased during the evaluation phase, particularly for elaboration and synthesis, indicating reduced confidence in scientific interpretation and integration.

Elaboration Indicator Analysis

Figure 3 illustrates elaboration trends across CAR cycles, showing strong idea expansion during plan and act phases but weaker performance during Reflect. This pattern suggests that students excel in procedural planning but require stronger scaffolding for analytical reflection. The prospective chemistry teachers with high creativity will be better able to develop learning plans that integrate chemistry material with relevant local products. In this context, ethnoscience-based durian acid learning will provide a more interesting and contextual learning experience and improve understanding of chemistry concepts, such as acid-base reactions or fermentation.

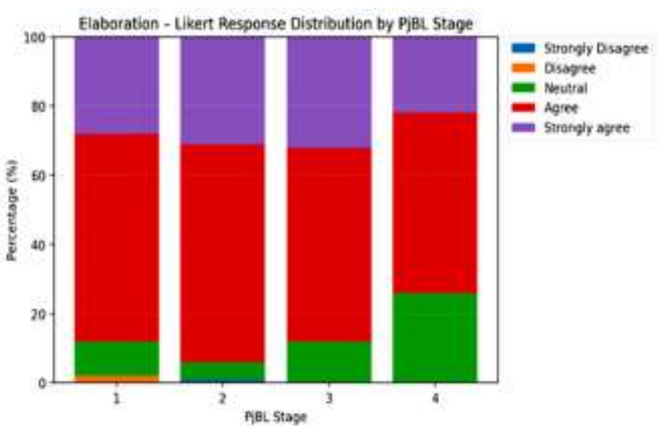

Figure 3. The data of elaboration indicator

Creativity in elaboration is very important in the development of an ethnoscience-based curriculum because it facilitates teachers in connecting chemistry knowledge with local culture, which in turn increases the depth of learning (Krajcik & Blumenfeld, 2006; Susilawati et al. 2025). This pattern is consistent with previous ethnoscience studies reporting that contextual learning materials stimulate idea elaboration and originality by encouraging students to relate scientific concepts to familiar cultural practices (Mashami et al., 2023; Sari et al., 2024). International research also confirms that project-based science environments promote creative ideation and product innovation (Albar & Southcott, 2021; Li & Tu, 2024).

Originality Indicator Analysis

Figure 4 indicates high originality during planning and implementation, while novelty declined slightly during evaluation due to feasibility considerations and result validation requirements. This shows that prospective chemistry teachers involved in developing ethnoscience-based products, such as durian acid, have the potential to introduce creative ideas in chemistry teaching that differ from conventional approaches. The novelty of integrating these local products not only provides a new dimension to learning but also provides a more applicable learning experience that is relevant to students' daily lives. According to Amabile (1996), novelty in the context of education can lead to deeper and more creative learning, which is important in ethnoscience-based chemistry teaching because it connects science with local cultural practices.

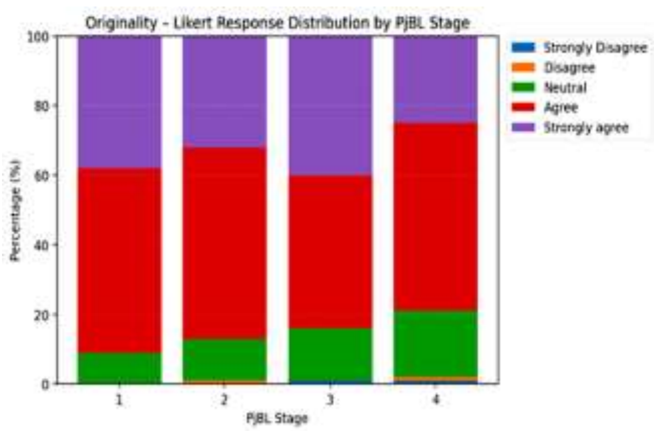

Figure 4. The data of originality indicator

Problem Solving Indicator Analysis

Figure 5 shows strong problem-solving performance during act and observe phases, supported by iterative experimentation and troubleshooting activities. The problem-solving process, which includes developing methods for making durian acid, testing its chemical content, and applying it in chemistry learning, is an important aspect of creating a holistic learning experience. In chemistry teaching, problem solving also includes the ability to connect theory with real-world applications, which is expected to improve students' understanding of chemistry concepts. Problem solving is an integral part of project-based education, which focuses on providing practical solutions to challenges faced by students in real-world contexts (Bell, 2010). Similar trends were reported in chemistry project-based laboratory studies, where students demonstrated stronger troubleshooting ability and procedural reasoning when working on authentic experimental tasks (Wang et al., 2021; Vergara-Castañeda et al., 2021). The other findings also support this pattern, indicating that PjBL improves science process skills and applied problem solving (Dibyantini et al., 2023).

Furthermore, the high scores in the problem-solving dimension align with the theoretical and empirical literature on project-based science learning. Bell (2010) emphasized that PjBL encourages learners to confront real-world constraints and iteratively improve their solutions, a pattern that was clearly observed when students adjusted fermentation methods, pH testing procedures, and product designs. This finding is also supported by Bayani et al. (2024), who showed that ethnomedicine-integrated PjBL promotes higher-order thinking, including problem solving and creativity, by situating learning in authentic cultural practices. In the context of this study, durian acid functioned as both a chemical substance and a cultural artifact, requiring students to apply scientific reasoning while respecting traditional knowledge.

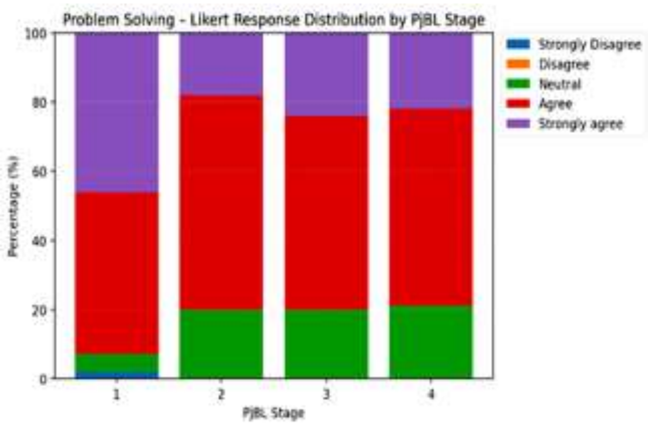

Figure 5. The data of problem solving indicator

Synthesis Indicator Analysis

Synthesis in ethnoscience-based learning serves to integrate various chemical concepts and elements of local culture, such as the process of making durian acid, into a more comprehensive learning experience as shown in Figure 6. Creative teachers will be able to bring together ideas from various disciplines, including chemistry and culture, so that students can see the connections between the concepts being taught. Good synthesis can result in more interdisciplinary teaching and motivate students to think critically. Synthesis in project-based learning helps students connect the various knowledge they have acquired from various sources, including local knowledge, and apply it in a broader context (Hmelo-Silver, 2004).

The synthesis dimension was most challenging during the reflect phase. Prospective chemistry teachers struggled to integrate fermentation chemistry, acid–base equilibrium, pH interpretation, and pedagogical application into cohesive explanations. Many groups could state that durian acid is "acidic," but struggled to explain buffering effects, weak acid dissociation, or the relationship between fermentation time and acidity changes. This reveals that synthesis in ethnoscience-based learning requires not only cultural relevance but also deep conceptual coherence, a central requirement of chemistry PCK. Difficulties in integrating experimental data, theory, and contextual knowledge during evaluation stages have also been reported in interdisciplinary chemistry projects (Piard et al., 2025; Greenwood et al., 2022). Similar challenges were observed in ethnoscience-based learning in Indonesia, highlighting the need for structured scaffolding to support conceptual integration (Yuliana et al., 2023; Marsila et al., 2025).

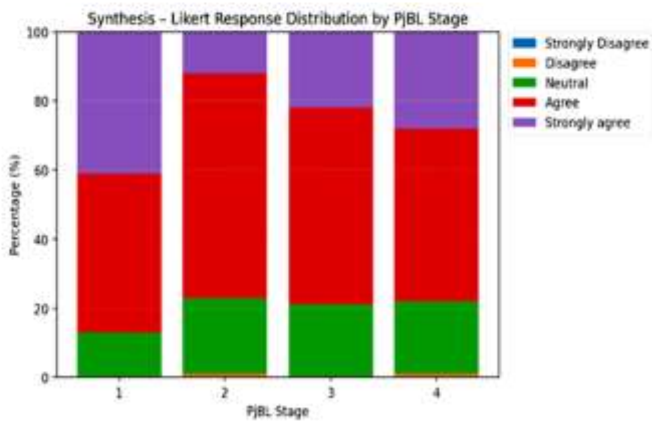

Figure 6. The data of synthesis indicator

The results of this study show that the ethnoscience-based durian acid product development project successfully elicited multiple dimensions of creativity among prospective chemistry teachers, particularly elaboration, originality, problem solving, and synthesis. Questionnaire data revealed that more than 74–93% of participants agreed or strongly agreed across all creativity dimensions during the orientation, planning, and implementation stages, indicating strong engagement in idea development, experimentation, and contextualization of chemistry concepts.

These findings are consistent with previous research showing that project-based learning (PjBL) provides an effective environment for fostering creative thinking in pre-service teachers. Suryandari et al. (2018) and Yamin et al. (2020) reported that engaging students in authentic projects significantly improves creativity indicators such as fluency, originality, and elaboration. Similarly, Christiana et al. (2024), in their meta-analysis of ethnoscience-based chemistry learning, found that culturally contextualized problem- and project-based models significantly enhance students' creative thinking skills. The strong elaboration and originality observed during the planning and implementation stages in this study confirm these conclusions, demonstrating that ethnoscience-based product development allows teacher candidates to generate diverse and meaningful ideas grounded in local culture.

The Data of Triangulation (Observe–Reflect Integration)

Triangulation combined questionnaire data (observe), classroom observation evidence (observe), and reflective interviews (reflect). This integration ensured convergence across data sources and strengthened analytical validity.

Based on the questionnaire results, it was found that elaboration showed responses dominated by agree/strongly agree from the orientation to evaluation stages, with the strongest achievement in planning and a downward/more neutral trend in evaluation. This is in line with the observation findings that in the orientation-planning stage, students detailed the steps for making durian acid, prepared tools/materials, determined variables, divided roles, and prepared worksheets/lesson plans; in the implementation stage, they revised procedures and enriched the documentation of results; while in the evaluation stage, some groups lacked depth in scientific reflection and data-based conclusions. Interviews also reinforced that detailed planning helped idea development, but the evaluation stage required stronger scientific justification, so that the triangulation conclusions were convergent and pointed to the need for scaffolding at the evaluation stage.

In terms of originality, the questionnaire showed stable and strong positive responses in planning and implementation, but weakened slightly during evaluation. Observations supported this through the emergence of new ideas (product/activity variations), experimental modifications, different demonstration methods, and the integration of durian acid into everyday contexts, while during evaluation, novelty decreased due to a focus on validating results and feasibility of implementation. Interviews confirm that the local context triggers innovative ideas, but it is difficult to prove "uniqueness" during evaluation; thus, triangulation is considered convergent, but partially divergent at the evaluation stage because novelty needs to be supported by scientific evidence and pedagogical reasons.

In problem solving, the questionnaire showed high positive responses that remained strong but tended to be more neutral in the final stage. Observations highlighted implementation in the form of troubleshooting (unstable pH, failed/different fermentation, limited tools/materials), retesting, changes in ratios/treatment, team discussions, and reference consultations; while in evaluation, the challenges lay in preparing solution justifications and the relevance of solutions to learning objectives. Interviews described the trial and error process and time/equipment constraints as factors affecting the final stage, resulting in convergent triangulation. Strengthening through troubleshooting logbooks and evidence-based evaluation rubrics is recommended.

Meanwhile, in synthesis, the questionnaires tended to be positive but relatively more challenging in planning/evaluation (more neutral). Observations show that students associate durian acid production with chemical concepts (acids–bases/fermentation), organize concept flows, and attempt to combine data–theory–cultural context in learning design, but difficulties arise when integrating everything into a coherent learning narrative, especially at the evaluation stage. Interviews reinforced that the integration of culture and chemistry is interesting but difficult to organize into a single set of materials and assessments, so triangulation was considered convergent with recommendations for support such as concept maps or argumentation frames. The triangulation results in Table 3 below can be concluded.

Table 3 shows generally convergent triangulation, but partial divergence was evident in the originality dimension during the evaluation stage. While questionnaire data indicated that students perceived their products as novel, classroom observations revealed that several outputs were adaptations of existing ideas rather than genuinely innovative instructional designs. This discrepancy, together with the decline in creativity indicators during the evaluation phase, reflects a weakness in the evaluative, reflective, and analytical components of Pedagogical Content Knowledge (PCK).

Although students were able to design and conduct experiments effectively, many experienced difficulties in interpreting pH data, justifying chemical reactions, and linking experimental results to acid–base theory. As a result, their procedural and representational PCK appeared stronger than their analytical and reflective PCK, leading to a gap between self-perceived creativity and evidence-based pedagogical innovation. This finding suggests that future teacher education programs must not only encourage creative expression, but also explicitly train prospective teachers to demonstrate creativity through scientifically grounded reasoning and pedagogically justified instructional design, enabling them to explain not only how a phenomenon occurs, but also why it occurs within a coherent conceptual framework.

Table 3. The Results of Data Triangulation

Dimension of creativity	Triangulation conclusion
Elaboration	Convergent: strong elaboration on planning/implementation; Evaluation requires scaffolding (reflection guide & report template).
Originality	Convergent: novelty emerges during design & implementation; Partial divergence in evaluation because novelty must be supported by scientific evidence and pedagogical reasons.
Problem solving	Convergent: PjBL gives rise to real problem solving; Improvement can be done through logbook troubleshooting and evidence-based evaluation rubrics.
Synthesis	Convergent: synthesis occurs, but is most challenging when it comes to integrating evidence, concepts, and cultural contexts into the final product; Need a concept map/argumentation frame.

These findings are consistent with previous research showing that ethnoscience-based PjBL promotes creative engagement during design and implementation, but that evaluation and synthesis require higher-level PCK and scientific reasoning (Christiana & Rohaeti, 2024; Krajcik & Blumenfeld, 2006). Similarly, studies on pre-service chemistry teachers have shown that difficulties in explaining acid–base equilibrium and data interpretation are major obstacles in developing robust PCK (Aydın & Akın, 2022; Shaafi et al., 2025).

The triangulated results demonstrate that ethnoscience-based durian acid projects effectively foster creativity during the design and experimentation stages, while simultaneously revealing a critical need to strengthen data-driven reflection, conceptual explanation, and the synthesis of chemistry concepts within Pedagogical Content Knowledge (PCK). Addressing these weaknesses through structured instructional scaffolding can enhance the role of such projects in preparing scientifically competent and creatively capable chemistry teachers.

The convergence between quantitative and qualitative evidence further supports these findings. Questionnaire data showing positive trends in elaboration, originality, problem solving, and synthesis were reinforced by classroom observations and interviews. Observations documented creative behaviors during the planning and implementation stages, including detailed idea development, emerging novelty, adaptive problem-solving strategies, and efforts to integrate scientific concepts with cultural contexts. Interviews clarified why some participants demonstrated more neutral responses during the evaluation stage, highlighting the need for stronger support in evidence-based reflection, scientific justification, and the integration of concepts, data, and ethnoscience into coherent learning products.

The creativity profile across the four dimensions indicates that the ethnoscience-based durian acid product development project provides a meaningful learning context for prospective chemistry teachers to elaborate ideas, generate novel products, solve practical problems, and synthesize chemistry content with local cultural values. These outcomes are consistent with expert claims that ethnoscience-based instructional models strengthen creative thinking in chemistry learning (Christiana & Rohaeti, 2024) and that contextual learning approaches promote higher-order cognitive abilities by linking scientific concepts with local cultural practices (Dewi et al., 2021; Doyan et al., 2023).

Empirical evidence from project-based learning research further reinforces this interpretation. Studies involving pre-service teachers have shown that engagement in authentic projects systematically enhances creativity indicators such as fluency, elaboration, originality, and flexibility (Suryandari et al., 2018; Yamin et al., 2020). In addition, systematic reviews of ethnomedicine-integrated PjBL highlight its effectiveness in promoting higher-order thinking, including creativity, within professional education contexts (Bayani et al., 2024). Together, these findings confirm that ethnoscience-based product development provides a theoretically grounded and empirically supported environment for cultivating creative competencies in teacher education.

Notably, the triangulation pattern observed in this study—characterized by strong elaboration and originality during design and implementation but weaker synthesis during evaluation—mirrors the findings reported by Sumarni et al. (2025). Their work similarly emphasizes that ethnoscience-enriched PjBL enhances creative ideation and collaboration, while requiring additional instructional scaffolding to support reflective integration and conceptual justification. This convergence strengthens the validity of the present findings and underscores the importance of structured reflection mechanisms in ethnoscience-based learning designs.

Within the CAR-integrated PjBL framework, creativity development was most prominent during the Plan and Act phases, whereas the Reflect phase revealed persistent challenges related to data interpretation, scientific justification, and conceptual synthesis. This pattern highlights the necessity of reinforcing reflective scaffolding strategies to ensure that creative activities are accompanied by robust analytical reasoning and conceptual coherence.

Taken together, the alignment between this study and prior empirical and theoretical research confirms that ethnoscience-based durian acid product development represents a scientifically sound and pedagogically effective approach for cultivating creativity in chemistry teacher education. By embedding chemical learning within culturally meaningful product design, this approach contributes to growing international evidence demonstrating that project-based chemistry education integrated with contextual and cultural elements provides a powerful learning environment for developing creativity, higher-order thinking skills, and pedagogical competence among pre-service teachers (Prokša et al., 2023; Piard et al., 2025; Li & Tu, 2024).

Conclusion

The CAR-integrated ethnoscience-based PjBL durian acid product provided a valid and culturally grounded context for developing pre-service chemistry teachers' PCK-driven creativity, with questionnaire results showing consistently high agreement (74–93%) in elaboration, originality, problem solving, and synthesis during the orientation–planning–implementation stages, reinforced by observations and interviews documenting detailed design work, emerging novelty, and iterative troubleshooting in hands-on product development and learning integration. Nevertheless, increased neutral responses during the evaluation (Reflect) phase—together with partial divergence in originality between self-perceptions and observation evidence—revealed a critical weakness in the evaluative, reflective, and analytical components of PCK, particularly the ability to interpret pH data, justify chemical reactions, and coherently included fermentation chemistry, pH interpretation, solution dilution, and acid strength comparisons, and pedagogical application into evidence-based explanations. These findings indicate that participants' procedural and representational PCK was stronger than their analytical and reflective PCK, underscoring the need for teacher education programs to strengthen professional competencies in scientific argumentation, data literacy, and reflective reasoning so that future teachers can explain not only how but also why chemical phenomena occur. To enhance transferability across comparable teacher-education contexts, institutions should embed ethnoscience-enriched PjBL within the curriculum as a structured PCK-development pathway, supported by systematic scaffolding (reflection guides, report templates, concept maps/argumentation frames, and troubleshooting logbooks) and program-level assessment rubrics that explicitly evaluate evidence-based pedagogical innovation, thereby ensuring culturally contextualized chemistry learning aligns with SDG 4 through measurable, sustainable improvements in teacher competence.

Acknowledgments
Thank you to the University of Riau for facilitating this research through the Institute for Research and Community Service of the University of Riau.

Author Contributions
Conceptualization, M.E; Writing—Review and Editing, S.N; Methodology, S.H; Writing—Original Draft Preparation, P.A.W; Data Curation, M.I.R.

Funding
This research and article publication fees (APC) was funded by the DIPA LPPM UNRI with contract number 20637/UN19.5.1.3/AL.04/2025.

Conflicts of Interest
No conflict of interest is declared by authors.

References

Albar, S. B., & Southcott, J. E. (2021). Problem and project-based learning through an investigation lesson: Significant gains in creative thinking behaviour within the Australian foundation (preparatory) classroom. *Thinking Skills and Creativity, 41*, 100853. https://doi.org/10.1016/j.tsc.2021.100853

Amabile, T. M. (1996). *Creativity in context: Update to the social psychology of creativity*. Westview Press.

Aydin-Gunbatar, S., & Akin, F. N. (2022). Pre-service chemistry teachers' use of pedagogical transformation competence to develop topic-specific pedagogical content knowledge for planning to teach acid–base equilibrium. *Chemistry Education Research and Practice, 23*(1), 137-158. https://doi.org/10.1039/d1rp00106j

Bakır, S., & Öztekin, E. (2014). Creative thinking levels of preservice science teachers in terms of different variables. *Journal of Baltic Science Education, 13*(2), 231. https://doi.org/10.33225/jbse/14.13.231

Bayani, F., Rokhmat, J., Hakim, A., & Sukarso, A. A. (2024). A systematic literature review at integrating ethnomedicine into project-based learning: Enhancing higher-order thinking skills in pharmaceutical education. *Jurnal Penelitian Pendidikan IPA*, 10(12), 996–1005. https://doi.org/10.29303/jppipa.v10i12.10065

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Christiana, L., & Rohaeti, E. (2024). Does ethnoscience based problem based learning model improve student's creative thinking skill in chemistry learning? Meta-analysis. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 96–104. https://doi.org/10.29303/jppipa.v10i3.6915

Chu, C., Dewey, J. L., & Zheng, W. (2023). An inorganic chemistry laboratory technique course using scaffolded, inquiry-based laboratories and project-based learning. *Journal of Chemical Education, 100*(9), 3500–3508. https://doi.org/10.1021/acs.jchemed.3c00547

Dewi, C. A., Erna, M., Martini, M., Haris, I., & Kundera, I. N. (2021). The effect of contextual collaborative learning based ethnoscience to increase student's scientific literacy ability. *Journal of Turkish Science Education*, *18*(3), 525–541. https://doi.org/10.36681/tused.2021.88

Dibyantini, R. E., Amdayani, S., Siregar, M. I., & Syafriani, D. (2023). Application of STEM-PjBL Based Chemistry Module to Improve Science Literacy and Student Learning Motivation. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 95–102. https://doi.org/10.29303/jppipa.v9iSpecialIssue.5872

Driel, J., Jong, O., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education, 86*(4), 572-590. https://doi.org/10.1002/sce.10010

Doyan, A., Susilawati, Harjono, A., Muliyadi, L., Hamidi, Fuadi, H., & Handayana, I. G. N. Y. (2023). The effectiveness of modern optical learning devices during the Covid-19 pandemic to improve creativity and generic science skills of students. *The 1st International Conference on Science Education and Sciences*, 020005. https://doi.org/10.1063/5.0122553

Fitri, M. N., Asrizal, Amnah, R., Hidayati, Emiliannur, & Helma. (2024). Development of Global Warming E-Module Integrated with PBL Model and Ethnoscience to Promote Students' Environmental Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8276–8289. https://doi.org/10.29303/jppipa.v10i11.9059

Greenwood, K. A., & colleagues. (2022). Citizen science and project-based approaches in chemistry education. *Chemistry Education Research and Practice.* https://doi.org/10.1039/D1RP00190F

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Ismulyati, S., Mariati, M., Armi, A., & Alfiansyah, I. (2025). Validation and practicality of biotechnology teaching materials ethnoscience based to improve students' entrepreneurial interests. *Proceedings of ICE, 3*(1), 266-271. https://doi.org/10.32672/pice.v3i1.3486

Januarti, I. M., & Muliyadi, L. (2024). Development of Ethnoscience-Based Student Worksheet Using the Guided Inquiry Learning Model to Increase Students' Learning Motivation and Scientific Literacy: A Review. *International Journal of Science Education and Science*, *1*(1), 13–18. https://doi.org/10.56566/ijses.v1i1.109

Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning. In *The Cambridge handbook of the learning sciences* (pp. 317–334). Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.020

Li, M.-M., & Tu, C.-C. (2024). Developing a project-based learning course model combined with the Think–Pair–Share strategy to enhance creative thinking skills in education students. *Education Sciences, 14*(3), 233. https://doi.org/10.3390/educsci14030233

Mahbubah, K., Santoso, A., & Djatmiko, R. (2025). Preliminary design: development of capillarity e-module based ethnoscience to promoting students' science literacy. *Jurnal Pendidikan Fisika Dan Teknologi, 11*(1), 1-7. https://doi.org/10.29303/jpft.v11i1.7261

Marsila, N., Yerimadesi, Alizar, & Andromeda. (2025). Development of an Acid-Base E-Module Based on Guided Discovery Learning with Ethnoscience Content to Improve Literacy and Numeracy. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 1125–1135. https://doi.org/10.29303/jppipa.v11i8.12439

Mashami, R. A., Suryati, S., Harisanti, B. M., & Khery, Y. (2023). Identification of Local Wisdom of The Sasak Tribe In Chemistry Learning as an Effort to Strengthen Student Character. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 337–345. https://doi.org/10.29303/jppipa.v9i1.2434

Muzaifa, M., Moulana, R., Aisyah, Y., Sulaiman, I., & Rezeki, T. (2015). Karakteristik kimia dan mikrobiologis asam drien (durian fermentasi dari

Aceh) pada berbagai metode pembuatan. *AGRITECH, 35*(3), 288–293. https://doi.org/10.22146/agritech.9339

Nazhifah, S., Erna. M., Wulandari, P.A., & Azuga, N.A., (2025). Ethnoscience study of shrimp paste at the Meranti Islands as a representation of chemistry learning. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 57–68. https://doi.org/10.12345/jppipa.v10i1.6789

Nurhayati, E., Andayani, Y., & Hakim, A. (2021). Pengembangan e-modul kimia berbasis STEM dengan pendekatan etnosains. *Chemistry Education Practice, 4*(2), 106–112. https://doi.org/10.23456/cep.v4i2.11234

Piard, J., Barreau, L., & Lambert, M. (2025). Interdisciplinary dialogue and project-based learning: Chemistry and design students collaborate on scientific exhibition. *Journal of Chemical Education, 102*(9), 3945. https://doi.org/10.1021/acs.jchemed.5c00442

Prokša, M., Križanová, M., Drozdíková, A., & Haláková, Z. (2023). Experiences with student projects focusing on chemistry shows in undergraduate chemistry teacher education. *Journal of Chemical Education.* https://doi.org/10.1021/acs.jchemed.3c00531

Sari, M. P., Muttaqiin, A., Putri, R. E., & Oktavia, R. (2024). Integrating Ethnoscience on Critical-Thinking Oriented Web-Based E-Module of Secondary School Science. *Jurnal Penelitian Pendidikan IPA*, *10*(1), 371–384. https://doi.org/10.29303/jppipa.v10i1.5928

Setyowati, D., Afryaningsih, Y., & Nurcahyo, M. A. (2023). Kajian etnosains pada pembelajaran di sekolah dasar. *Jurnal Pendidikan Informatika dan Sains*, *12*(1), 225–235. https://doi.org/10.56789/jpis.v12i1.22345

Shaafi, N., Yusof, M., Ellianawati, E., Subali, B., & Raji'e, M. (2025). Investigating misconceptions about acids and bases among pre-service science teachers. *Journal of Education and Learning (Edulearn),* 19(1), 460-477. https://doi.org/10.11591/edulearn.v19i1.21803

Sumarni, W., Sumarti, S., Dewi, S., & Imaduddin, M. (2025). Collaborative ethno-steam enriched project-based learning (coe-steam-pjbl): its impact on prospective science teachers' collaboration and creative thinking skills. *Jurnal Pendidikan Ipa Indonesia, 14*(3). https://doi.org/10.15294/jpii.v14i3.25487

Suryandari, K. C., Sajidan, S., Rahardjo, S. B., Prasetyo, Z. K., & Fatimah, S. (2018). Project-based science learning and pre-service teachers' science literacy skill and creative thinking. *Jurnal Cakrawala Pendidikan*, 37(3), 345–355. https://doi.org/10.21831/cp.v37i3.17229

Susilawati, Doyan, A., Rokhmat, J., Muliyadi, L., Rizaldi, D. R., Fatimah, Z., Ikhsan, M., & Ardianti, N. R. (2025). Integration of Smartphone-Based Learning Media and Project-Based Learning to Enhance Creativity and Scientific Literacy in Physics. *International Journal of Information and Education Technology*, *15*(7), 1449–1459. https://doi.org/10.18178/ijiet.2025.15.7.2346

Tahya, D., Dahoklory, F. S., & Dahoklory, S. R. (2022). The development of local wisdom-based chemistry modules to improve students' science process skills. *Jurnal Penelitian Pendidikan IPA, **8***(2), 731–739. https://doi.org/10.29303/jppipa.v8i2.142

Usmeldi, U., & Amini, R. (2022). Creative project-based learning model to increase creativity of vocational high school students. *International Journal of Evaluation and Research in Education, 11*(4), 2155–2164. https://doi.org/10.11591/ijere.v11i4.21214

Utari, R., Andayani, Y., Savalas, L. R. T., & Anwar, Y. A. S. (2021). Validity of ethnoscience based chemistry learning media emphasizing character values and conservation behavior. *Jurnal Penelitian Pendidikan IPA, 7*(1), 45–48. https://doi.org/10.29303/jppipa.v7i1.469

Vergara-Castañeda, A., Cervera-Ceballos, E., & colleagues. (2021). Learning organic chemistry through online practical courses: A case study. *Journal of Chemical Education, 98*(11), 3502–3508. https://doi.org/10.1021/acs.jchemed.1c00379

Wahyudiati, D., & Qurniati, D. (2023). Ethnochemistry: Exploring the potential of Sasak and Javanese local wisdom as a source of chemistry learning to improve the learning outcomes of pre-service teachers. *Jurnal Pendidikan Kimia Indonesia, 6(2)*, 116–122. https://doi.org/10.23887/jpki.v6i2.49890

Wang, Y., Cao, J., & colleagues. (2021). Improving student understanding of organic compound separation through project-based learning. *Journal of Chemical Education, 98*(9), 2789–2797. https://doi.org/10.1021/acs.jchemed.0c01245

Yamin, Y., Permanasari, A., Redjeki, S., & Sopandi, W. (2020). Project-based learning to enhance creative thinking skills of the non-science students. *JHSS (Journal of Humanities and Social Studies), 4*(2), 107–111. https://doi.org/10.33751/jhss.v4i2.2450

Yang, Y., Li, J., & colleagues. (2021). Virtual laboratory as a tool to promote fermentation-related chemistry learning. *Journal of Chemical Education.* https://doi.org/10.1021/acs.jchemed.0c01227

Yuliana, Y., Fathurohman, A., & Siahaan, S. M. (2023). Analysis of Needs for the Development of Local Wisdom-Based Junior High School Science E-Modules Related to Ethnoscience in South Sumatera. *Jurnal Penelitian Pendidikan IPA*, *9*(10),

7865–7870.
https://doi.org/10.29303/jppipa.v9i10.5292

Zuraidah, Z., Nursanty, R., & Rahmi, R. (2024). Morphology of bacteria and fungi from the fermentation of asam drien as a local food ingredient of West Aceh. *BIOTIK: Jurnal Ilmiah Biologi Teknologi dan Kependidikan, 12*(2), 212–227. https://doi.org/10.22373/biotik.v12i2.26137