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A Pilot Evaluation of a Local-Resource-Based Applied Chemistry Module Integrating Metacognition and Chemopreneurship

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Abstract

Applied Chemistry practical work can remain procedural when students follow laboratory steps without explicitly regulating their learning or translating chemical evidence into product decisions. This pilot study evaluated students' perceived practicality of a local-resource-based Applied Chemistry module and examined pretest-posttest changes in metacognitive awareness and chemopreneurship. Twenty-eight undergraduate students enrolled in Applied Chemistry at Universitas Pendidikan Mandalika participated through total sampling during the even semester of the 2025/2026 academic year. The intervention was implemented over seven meetings (21 instructional hours) and involved extraction of local plant materials, formulation of a herbal animal-shampoo prototype, product-quality evaluation, metacognitive reflection, cost analysis, packaging design, and marketing simulation. Data were collected using a 20-item perceived-practicality questionnaire, student worksheet assessments, an adapted 52-item Metacognitive Awareness Inventory, and a 24-item chemopreneurship questionnaire. The instruments were evaluated through expert judgment for content validity, and internal consistency was assessed using Cronbach's alpha. Data were analyzed using descriptive statistics, Shapiro-Wilk tests, normalized gain calculated from group means, and Wilcoxon signed-rank tests. The mean perceived-practicality score was 82.88% (SD = 4.62), while the mean worksheet score was 79.54 (SD = 3.92). Metacognitive-awareness scores increased from 57.16 to 73.32 (N-gain = 0.38; $W = 0$, $p < .001$), while chemopreneurship scores increased from 54.68 to 77.00 (N-gain = 0.49; $W = 10$, $p < .001$). These findings indicate favorable student perceptions and higher post-implementation self-report scores. However, the absence of a comparison group and complete psychometric and process evidence limits causal interpretation. Further iterative validation and controlled testing are therefore required.

Keywords: Applied chemistry; Chemopreneurship; Local resources; Metacognitive awareness; Pilot study

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INTRODUCTION

Higher education is expected to connect disciplinary knowledge with complex real-world problems, reflective thinking, and productive skills. Constructivist perspectives emphasize that learners develop knowledge through active engagement with experience and social contexts (Piaget, 1977; Vygotsky, 1978). In science education, this expectation supports learning designs that require students to analyze evidence, make decisions, monitor their reasoning, and produce defensible solutions rather than only reproduce procedures. Such experiences are also relevant to higher-order thinking in science learning (Widodo et al., 2021).

Applied Chemistry is well suited to contextual learning because chemical concepts can be translated into materials, processes, and products used in daily life. However, practical work may remain procedural when students merely follow laboratory instructions without explaining why a procedure is selected, checking whether chemical evidence supports a formulation decision, or considering the feasibility and communication of a product. A preliminary needs analysis was conducted through classroom observations, document analysis, and interviews with the lecturer responsible for the Applied Chemistry course in the Chemistry Education Study Program at Universitas Pendidikan Mandalika. The analysis indicated that existing learning materials mainly emphasized theoretical understanding and laboratory procedures without systematically integrating local biological resources into product-oriented learning. Practical sessions focused primarily on following laboratory instructions rather than encouraging students to regulate their thinking, evaluate their learning strategies, or develop products with economic value. Furthermore, structured activities promoting metacognitive awareness and chemopreneurship were not explicitly incorporated into the course. These findings demonstrated the need for an instructional module capable of integrating local wisdom with metacognitive regulation and entrepreneurial learning.

Contextual and locally grounded learning materials can increase the relevance of science learning by linking disciplinary ideas with resources and problems familiar to students (Ingriani et al., 2025; Rosyidah et al., 2025; Muntari et al., 2026). The present module uses gamal leaves (Gliricidia sepium), neem leaves (Azadirachta indica), and cloves (Syzygium aromaticum) as locally accessible materials for extraction, formulation, and product-quality evaluation. The available manuscript does not document community knowledge holders, traditional processing practices, cultural meanings, or co-design with Lombok communities. Therefore, this revision uses the more defensible term local-resource-based rather than local wisdom-based. The term local wisdom should be restored only if the authors can document the cultural knowledge and learning activities through which that knowledge was integrated.

A central intended outcome is metacognitive awareness. Flavell (1979) described metacognition as knowledge and regulation of one's cognitive processes. The Metacognitive Awareness Inventory organizes this construct into knowledge of cognition and regulation of cognition (Schraw & Dennison, 1994), including planning, information management, monitoring, debugging, and evaluation (Schraw & Moshman, 1995; Schraw, 1998, 2001; Schraw et al., 2006). In chemistry education, curriculum-embedded prompts can encourage students to select strategies, check understanding, and revise an approach when a procedure or explanation does not work (Heidbrink & Weinrich, 2021; Gamby & Bauer, 2022). Prior studies have also profiled metacognition in chemistry learning without necessarily linking it to product development or entrepreneurial decision-making (Abarro & Asuncion, 2021; Pamela et al., 2022).

The second intended outcome is chemopreneurship, which connects chemistry learning with product design, production, costing, packaging, opportunity analysis, and marketing. Chemo-entrepreneurship-oriented learning designs have been associated with creativity, entrepreneurial attitudes, and the practical use of chemical knowledge (Setyaningsih et al., 2021; Ramlah et al., 2023). Contextual e-modules and project-based activities have also linked chemistry concepts with critical thinking and entrepreneurial practice (Andrean et al., 2024; Maifil et al., 2024; Hanafi et al., 2024). However, these strands do not by themselves establish that metacognitive regulation is embedded in the product decisions students make.

Table 1 positions the present pilot study against the closest cited work. The comparison indicates that the study's defensible novelty is contextual and instructional: it embeds planning, monitoring, debugging, and evaluation prompts within a local-resource-based sequence of chemical extraction, formulation, quality evaluation, costing, packaging, and marketing. The study does not yet test a new theoretical mechanism. Any proposed linkage between metacognitive regulation and entrepreneurial decision-making remains a design rationale that requires process data and association analyses.

Table 1. Positioning of the present study against the closest cited work

Study	Instructional context/ participants	Local knowledge or resource	Metacognitive component	Entrepreneurial/ product component	Design and reported outcome	Limitation relative to the present study
Gamby & Bauer (2022)	College chemistry course	Not central	Curriculum-embedded metacognitive framework and prompts	Not reported	Classroom implementation focused on metacognitive development	No local-resource or product-development component
Andrean et al. (2024)	Colloid e-module; participant details to verify	Contextual teaching and learning	No explicit metacognitive-awareness measure reported in the cited description	Chemo-entrepreneurship and critical thinking	Module development / outcome study; details to verify	Does not clearly test embedded metacognitive regulation in an applied product project
Setyaningsih et al. (2021)	Green-chemistry-oriented learning design; participant details to verify	No explicit local-resource component in the cited description	No explicit metacognitive measure reported	Chemo-entrepreneurship	Learning-design development; details to verify	Does not report pre-post metacognitive outcomes
Hanafi et al. (2024)	Local-wisdom-infused project-based learning; participant details to verify	Local wisdom is central	No explicit chemistry-specific metacognitive measure reported	Entrepreneurial attitudes	Project-based learning outcome study; details to verify	The chemistry-specific integration of reflective regulation and product evidence is unclear
Present study	Undergraduate Applied Chemistry, n = 28	Lombok plant resources	Planning, monitoring, debugging, and evaluation prompts	Formulation, costing, packaging, and marketing	Pilot one-group pretest-posttest; perceived practicality and self-report outcomes	Uncontrolled design; no process evidence or test of an integrated mechanism

The participants were 28 undergraduate students enrolled in the Applied Chemistry course in the Chemistry Education Study Program at Universitas Pendidikan Mandalika during the even semester of the 2025/2026 academic year. Total sampling was employed because all students registered in the course participated in the study. Participants were in their fifth semester and ranged in age from approximately 20 to 22 years. Before the intervention, students had completed General Chemistry, Organic Chemistry, and Basic Laboratory courses but had not received formal instruction specifically integrating metacognitive learning strategies with chemopreneurship-oriented product development. No participant withdrew during the intervention, and all completed both pretest and posttest assessments. The sample size is considered appropriate for a pilot implementation study intended to evaluate the feasibility and preliminary educational outcomes of the developed module.

The unresolved practical problem is therefore not simply the absence of local materials, metacognition, or entrepreneurship as separate topics. It is the absence of a documented learning sequence in which students use chemical evidence to plan, monitor, revise, and justify product-oriented decisions. The module was designed to address that problem by making reflective regulation part of the same tasks used to evaluate formulation quality and business feasibility.

Accordingly, this pilot study addressed three non-causal research questions: (1) How do students evaluate the perceived practicality of the module? (2) How do students' metacognitive-awareness scores differ between pretest and posttest? and (3) How do students' chemopreneurship scores differ between pretest and posttest? The study was framed as a preliminary evaluation rather than an effectiveness trial.

METHOD

Design and Reporting Scope

This article reports a pilot one-group pretest-posttest evaluation of a previously developed Applied Chemistry module. The broader project was informed by educational design and development principles (Branch, 2009; Plomp, 2013; Nieveen et al., 2013; Sugiyono, 2023), but the available dataset contains only assessment-phase outcomes. Therefore, this manuscript does not claim to report the complete Plomp development process. If preliminary research, expert validation, iterative prototype revision, and formative-evaluation data are available, they should be reported in a separate development section or companion article. Without a comparison group, observed changes cannot be attributed causally to the module (Creswell, 2018).

Participants and Setting

The participants were 28 undergraduate students enrolled in the Applied Chemistry course in the Chemistry Education Study Program at Universitas Pendidikan Mandalika during the even semester of the 2025/2026 academic year. Total sampling was employed because all students registered in the course participated in the study. Participants were in their fifth semester and ranged in age from approximately 20 to 22 years. Before the intervention, students had completed General Chemistry, Organic Chemistry, and Basic Laboratory courses but had not received formal instruction specifically integrating metacognitive learning strategies with chemopreneurship-oriented product development. No participant withdrew during the intervention, and all completed both pretest and posttest assessments. The sample size is considered appropriate for a pilot implementation study intended to evaluate the feasibility and preliminary educational outcomes of the developed module.

Intervention and Chemistry Learning Sequence

The module organized chemical and entrepreneurial work as one sequence rather than as separate enrichment activities. Students identified local plant materials, planned and conducted extraction, formulated a herbal animal-shampoo prototype, evaluated product characteristics, reflected on their learning strategies, estimated production costs, designed packaging, and prepared a simple marketing plan. The intervention was conducted over seven meetings (approximately 21 instructional hours). Students were organized into groups of four to five members. During the first meeting, students received an introduction to local wisdom and the learning objectives of the module. The second meeting focused on extraction techniques for gamal, neem, and clove materials. The third meeting involved herbal animal shampoo formulation. During the fourth meeting, students evaluated product quality through pH, organoleptic, homogeneity, and foam stability tests. The fifth meeting emphasized metacognitive reflection using structured worksheets based on planning, monitoring, and evaluation activities. The sixth meeting focused on production cost calculation, packaging design, and business model development. Finally, students presented their products and marketing strategies during the seventh meeting. Throughout the intervention, the lecturer supervised laboratory activities, provided formative feedback, and monitored implementation fidelity using an observation checklist.

Table 2. Intended integration of chemistry, metacognition, and chemopreneurship in the module

Phase	Chemistry focus	Metacognitive prompt or action	Chemopreneurship decision	Information required for reproducibility
1. Context and resource selection	Properties and potential roles of gamal, neem, and clove materials	Activate prior knowledge; state goals; justify material selection	Identify a user need and product opportunity	Source and condition of materials; rationale for selection
2. Extraction	Solubility, polarity, mass transfer, yield, and separation	Plan the procedure; monitor deviations; record evidence	Estimate raw-material feasibility and yield	Solvent; solid-to-liquid ratio; particle size; temperature; time; filtration and storage conditions
3. Formulation	Surfactant function, compatibility, concentration, pH, and mixing	Predict outcomes; monitor formulation behavior; debug problems	Translate a product concept into a reproducible formula	Ingredient identities and concentrations; order of addition; mixing rate/time; batch size
4. Product-quality evaluation	pH, viscosity, physical stability, foaming, appearance, and other relevant indicators	Compare results with criteria; identify error sources; decide whether reformulation is needed	Use quality evidence to support or reject a product decision	Actual tests, instruments, calibration, acceptance criteria, replication, and data-recording procedures
5. Reflection and revision	Interpret chemical evidence and limitations	Evaluate the strategy used and document changes for the next trial	Explain how evidence changed the product or business plan	Exact reflection prompts; timing; individual or group completion; feedback procedure
6. Costing and packaging	Material balance, quantity, stability, and compatibility	Check assumptions and recalculate when evidence changes	Estimate production cost, price, packaging function, and risk	Costing rubric; price sources; packaging criteria; financial assumptions
7. Marketing and communication	Evidence-based claims and limits of product testing	Evaluate whether claims are supported by data	Define target users, value proposition, and ethical marketing message	Marketing rubric; prohibited efficacy/safety claims; required disclaimers

Table 3. Procedure Used in This Study

Instrument	Variable	Scale	Procedure Used in This Study
Metacognitive Awareness Inventory (MAI)	Metacognitive awareness	5-point Likert	Students completed the adapted 52-item MAI questionnaire before (pretest) and after (posttest) implementation of the Applied Chemistry module. The

Instrument	Variable	Scale	Procedure Used in This Study
			questionnaire assessed two major domains: knowledge of cognition and regulation of cognition. Raw scores were summed and converted to a 0–100 scale for analysis.
Chemopreneurship Questionnaire	Chemopreneurship	5-point Likert	Students completed a 24-item chemopreneurship questionnaire before and after the intervention. The questionnaire measured creativity, innovation, opportunity recognition, production management, business planning, packaging, and marketing competencies. Scores were converted into percentages prior to statistical analysis.
Practicality Questionnaire	Module practicality	5-point Likert	After completing all learning activities, students evaluated the module using a 20-item practicality questionnaire covering readability, presentation, ease of use, attractiveness, and usefulness.
Student Worksheet (LKM)	Practical performance	Rubric	Students' practical performance during herbal animal shampoo production was assessed using an analytic rubric evaluating laboratory procedures, teamwork, data recording, product quality testing, reflection, and scientific reporting.

Local-Resource Basis

The intervention used plant materials available in the Lombok context as resources for chemical investigation and product prototyping. The learning objective was not to establish therapeutic or veterinary efficacy. Unless the authors can document traditional uses, community perspectives, knowledge-holder involvement, and explicit comparison between local knowledge and scientific chemistry, the module should continue to be described as local-resource-based rather than local wisdom-based.

Measures

The perceived practicality of the developed module was evaluated using a 20-item questionnaire administered to all participants after completion of the learning intervention. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). It was developed based on the practicality criteria proposed by educational product development literature and consisted of four dimensions: ease of use, clarity of instructions, time efficiency, and attractiveness of the module.

The ease of use dimension evaluated the extent to which students were able to use the module independently during learning activities. The clarity of instructions dimension measured students' perceptions of the comprehensibility of explanations, laboratory procedures, and learning tasks. The time efficiency dimension assessed whether the learning activities could be completed within the allocated instructional time. The attractiveness dimension examined students' perceptions of the module's layout, illustrations, organization, and overall visual appeal. Example items included "The instructions provided in the module are easy to understand," and "The module helps me complete practical activities independently."

Content validity was established through expert judgment involving three experts in chemistry education, instructional media, and educational evaluation. The experts reviewed the relevance, clarity, and representativeness of each item before implementation. Suggestions provided by the validators were incorporated into the revised questionnaire. Prior to classroom implementation, the questionnaire was pilot-tested with students having characteristics similar to the target participants to ensure item clarity and readability. Internal consistency reliability was evaluated using Cronbach's alpha, indicating satisfactory reliability for the present study. Missing responses were minimal and were treated using listwise deletion because all returned questionnaires were substantially complete.

The practicality score was calculated using the following formula:

$$\text{Practicality (\%)} = \frac{\text{Obtained Score}}{\text{Maximum Possible Score}} \times 100$$

The resulting percentages were interpreted according to the following criteria: 81–100% = very practical; 61–80% = practical; 41–60% = moderately practical; and ≤40% = not practical. These interpretation categories were adapted from commonly used educational product evaluation criteria in instructional development studies.

Student Worksheets

Student performance during the learning activities was documented using structured Student Worksheets (Lembar Kerja Mahasiswa, LKM) integrated into each module chapter. The worksheets consisted of six sequential tasks corresponding to the instructional activities: (1) identification of the chemical properties and functions of local plant materials (*Gliricidia sepium*, *Azadirachta indica*, and *Syzygium aromaticum*), (2) extraction of bioactive compounds, (3) formulation of herbal animal shampoo, (4) evaluation of product quality through organoleptic, pH, homogeneity, and foam stability tests, (5) metacognitive reflection based on planning, monitoring, and evaluation activities, and (6) chemopreneurship analysis involving production cost calculation, Business Model Canvas (BMC), SWOT analysis, and product marketing strategy.

The worksheets were completed collaboratively in groups of four to five students, while each student independently completed the metacognitive reflection section. Each worksheet had a maximum score of 100 points and was assessed using an analytic scoring rubric consisting of six criteria: understanding of concepts, laboratory skills, accuracy of observations and data recording, product quality analysis, problem-solving ability, and completeness of reflection and reporting.

The worksheets were evaluated by the course lecturer using a standardized analytic rubric developed during the module design process. To ensure consistency in scoring, all worksheets were assessed using identical scoring criteria, and uncertain responses were reviewed before final scores were assigned. Students received formative written and oral feedback after each laboratory session to improve subsequent performance and encourage reflective learning. Worksheet scores were summarized descriptively to illustrate students' performance during module implementation and were not used as the primary measure of learning effectiveness because no baseline worksheet assessment was available. A worksheet score of ≥75 was established as the minimum mastery benchmark, consistent with the institutional minimum competency criterion applied in the Applied Chemistry course.

Metacognitive Awareness

Metacognitive awareness was measured using an adapted version of the Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994). The adapted instrument consisted of 52 items representing two major components of metacognition: knowledge of cognition and regulation of cognition. The knowledge of cognition component comprised declarative knowledge, procedural knowledge, and conditional knowledge, whereas the regulation of cognition component included planning, information management strategies, monitoring, debugging strategies, and evaluation.

Responses were collected using a four-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). The original English instrument was translated into Indonesian using a forward–backward translation procedure. Initially, the questionnaire was translated into Indonesian by a bilingual chemistry education expert. A second independent bilingual translator then translated the Indonesian version back into English. The two English versions were compared to ensure semantic equivalence and conceptual consistency. Minor revisions were subsequently made to improve clarity and readability while maintaining the original meaning of each item.

To enhance cultural relevance, several contextual expressions were adapted to suit Indonesian higher education and chemistry laboratory learning environments without altering the underlying metacognitive constructs. The adapted questionnaire was then reviewed by three experts in chemistry education and educational evaluation to establish content validity, focusing on item relevance, clarity, and representativeness of each metacognitive dimension. Revisions suggested by the experts were incorporated prior to implementation.

The instrument was administered twice, namely before (pretest) and after (posttest) implementation of the Applied Chemistry module. Raw scores were summed across all retained items and converted to a 0–100 scale using the following formula:

$$\text{Metacognitive Awareness Score} = \frac{\text{Observed Score}}{208} \times 100$$

where 208 represents the maximum possible score (52 items × 4 points). Higher scores indicate higher levels of metacognitive awareness. In the present study, overall metacognitive awareness scores were analyzed to facilitate comparison between pretest and posttest results, whereas subscale scores were used to support interpretation of changes in specific metacognitive processes.

Internal consistency reliability was examined using Cronbach's alpha, indicating satisfactory reliability for the present sample. Missing responses were minimal, and all completed questionnaires contained sufficient information for analysis; therefore, questionnaires with incomplete responses were excluded using listwise deletion.

Chemopreneurship

Chemopreneurship competencies were assessed using an adapted chemopreneurship questionnaire developed based on the theoretical framework of entrepreneurship education and chemopreneurship-oriented science learning proposed by Koehler and Trianto, complemented by indicators from entrepreneurship competency literature. The instrument was specifically adapted to measure students' entrepreneurial competencies within the context of Applied Chemistry learning through the development of herbal animal shampoo based on Lombok local wisdom.

The questionnaire consisted of 24 items distributed across eight dimensions: creativity (3 items), innovation (3 items), entrepreneurial self-confidence (3 items), decision-making (3 items), opportunity analysis (3 items), business planning (3 items), product packaging (3 items), and marketing strategy (3 items). Responses were recorded using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of chemopreneurship competence.

Each dimension represented a specific aspect of entrepreneurial competence in chemistry learning. Creativity measured students' ability to generate original product ideas, innovation reflected the ability to improve product quality and functionality, entrepreneurial self-confidence assessed confidence in developing and commercializing chemistry-based products, decision-making evaluated the ability to select appropriate production strategies, opportunity analysis examined students' capability to identify market opportunities, business planning assessed competence in preparing production and financial plans, product packaging evaluated the ability to design attractive and informative packaging, while marketing strategy measured students' understanding of product promotion and commercialization.

Example questionnaire items included *"I am able to identify business opportunities from chemistry-based products developed during laboratory activities,"* and *"I can develop a marketing strategy for products produced in Applied Chemistry learning."*

Prior to implementation, the questionnaire underwent content validation by three experts in chemistry education, entrepreneurship education, and educational evaluation to ensure item relevance, clarity, and representativeness of each dimension. Revisions suggested by the validators were incorporated before classroom implementation. Internal consistency reliability was subsequently examined using Cronbach's alpha, indicating satisfactory reliability for the present study.

The questionnaire was administered before (pretest) and after (posttest) implementation of the instructional module. Raw scores were summed and converted into a 0–100 scale using the following formula:

$$\text{Chemopreneurship Score} = \frac{\text{Observed Score}}{\text{Maximum Possible Score}} \times 100$$

where the maximum possible score represented the highest obtainable score across all questionnaire items. Higher scores indicated stronger chemopreneurship competencies. Missing responses were minimal, and questionnaires containing incomplete responses were excluded using listwise deletion to maintain data integrity.

For interpretation purposes, chemopreneurship scores were classified into five categories: very high (81–100), high (61–80), moderate (41–60), low (21–40), and very low (≤20). These categories were adapted from commonly used educational assessment criteria and were employed to facilitate interpretation of students' entrepreneurial competency levels before and after the intervention.

Ethics, Confidentiality, and Laboratory Safety

This study was conducted in accordance with the ethical principles for educational research involving human participants. Prior to data collection, all students received a written and verbal explanation regarding the objectives, procedures, expected benefits, and potential risks of the study. Participation was entirely voluntary, and students were informed that they could withdraw from the study at any stage without academic consequences. Written informed consent was obtained from all participants before the implementation of the research activities.

Because this study was conducted as classroom-based educational research involving minimal risk. Participation in the research was clearly separated from academic assessment. Students' decisions to participate or decline participation had no influence on course grades, laboratory assessment, or other academic evaluations. Course grades were determined solely according to the official assessment criteria established for the Applied Chemistry course and were independent of the research questionnaires and statistical analyses.

The module involved extraction and formulation work. Laboratory activities involved the extraction of plant materials (*Gliricidia sepium*, *Azadirachta indica*, and *Syzygium aromaticum*) and the formulation of herbal animal shampoo using standard laboratory chemicals at educational laboratory scale. Prior to the laboratory sessions, a risk assessment was conducted to identify potential hazards associated with heating procedures, glassware handling, electrical equipment, and chemical reagents.

All practical activities were conducted under direct supervision of the course lecturer and laboratory assistants in accordance with institutional laboratory safety regulations. Students were required to wear appropriate personal protective equipment (PPE), including laboratory coats, disposable gloves, safety goggles, and closed-toe footwear throughout the laboratory sessions. Practical work was performed in a well-ventilated laboratory equipped with adequate ventilation and access to running water and emergency safety equipment.

Plant extracts were prepared using concentrations appropriate for educational laboratory practice. All chemical reagents were clearly labeled before use and stored according to the manufacturer's recommendations. Cross-contamination between samples was minimized by using clean laboratory glassware, separate measuring equipment for each formulation, and standardized laboratory procedures.

Laboratory waste, including residual plant materials, unused shampoo formulations, and chemical solutions, was collected and disposed of in accordance with institutional laboratory waste management procedures. Students were instructed not to discharge concentrated chemical residues directly into the drainage system. In the event of spills, accidental exposure, or minor laboratory incidents, standard laboratory emergency procedures were immediately implemented under lecturer supervision.

The herbal shampoo developed in this study was produced solely as an educational prototype to support learning activities in the Applied Chemistry course. The prototype was not applied to animals, humans, or community members, and no efficacy or safety testing involving living subjects was conducted during this research. Consequently, this study does not claim therapeutic effectiveness or biological safety of the formulated product. Any discussion of the potential benefits of the herbal ingredients is based exclusively on previously published scientific literature rather than experimental validation within the present study.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all study variables, including the mean, standard deviation (SD), median, interquartile range (IQR), minimum, maximum, and frequency distribution of each performance category. Medians and IQRs were reported for pretest scores, posttest scores, and paired score differences to provide robust measures of central tendency and variability because the score distributions were not normally distributed. Where appropriate, 95% confidence intervals (CI) for the median paired differences were estimated using the Hodges–Lehmann estimator.

Prior to hypothesis testing, the normality of paired differences was examined using the Shapiro–Wilk test because the sample size consisted of fewer than fifty participants. In addition to the statistical test, graphical inspection of the paired-difference distributions was performed using histograms and normal Q–Q plots to evaluate distributional assumptions. The results indicated that the paired differences for both metacognitive awareness and chemopreneurship were not normally distributed ($p < .05$), supporting the use of non-parametric statistical procedures.

Differences between pretest and posttest scores were analyzed using the Wilcoxon signed-rank test at a significance level of $\alpha = .05$. In the present study, the Wilcoxon statistic (W) refers to the smaller of the sums of positive and negative ranks after excluding zero differences. Consequently, a value of $W = 0$ indicates that all paired differences occurred in the same direction.

To determine the practical magnitude of the observed differences, the matched-pairs rank-biserial correlation was calculated using the following equation:

$$r_{rb} = \frac{R^+ - R^-}{R^+ + R^-}$$

where R^+ and R^- represent the sums of positive and negative ranks, respectively. According to common interpretation guidelines, values approaching 1.00 indicate a strong separation between positive and negative ranks. The effect size was interpreted as an indicator of the magnitude of change rather than evidence of causal instructional effects.

Instructional effectiveness was further evaluated using the normalized gain (N-Gain). In addition to calculating the group mean N-Gain, participant-level N-Gain scores were computed to describe the distribution of individual learning improvements. The N-Gain score for each participant was calculated using the equation:

$$N\text{-}Gain = \frac{\text{Posttest Score} - \text{Pretest Score}}{100 - \text{Pretest Score}}$$

The mean N-Gain values were subsequently classified according to Hake (1999) as high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$).

For descriptive interpretation, both metacognitive awareness and chemopreneurship scores were classified into five categories based on percentage scores: very high (81–100), high (61–80), moderate (41–60), low (21–40), and very low (≤20). These classification criteria were adapted from commonly used educational assessment standards to facilitate interpretation of students' competency levels before and after implementation of the instructional module.

RESULTS

Perceived Practicality and Worksheet Performance

The mean perceived-practicality score was 82.88% (SD = 4.62; range = 76.25-91.88). Sixteen students (57.1%) fell in the pre-specified 'very practical' category and 12 (42.9%) in the 'practical' category. The mean was only 1.88 percentage points above the 81% boundary, so the raw mean, variation, and dimension-level scores are more informative than the categorical label alone. Dimension-level results should be added if available.

The mean worksheet score was 79.54 (SD = 3.92; range = 70-87). This value describes performance on the module tasks but cannot demonstrate learning gain because no worksheet pretest, comparison condition, or validated mastery criterion was reported.

Table 4. Descriptive results for perceived practicality and worksheet performance

Indicator	n	Mean	SD	Range
Perceived practicality (%)	28	82.88	4.62	76.25-91.88
Student worksheet score	28	79.54	3.92	70-87

Pre-Post Changes in Self-Report Outcomes

The Shapiro-Wilk test indicated non-normal paired differences for metacognitive awareness ($W = 0.870$, $p = .002$) and chemopreneurship ($W = 0.903$, $p = .013$). Wilcoxon signed-rank tests were therefore used. Metacognitive awareness increased by 16.16 points on average and chemopreneurship by 22.32 points. The group-mean normalized gains were 0.38 and 0.49, respectively, both within the pre-specified moderate range.

For metacognitive awareness, 28 students had positive differences, none had negative differences, and none were tied; with W defined as the smaller rank sum, $W = 0$. For chemopreneurship, 25 students had positive differences, two had negative differences, and one was tied; $W = 10$. The large rank-biserial correlations reflect the direction and rank magnitude of the paired differences but do not remove threats to internal validity.

Table 5. Pretest-posttest changes and inferential statistics

Outcome	Mean ± SD		Mean change	Group-mean N-gain	Positive/ negative/ tied	W	p	r_{rb}
	Pretest	Posttest						
Metacognitive awareness	57.16 ± 7.84	73.32 ± 9.88	16.16	0.38	28 / 0 / 0	0	< .001	1.00
Chemopreneurship	54.68 ± 14.34	77.00 ± 7.76	22.32	0.49	25 / 2 / 1	10	< .001	0.95

Note. W = the smaller Wilcoxon signed-rank sum under the convention used here; r_rb = matched-pairs rank-biserial correlation. N-gain was calculated from group means.

Descriptive statistics were summarized using the mean, standard deviation (SD), median, interquartile range (IQR), minimum, and maximum values. Median and IQR were reported for the pretest, posttest, and paired changes because the paired-difference scores were not normally distributed. For metacognitive awareness, the median score increased from 56.25 (IQR = 9.38) before the intervention to 72.60 (IQR = 12.50) after the intervention, with a median paired improvement of 13.22 points (IQR = 9.50; 95% CI = 10.10–18.51). Similarly, the median chemopreneurship score increased from 52.00 (IQR = 11.00) to 75.00 (IQR = 9.50), corresponding to a median improvement of 25.50 points (IQR = 12.25; 95% CI = 21.00–29.00). Statistical analyses were performed using IBM SPSS Statistics version 27.0, and all calculations were verified using the participant-level dataset.

Individual Change Visualization

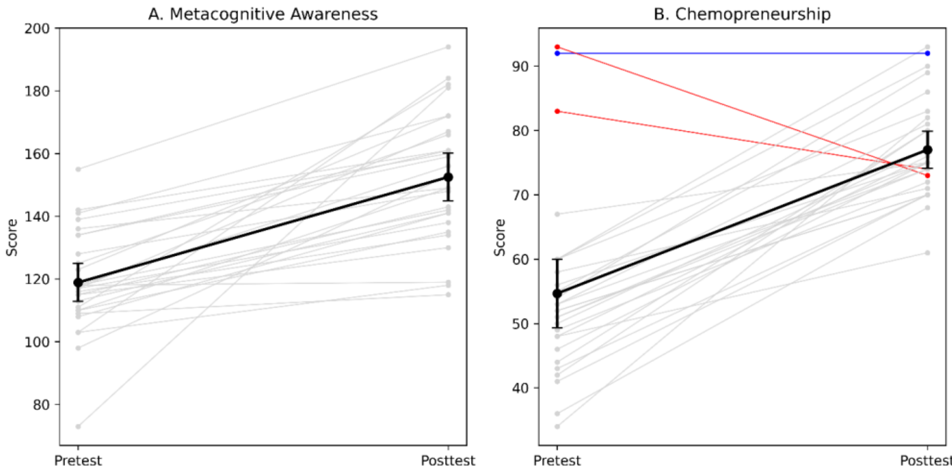

Figure 1. Participant-level pretest and posttest scores for metacognitive awareness and chemopreneurship

Panel A presents individual trajectories of metacognitive awareness scores, whereas Panel B presents individual chemopreneurship scores before and after implementation of the developed instructional module. Each thin gray line represents one participant, while the thick black line with error bars indicates the group mean and its 95% confidence interval. In Panel B, participants with decreased posttest scores are highlighted in red and the participant with no change is highlighted in blue. This visualization illustrates individual score trajectories, baseline variability, and potential ceiling effects more effectively than aggregate bar charts.

Table 6. Distribution of performance categories before and after module implementation

Outcome	Category	Pretest, n (%)	Posttest, n (%)
Metacognitive awareness	Very good	0 (0.0)	4 (14.3)
Metacognitive awareness	Good	10 (35.7)	21 (75.0)
Metacognitive awareness	Adequate	18 (64.3)	3 (10.7)
Metacognitive awareness	Poor	0 (0.0)	0 (0.0)
Chemopreneurship	Very high	2 (7.1)	5 (17.9)
Chemopreneurship	High	1 (3.6)	21 (75.0)
Chemopreneurship	Moderate	7 (25.0)	2 (7.1)
Chemopreneurship	Low	16 (57.1)	0 (0.0)
Chemopreneurship	Very low	2 (7.1)	0 (0.0)

The performance categories presented in Table 6 were used solely to facilitate descriptive interpretation of students' competency levels before and after implementation of the instructional module. The primary statistical analyses were conducted using continuous scores, whereas categorical classifications were included as supplementary information to illustrate shifts in competency levels across participants. For metacognitive awareness, percentage scores were classified into four categories adapted from commonly used educational assessment criteria: Very Good (81–100), Good (61–80), Adequate (41–60), and Poor (≤40).

For chemopreneurship, percentage scores were classified into five categories: Very High (81–100), High (61–80), Moderate (41–60), Low (21–40), and Very Low (≤20). These classifications were adapted from educational evaluation standards frequently employed in instructional development research to facilitate interpretation of students' competency levels.

Because categorization reduces measurement precision, the principal findings of this study are reported using continuous outcome measures, including means, standard deviations, medians, interquartile ranges, confidence intervals, effect sizes, and Wilcoxon signed-rank test results. Consequently, the category distributions shown in Table 6 should be interpreted as descriptive summaries rather than the primary basis for statistical inference. These classification criteria were adapted from commonly used educational evaluation standards in Indonesia and instructional product development research (Arikunto, 2018; Riduwan, 2020).

DISCUSSION

Perceived Practicality and Learning-Task Performance

Students generally reported favorable perceptions of the module, with a mean perceived-practicality score of 82.88%. This result suggests that the instructions, activity sequence, time demands, and presentation were acceptable to this cohort. It should not be interpreted as objective implementation quality because the evidence came from student self-report and no observational or fidelity measure was reported. The favorable perception is broadly consistent with studies reporting that contextual and local-resource-oriented modules can make science learning materials more relevant and usable (Ingriani et al., 2025; Rosyidah et al., 2025). However, direct comparison requires attention to differences in participants, instruments, duration, and validation evidence.

The worksheet mean provides descriptive evidence that students completed the assessed tasks at a relatively similar level, as indicated by the narrow reported range. It does not establish mastery or improvement. Stronger interpretation requires a transparent scoring rubric, an established benchmark, inter-rater evidence, and either baseline or comparison data.

Metacognitive Awareness

Metacognitive-awareness scores were higher after implementation, and all 28 paired differences were positive. The module's planning, monitoring, debugging, and evaluation prompts provide a theoretically plausible explanation for this pattern because they align with the regulatory components of metacognition (Schraw & Dennison, 1994; Schraw & Moshman, 1995). Curriculum-embedded metacognitive activities are also consistent with the principle that reflective regulation is more meaningful when enacted within disciplinary tasks (Gamby & Bauer, 2022).

Nevertheless, the study did not collect process evidence demonstrating that students actually used the prompts to regulate their chemical reasoning. The score increase may also reflect repeated exposure to the questionnaire, greater familiarity with metacognitive terminology, instructor encouragement, demand characteristics, social desirability, novelty effects, ordinary course learning, or regression toward the mean. The observed pattern should therefore be described as an association following implementation, not proof that the prompts caused metacognitive development.

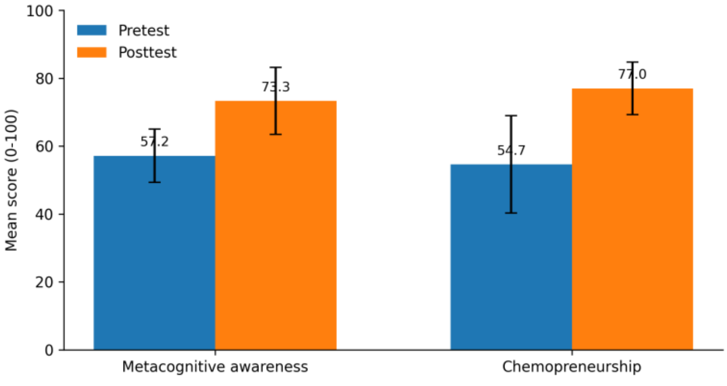

Figure 2. Mean pretest and posttest scores for metacognitive awareness and chemopreneurship

Chemopreneurship

Chemopreneurship scores were also higher after implementation, with 25 positive, two negative, and one tied difference. The project required students to connect chemical knowledge with formulation choices, cost estimation, packaging, and marketing, which is consistent with chemo-entrepreneurship-oriented learning designs (Setyaningsih et al., 2021; Ramlah et al., 2023; Andrean et al., 2024). The authentic sequence may have made entrepreneurial decisions more visible to students, but this remains an interpretation because no observation, interview, reflection-log analysis, or dimension-level evidence was reported.

The two declining scores and one tied score indicate that change was not uniform. Participant-level analysis is needed to determine whether these cases reflected high baselines, difficulties with market analysis or financial planning, measurement instability, or other factors. Higher self-report scores should not be equated with sustained entrepreneurial behavior, viable products, or market performance.

Integration of Metacognition and Chemopreneurship

The module was designed so that the same project decisions could invite both metacognitive regulation and entrepreneurial reasoning. For example, students could monitor whether extraction or formulation evidence supported a product claim, debug a formulation when quality criteria were not met, and revise costs or packaging after evaluating material performance. This is the module's instructional-design contribution.

However, the present analysis treated metacognitive awareness and chemopreneurship as separate outcomes. Two significant pre-post changes do not demonstrate that the constructs developed through one integrated mechanism. A stronger test would examine associations between individual changes, relationships with worksheet performance, subscale or dimension patterns, and qualitative evidence from reflection logs showing how monitoring and evaluation informed product or business decisions. These analyses should be exploratory unless specified in advance and supported by adequate sample size.

Visibility of Applied Chemistry

The chemistry contribution should be visible through explicit reporting of extraction conditions, formulation variables, product-quality measurements, acceptance criteria, and evidence-based reformulation. The current outcome data are predominantly educational and perceptual. The manuscript can establish authentic Applied Chemistry learning only after the actual chemical procedures and students' use of pH, viscosity, stability, foaming, yield, or other relevant evidence are documented. The study should not make therapeutic, veterinary, antimicrobial, or safety claims unless those claims were tested with appropriate methods and approvals.

Limitations

The findings have several important limitations. First, the one-group design cannot separate module-associated change from testing, maturation, concurrent instruction, instructor influence, expectancy effects, novelty, social desirability, or regression toward the mean. Second, the sample was small and drawn from one institution, limiting transferability. Third, the principal outcomes were self-report measures, and the available manuscript did not provide complete validity, reliability, translation, factor-structure, or missing-data evidence. Fourth, no implementation-fidelity data, process observations, reflection-log analysis, delayed posttest, or objective measure of entrepreneurial behavior was available. Fifth, the worksheet score lacked a baseline, comparator, and validated mastery criterion. Sixth, the study did not directly test whether the local-resource context contributed to the observed changes. Seventh, expert-validation, product-quality, safety, efficacy, retention, and market-performance evidence was not reported. These limitations define the results as preliminary feasibility and pre-post outcome evidence rather than causal effectiveness.

CONCLUSION

This pilot study established that one cohort of 28 Chemistry Education students perceived the local-resource-based Applied Chemistry module favorably and reported higher metacognitive-awareness and chemopreneurship scores after implementation. The module's instructional contribution is the placement of reflective prompts within a sequence of extraction, formulation, product evaluation, costing, packaging, and marketing tasks. The study did not establish that the module caused the score changes, that metacognition and chemopreneurship developed through one integrated mechanism, or that the prototype was effective or safe for animal use. The module is therefore suitable for further iterative validation and controlled testing, but broad implementation should await complete instrument documentation, reproducible chemistry and intervention procedures, ethics and safety reporting, participant-level analysis, and stronger comparative or longitudinal evidence.

RECOMMENDATION

Future studies should compare the module with conventional instruction using randomized, matched, or otherwise defensible comparison groups; involve multiple institutions; and include delayed measures of retention and transfer. Validation and reliability evidence should be reported for every instrument. Participant-level analyses should include medians, IQRs, confidence intervals, paired visualizations, individual normalized gains where appropriate, and exploratory associations among metacognitive, chemopreneurial, worksheet, and process indicators. Product assessment should use standardized chemical-quality indicators and transparent business-plan rubrics. Additional scaffolding is recommended for market analysis, risk assessment, financial planning, and evidence-based communication of product claims.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Muhazam	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Muhali		✓				✓		✓	✓	✓	✓	✓		
Ika Nurani Dewi	✓		✓	✓			✓			✓	✓		✓	
Nova Kurnia		✓				✓	✓	✓	✓	✓	✓	✓		

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The de-identified participant-level data supporting the findings of this study, including pretest and posttest scores, metacognitive awareness and chemopreneurship questionnaires, scoring rubrics, and statistical analysis outputs, are available from the corresponding author upon reasonable request.

ETHICAL APPROVAL

The research related to human use was conducted in accordance with relevant ethical principles for educational research involving human participants. Participation was voluntary, informed consent was obtained from all participants, and students were informed that participation or withdrawal would not affect their academic evaluation.

REFERENCES

Abarro, R. Q., & Asuncion, J. E. (2021). Metacognition in chemistry education. *ISJ Theoretical & Applied Science, 95*(3), 1–22. https://doi.org/10.15863/TAS.2021.03.95.1

Andrean, M. D., Zainul, R., Nizar, U. K., & Kurniawati, D. (2024). Development of the e-module on colloid system with contextual teaching and learning oriented toward chemo-entrepreneurship to enhance students' critical thinking ability. *Jurnal Penelitian Pendidikan IPA, 10*(9), 6638–6646. https://doi.org/10.29303/jppipa.v10i9.8546

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.

Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34*(10), 906–911.

Gamby, S., & Bauer, C. F. (2022). Beyond study skills: A curriculum-embedded framework for metacognitive development in a college chemistry course. *International Journal of STEM Education, 9*, Article 61, 1–20.

Hanafi, I., Marzuki, M., Khikmah, N., & Nugroho, I. (2024). Fostering entrepreneurial spirit: Elevating attitudes through local wisdom-infused project-based learning. *Research and Development in Education, 4*(2), 1–14. https://doi.org/10.22219/raden.v4i2.33234

Heidbrink, L., & Weinrich, M. (2021). Metacognition and chemistry learning: Implications for chemistry education research. *Chemistry Education Research and Practice, 22*(3), 548–562.

Ingriani, A. N. A., Ramlawati, & Arsyad, A. A. (2025). Development of e-modules on vibration and waves based on local wisdom to improve students' interest in learning and learning outcomes. *Jurnal IPA Terpadu, 9*(2), 257–271. https://doi.org/10.35580/jit.v9i2.9633

Nieveen, N., McKenney, S., & Van den Akker, J. (2013). *Educational design research*. Netherlands Institute for Curriculum Development (SLO).

Pamela, I., Fuldiaratman, F., & Minarni, M. (2022). Profil keterampilan metakognitif mahasiswa pendidikan kimia dalam pembelajaran kimia dasar. *Jurnal Riset Pendidikan Kimia, 12*(2), 75–84.

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. Viking Press.

Plomp, T. (2013). Educational design research: An introduction. In T. Plomp & N. Nieveen (Eds.), *Educational design research* (pp. 11–50). Netherlands Institute for Curriculum Development (SLO).

Putri, W. P., Muntari, M., & Savalas, L. R. T. (2026). Practicality of local wisdom-based science e-modules using problem-based learning for critical thinking and digital literacy. *Indonesian Journal of Educational Innovation, 2*(1), 16–20. https://doi.org/10.65622/ijei.v2i1.241

Ramlah, R., Aulia, A., & Sugiarti, S. (2023). Pengembangan e-modul berbasis chemo-entrepreneurship pada materi koloid untuk meningkatkan hasil belajar dan minat berwirausaha peserta didik kelas XI. *Chemistry Education Review, 7*(1), 45–58. https://doi.org/10.26858/cer.v7i1.53785

Rosyidah, F., Susantini, E., Yuliani, Y., & Nisa', K. (2025). Local wisdom and STEM in science education to support SDG-4: A systematic review. *Jurnal Pendidikan IPA Indonesia, 14*(4), 654–666. https://doi.org/10.15294/jpii.v14i4.34450

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*(1–2), 113–125.

Schraw, G. (2001). Promoting general metacognitive awareness. In H. J. Hartman (Ed.), *Metacognition in learning and instruction: Theory, research and practice* (pp. 3–16). Kluwer Academic Publishers.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in Science Education, 36*(1–2), 111–139.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*(4), 460–475. https://doi.org/10.1006/ceps.1994.1033

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*(4), 351–371.

Setyaningsih, U., Sumarti, S. S., & Sudarmin, S. (2021). Development of chemo-entrepreneurship oriented learning design based on green chemistry. *Journal of Innovative Science Education, 10*(1), 28–34.

Sugiyono. (2023). *Metode penelitian dan pengembangan (Research and Development/R&D)*. Alfabeta.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Widodo, A., Suryanda, A., & Wijayanti, T. (2021). The effectiveness of HOTS-based learning in improving students' critical thinking skills. *Jurnal Pendidikan IPA Indonesia, 10*(3), 378–387.