Indonesian Journal of Society Development (IJSD)
Vol.5, No.4, 2026: 371-382

# Hands-on Contextual Chemistry Experiments Using Local Materials to Enhance Students' Scientific Understanding at SMP Negeri 42 Samarinda

Nanang Tri Widodo[1], Noor Hindryawati[2*], Eva Marliana[3], Winni Astuti[4], Subur P. Pasaribu[5], Aman Sentosa Panggabean[6], Alimuddin[7], Djihan Ryn Pratiwi[8], Irvin Dayadi[9], Irmanda Putri Agesti[10], Nurul Aisyah[11]
Mulawarman University
**Corresponding Author:** Noor Hindryawati hindryawati@gmail.com

A R T I C L E I N F O

*Kata Kunci:* Chemistry Outreach, Contextual Learning, Hands-On Learning, Local Materials; Natural Indicators, Science Education

*Received : 3 June 2026*
*Revised : 19 July 2026*
*Accepted: 20 August 2026*



A B S T R A K

Chemistry concepts at the junior high school level can be difficult to understand when learning is dominated by theoretical explanations and students have limited opportunities to observe scientific phenomena directly. This community engagement activity aimed to introduce contextual chemistry through simple, low-cost experiments using materials that are readily available in the students' surroundings. The activity was conducted at SMP Negeri 42 Samarinda on 27 July 2026 and involved 60 students from Grades 7, 8, and 9. Grade 7 students investigated simple water filtration using activated carbon, silica sand, zeolite, and gravel; Grade 8 students investigated carbon dioxide formation from vinegar and baking soda; and Grade 9 students investigated acid–base properties using natural indicators prepared from butterfly pea flowers, hibiscus flowers, and turmeric. The program consisted of an opening session, a 10-item pre-test, conceptual presentation, hands-on practical activities, a 10-item post-test, and student appreciation. The pre-test mean score was 45.5, with 60% of students scoring 40, 25% scoring 50, and 15% scoring 60. After the practical activities, the mean score increased to 89.5; 95% of students achieved a score of 90 and 5% achieved 80. The mean score therefore increased by 44 points, equivalent to a 96.70% relative increase. The findings indicate that contextual, hands-on chemistry activities using accessible local materials can improve students' demonstrated conceptual understanding and stimulate interest in science learning

## INTRODUCTION

Science learning at the junior high school level is expected to develop not only factual knowledge but also students' ability to observe phenomena, interpret evidence, communicate explanations, and connect scientific concepts with everyday life. In practice, however, chemistry-related concepts may remain abstract when students receive concepts mainly through lectures and textbook explanations. Practical activities provide an opportunity to bridge this gap by allowing students to encounter scientific phenomena directly.

Laboratory activities have long been recognized as an important component of science education because they provide experiences through which students can observe phenomena, manipulate materials, and relate observations to scientific concepts. Hofstein and Lunetta (2004) emphasized the distinctive role of laboratory experiences in science education. More recent work on hands-on chemistry outreach has also shown that activity design and the physical format of hands-on experiences can contribute to students' interest, perceived relevance, and self-efficacy in chemistry (Anderson et al., 2021).

Experiential learning is particularly relevant to this type of activity because students learn through concrete experience followed by reflection and conceptualization. A systematic review of experiential learning in science education reported improvements in curiosity, motivation, understanding, competence, and learning achievement across the reviewed studies (Susiloningsih et al., 2023). In the present program, students were not only introduced to concepts but were asked to observe, manipulate materials, discuss results, and relate observations to explanations.

The use of accessible materials is also important for schools that do not have extensive laboratory resources. Low-cost chemistry activities can reduce dependence on specialized equipment while maintaining the central scientific idea of an experiment. Kelley (2021), for example, demonstrated that wet chemistry activities can be designed around inexpensive and accessible materials while retaining meaningful hands-on experiences.

Natural indicators provide a particularly suitable example for contextual chemistry. Butterfly pea flowers (Clitoria ternatea) contain anthocyanins that produce visible color responses under different acid–base conditions. Naimi et al. (2024) demonstrated an accessible butterfly-pea indicator activity for learners aged 7–14 and reported that students could use the indicator to distinguish acidic and basic household solutions. Hanifa et al. (2024) likewise reported the practicality of butterfly pea flower indicators for acid–base practical learning. These findings support the educational potential of natural indicators as a bridge between familiar plant materials and abstract acid–base concepts.

Water filtration and gas-forming reactions also provide accessible contexts for introducing chemistry and physical science. A simple multilayer filter can be used to discuss separation processes and the different functions of filtration media, whereas the reaction between vinegar and baking soda provides a visible demonstration of gas formation. The latter is particularly useful because balloon inflation provides a concrete phenomenon that students can connect with chemical change.

The present community engagement activity was conducted at SMP Negeri 42 Samarinda, Indonesia, with three grade-specific experiments. The program was designed to transform chemistry from an abstract subject into a direct and contextual learning experience using materials that students could recognize and readily obtain. The objective was to introduce simple chemistry concepts through hands-on experimentation and to evaluate changes in students' demonstrated understanding using pre-test and post-test assessments

## IMPLEMENTATION AND METHODS

### Program Setting and Participants

The activity was conducted at SMP Negeri 42 Samarinda, East Kalimantan, Indonesia, on Monday, 27 July 2026, beginning at 09:00 and continuing until the program was completed. The participants were 60 students drawn from Grades 7, 8, and 9. The practical activities were differentiated by grade level so that each group investigated a chemistry-related phenomenon appropriate to its learning context (Table 1).

## RESULTS AND DISCUSSION

Di bagian ini, Anda harus menjelaskan setiap langkah yang diambil untuk menyelesaikan proses pengabdian Anda beserta materi yang disampaikan. Hasil diskusi juga boleh disampaikan disini. Anda tidak boleh terlalu banyak memasukkan hasil statistik deskriptif di sini; di sisi lain, itu harus diringkas dalam tabel atau grafik yang lebih mudah dibaca. Anda tidak boleh melupakan nomor untuk setiap tabel dan bagan yang disajikan dalam makalah Anda.

Table 1. The Practical Activities of Students

| Grade | Practical activity | Main concept |
|---|---|---|
| 7 | Simple water filtration | Separation of mixtures and filtration |
| 8 | $CO_2$ generation from vinegar and baking soda | Chemical reaction and gas formation |
| 9 | Natural acid–base indicators | Acid–base properties and qualitative indication |

### Program Procedure

The activity began with an opening session led by the Principal of SMP Negeri 42 Samarinda. A 10-item pre-test was then administered to assess students' initial understanding. This was followed by a short presentation of the scientific concepts by Dr. Noor Hindryawati, S.Pd., M.Si. and Prof. Dr. Eva Marliana, M.Si. The practical sessions were subsequently conducted under the guidance of Nanang Tri Widodo, M.Si.,. Rira Hairani, Ph.D., Ritbey Ruga, Ph.D., and 12 undergraduate chemistry students. Figure 1. Opening session of the community engagement program at SMP Negeri 42 Samarinda, attended by the school principal, teachers, and participating students.

Figure 1. Opening Session of the Community Engagement Program at SMP Negeri 42 Samarinda.

The practical component followed a learning-by-doing sequence. Students first observed the materials and procedures, conducted the experiment with facilitator guidance, recorded observations, discussed the observed phenomena, and connected the observations to the corresponding scientific concept. After the practical sessions, students completed the same 10-item post-test format and received appreciation for their participation.

**Practical Activities**

Grade 7 students constructed and investigated a simple water filtration system using activated carbon, silica sand, zeolite, and gravel. The activity focused on the idea that a multilayer filtration system contains materials with different physical and adsorption-related functions. The activity was used to introduce separation science and to encourage students to compare the condition of water before and after filtration. The filtered water was not presented as automatically safe for drinking. Figure 2. Grade 7 students conducting a simple water filtration experiment using activated carbon, silica sand, zeolite, and gravel.

Figure 2. Grade 7 Students Conducting a Hands-On Water Filtration Experiment Using Locally Accessible Filtration Materials.

Grade 8 students investigated a simple gas-forming reaction using vinegar and baking soda. When the two materials were mixed, bubbles appeared and a balloon connected to the container gradually inflated. This phenomenon attracted students' attention because they could directly observe the formation of a gas. Figure 3. Grade 8 students observing carbon dioxide formation through the vinegar–baking soda reaction, as indicated by balloon inflation.

Figure 3**.** Grade 8 Students Observing Carbon Dioxide Formation Through the Vinegar–Baking Soda Reaction, as Indicated by Balloon Inflation

Vinegar contains acetic acid ($CH_3COOH$), while baking soda contains sodium bicarbonate ($NaHCO_3$). When they react, carbon dioxide ($CO_2$) gas is produced, together with water and sodium acetate. The reaction can be written as:

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

The students were guided to understand that the balloon inflated because the reaction produced $CO_2$ gas. Thus, the balloon provided a simple visual indication of gas formation. Before the experiment, several students had difficulty explaining why the balloon could inflate without being blown. After performing the experiment, students were able to relate the balloon inflation to the formation of $CO_2$. The activity helped students understand the concept of chemical reactions through a familiar and simple phenomenon. The use of vinegar and baking soda also made the experiment easy to conduct and showed students that chemistry can be observed using materials available in everyday life.

Grade 9 students prepared and used natural indicators from butterfly pea flowers, hibiscus flowers, and turmeric. The extracts were introduced to selected household-type test solutions so that students could observe color changes and use the observations to discuss acidic and basic conditions. Butterfly pea flower was especially useful because its anthocyanin pigments show visible pH-dependent color changes (Naimi et al., 2024). Figure 4. Grade 9 students observing color changes in natural indicators from butterfly pea flowers, hibiscus flowers, and turmeric during the acid–base experiment.

**Figure 4.** Grade 9 Students Observing Color Changes in Natural Indicators from Butterfly Pea Flowers, Hibiscus Flowers, and Turmeric During the Acid–base Experiment

**Assessment and Data Analysis**

Student understanding was assessed using a 10-item pre-test and a 10-item post-test. The questions were designed to emphasize analysis of phenomena rather than simple recall. The items addressed the function of indicators, interpretation of color changes, the rationale for multilayer filtration, the function of filtration media, evidence of chemical reactions, carbon dioxide formation, and the cause of balloon inflation.

For the reported 60 participants, the pre-test distribution consisted of 36 students (60%) scoring 40, 15 students (25%) scoring 50, and 9 students (15%) scoring 60. The post-test distribution consisted of 57 students (95%) scoring 90 and 3 students (5%) scoring 80. Mean scores were calculated from these distributions. The relative increase was calculated as [(post-test mean − pre-test mean) / pre-test mean] × 100%. Because individual paired scores were not available, no inferential statistical test or normalized gain was calculated.

**Student Engagement and Contextual Learning**

The practical sessions generated strong student interest. Students responded enthusiastically to activities because the materials were familiar and readily obtainable. Rather than encountering chemistry only through laboratory-grade reagents, students worked with flowers, turmeric, vinegar, baking soda, gravel, sand, zeolite, and activated carbon. This material choice helped establish a direct connection between classroom science and the students' surroundings.

The engagement observed during the activity is consistent with findings from hands-on chemistry outreach. Anderson et al. (2021) found that both the content embedded in an activity and the format of hands-on engagement can influence interest, perceived relevance, and self-efficacy. In the present program, the novelty was not primarily the complexity of the equipment but the opportunity to perform recognizable chemical phenomena themselves.

The activity also created a university–school interaction in which chemistry students served as facilitators. The involvement of 12 undergraduate chemistry students allowed the participating school students to receive closer guidance during practical work while providing university students with an authentic science outreach experience.

**Pre-test and Post-test Performance**

The pre-test results showed that students' initial demonstrated understanding was relatively low. The mean pre-test score was 45.5. Sixty percent of students scored 40, 25% scored 50, and only 15% scored 60. This distribution suggests that the concepts investigated in the practical activities were not yet well understood by most participants before the intervention. Figure 5. Show the students participating in the pre-test session before the chemistry practical activities.

Figure 5. Students Completing the Pre-Test Before the Practical Activities

After the practical activities, the mean post-test score increased to 89.5. Fifty-seven students (95%) achieved a score of 90, while three students (5%) achieved a score of 80. The difference between the two means was 44 points, corresponding to a 96.70% relative increase from the pre-test mean.

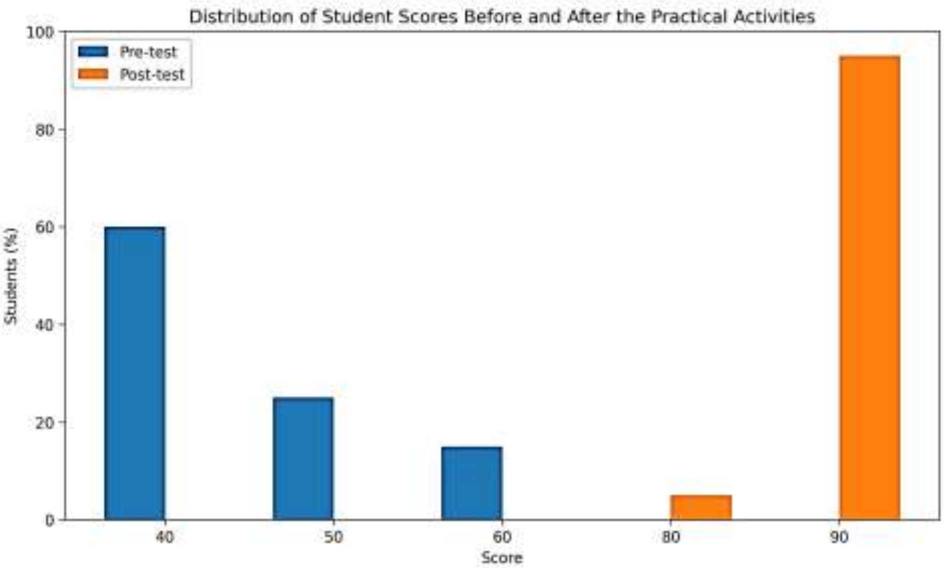


Figure 6. Distribution of Student Scores Before and After the Practical Activities.

Figure 6 shows a clear shift in the score distribution. Before the activity, all students were within the 40–60 score range. After the activity, the distribution shifted to 80–90, with the large majority at 90. The result indicates a substantial improvement in students' demonstrated performance after the hands-on learning experience.

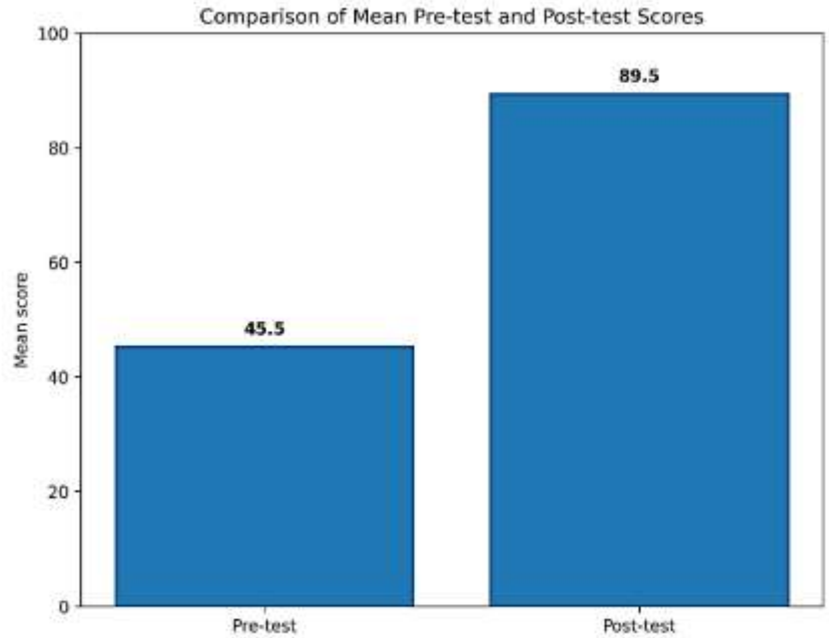


Figure 7. Comparison of Mean Pre-Test and Post-Test Scores.

Figure 7 further illustrates the change in central tendency, with the mean score increasing from 45.5 to 89.5. The magnitude of this descriptive change is educationally meaningful; however, it should not be interpreted as a statistically significant effect because individual paired scores and inferential statistics were not available.

The improvement can be interpreted in relation to the experiential sequence used in the program. Before the activity, students were asked to reason about phenomena that they had not yet directly experienced. During the practical sessions, they were able to observe the phenomena, manipulate materials, and discuss the resulting observations. This sequence provides concrete experiences that can support subsequent conceptualization, consistent with experiential learning theory. A recent systematic review similarly reported that experiential learning in science education can improve students' curiosity, motivation, understanding, competence, and learning achievement (Susiloningsih et al., 2023).

**Understanding Natural Acid–Base Indicators**

The Grade 9 activity addressed an initial difficulty identified in the pre-test: students' limited understanding of what an indicator does and why a color change provides information about a solution. The use of butterfly pea flowers, hibiscus flowers, and turmeric allowed students to see the indicator response directly. This approach transformed the concept of an indicator from a definition into an observable chemical tool.

The educational relevance of butterfly pea flower is supported by Naimi et al. (2024), who developed a hands-on activity for learners aged 7–14 using butterfly pea flower anthocyanins as a pH indicator. Their activity enabled learners to compare household acids and bases and connect indicator colors with acid–base chemistry. Hanifa et al. (2024) also reported that a practicum guide using butterfly pea flower indicators was considered valid and practical for acid–base learning. The present activity extends this principle into a community engagement context by combining butterfly pea flower with hibiscus and turmeric and by using materials familiar to students.

The pedagogical value of this approach lies in the opportunity for students to ask analytical questions: why does the color change, why do different solutions produce different colors, and how can the observation be used to classify solutions? Such questions move the activity beyond simple observation toward interpretation and explanation.

**Understanding Gas Formation through the Vinegar–Baking Soda Reaction**

The Grade 8 experiment provided a direct response to another conceptual difficulty identified in the pre-test: students' inability to explain why a balloon could inflate without being blown. When vinegar and baking soda were combined, students observed vigorous bubbling and balloon inflation. The visible phenomenon provided an immediate basis for discussing gas formation during a chemical reaction.

The importance of such an activity lies in its ability to connect an everyday observation with a scientific explanation. Students could first observe the balloon becoming larger and then reason that the additional volume must come from gas generated by the reaction. The activity therefore supported a progression from observation to explanation rather than asking students to memorize the definition of a chemical reaction.

This type of hands-on design is consistent with evidence that chemistry activities can become more interesting and relevant when learners actively manipulate materials and encounter visible phenomena (Anderson et al., 2021). The use of vinegar and baking soda also makes the activity readily replicable in school settings where conventional laboratory reagents may be limited.

**Understanding Multilayer Water Filtration**

For Grade 7 students, the filtration experiment addressed the question of why a filter should contain several layers rather than a single material. Students used gravel, silica sand, zeolite, and activated carbon. The layered design created an accessible model for discussing separation processes and the different functions of filtration materials.

The pre-test responses indicated that students initially had difficulty explaining the rationale for multilayer filtration. After observing the process, students were better able to relate the physical structure of the filter to its function. This is an important conceptual shift because filtration should not be presented simply as a process that makes dirty water 'clean'; rather, it is a separation process whose effectiveness depends on the characteristics of the materials and contaminants involved.

The activity also supported environmental awareness because water quality is an everyday issue that students can recognize. Importantly, the demonstration was framed as a simple educational filtration model, not as a validated drinking-water treatment system. This distinction prevents students from interpreting visual improvement alone as proof of potability.

**Educational Implications**

The combined findings suggest that the value of the program was not limited to increasing test scores. The practical activities provided a model of how teachers can introduce chemistry concepts using low-cost and accessible materials. Such an approach is particularly relevant to schools that face limitations in laboratory infrastructure.

The program also demonstrates that simple experiments can be differentiated by grade level while maintaining a common pedagogical principle: students encounter a concrete phenomenon, record or discuss what they observe, and connect it with a scientific concept. This structure is compatible with experiential learning and contextual learning approaches. The use of local materials further increases the feasibility of repeating the activities after the community engagement program has ended.

Nevertheless, the assessment has limitations. The available dataset is aggregated by score category rather than by individual student. Therefore, the study cannot determine individual learning gains, statistical significance, or relationships between student characteristics and outcomes. In addition, the post-test results were highly concentrated at 80–90, suggesting a possible ceiling effect that should be considered in future assessments. Future programs should retain individual pre-test and post-test records and use paired analyses, such as a paired t-test or a non-parametric alternative when assumptions are not met, together with effect-size measures.

## CONCLUSION AND RECOMENDATION

The community engagement program at SMP Negeri 42 Samarinda demonstrated that simple, contextual chemistry experiments using accessible materials can support students' conceptual understanding and stimulate interest in science. Sixty students participated in grade-specific activities involving water filtration, carbon dioxide formation, and natural acid–base indicators. The mean score increased from 45.5 in the pre-test to 89.5 in the post-test, while 95% of students achieved a post-test score of 90. The approach offers a practical model for chemistry outreach in schools with limited laboratory resources. Future programs should collect individual paired assessment data to enable stronger statistical evaluation.

## ACKNOWLEDGMENTS

The authors express their appreciation to the Principal, teachers, and students of SMP Negeri 42 Samarinda for their participation and support. The authors also acknowledge the contribution of the undergraduate chemistry students who assisted with the practical activities. The authors are grateful to the

Faculty of Mathematics and Natural Sciences, Mulawarman University, for supporting the community engagement program through the PNBP Grant.

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