Multi Discere Journal
https://journal-center.litpam.com/index.php/mdj

November 2023 Vol. 2, No. 2
ISSN: 2964-8718
pp. 140-150

The Influence of Food-Based Contextual Experiments on Students' Understanding of Chemical Reaction Concepts

[1]Yola Kamaliana, [2]Ahmadi

[1]Department of Chemistry Education, Mandalika University of Education, Mataram, 83125, Indonesia
[2]Department of Chemistry Education, Mandalika University of Education, Mataram, 83125, Indonesia

*Corresponding Author e-mail: ahmadi@undikma.ac.id

Received: August 2023; Revised: October 2023; Published: November 2023

Abstract

This study investigates the influence of food-based contextual experiments on students' understanding of chemical reaction concepts. Chemical reactions are fundamental topics in chemistry; however, students often experience difficulties in understanding reaction processes because they involve macroscopic observations, symbolic equations, and submicroscopic particle interactions. Food-based contextual experiments were used as an instructional strategy to connect abstract chemical reaction concepts with familiar materials found in students' daily lives, such as vinegar, baking soda, milk, salt, sugar, and fermented food products. This study employed a pre-experimental design using a one-group pretest–posttest format. The participants consisted of 31 Grade X students at Pondok Pesantren Nurul Hakim Kediri. Data were collected through a conceptual understanding test consisting of five items related to indicators of chemical reaction concepts, including evidence of chemical reactions, reactants and products, conservation of mass, reaction types, and factors affecting reactions. The data were analyzed using descriptive statistics and a paired-sample t-test. The findings showed that students' conceptual understanding significantly improved after learning through food-based contextual experiments compared with their initial understanding. The learning activities enabled students to observe real chemical phenomena, discuss reaction evidence, and relate experimental results to chemical equations. These findings suggest that food-based contextual experiments can serve as an effective contextual learning approach to improve students' understanding of chemical reaction concepts.

Keywords: *Chemical Reactions; Chemistry Education; Conceptual Understanding; Contextual Learning; Food-Based Experiments*

How to Cite: Kamaliana, Y. ., & Ahmadi, A. (2023). The Influence of Food-Based Contextual Experiments on Students' Understanding of Chemical Reaction Concepts. *Multi Discere Journal*, *2*(2), 140-150. https://journal-center.litpam.com/index.php/mdj/article/view/5581

https://journal-center.litpam.com/index.php/mdj/article/view/5581

INTRODUCTION

Chemical reactions are one of the central concepts in chemistry because they explain how substances interact, change, and form new products. Understanding chemical reactions is not limited to recognizing visible changes such as gas formation, color change, precipitation, or temperature change; it also requires students to interpret reactants and products, conservation of mass, reaction types, and factors that affect reaction processes. However, students frequently experience difficulty in learning chemical reactions because the topic requires them to connect observable phenomena with symbolic equations and submicroscopic particle interactions. Yan and Talanquer (2015) emphasized that meaningful understanding of chemical reactions depends on students' ability to integrate ideas related to particles, bonding, reaction mechanisms, kinetics, and thermodynamics, while persistent conceptual difficulties may still appear even among more advanced learners.

One major challenge in chemistry learning is the need to move across macroscopic, submicroscopic, and symbolic representations. At the macroscopic level, students observe physical evidence of a reaction; at the submicroscopic level, they need to explain interactions among particles; and at the symbolic level, they represent the process through formulas and chemical equations. Taber (2013) argues that chemistry education often depends on this representational "triplet," and learning becomes meaningful when students are supported in connecting the three levels rather than treating them separately. This is especially important for Grade X students, who are still developing foundational chemical reasoning and may rely heavily on memorized definitions or equations without fully understanding the real processes represented by those symbols.

Previous studies have shown that instructional strategies involving multiple representations, inquiry, analogy, and contextual learning can improve students' understanding of chemical concepts. Milenković, Segedinac, and Hrin (2014) found that instruction based on the interaction of multiple representation levels improved chemistry performance and reduced students' cognitive load. Similarly, Supasorn and Promarak (2015) reported that 5E inquiry combined with analogy learning effectively enhanced Grade 11 students' conceptual understanding of chemical reaction rate. These findings indicate that students need learning experiences that do not merely present chemical concepts verbally, but also allow them to observe, discuss, explain, and represent chemical phenomena through meaningful activities.

Contextual learning is one approach that can bridge abstract chemical concepts with students' everyday experiences. In chemistry education, context-based learning places scientific concepts within real-life situations so that students can recognize the relevance of chemistry to their surroundings. A systematic review by Minata, Rahayu, and Dasna (2022) concluded that context-based chemistry learning has positive effects on students' cognitive, affective, psychomotor, and social aspects, particularly when the selected contexts are appropriate, applicable, and supported by active student participation. In the Indonesian context, Dewi et al. (2021) also showed that contextual collaborative learning based on ethnoscience improved students' scientific literacy in content, process, and attitude dimensions. Therefore, contextual learning is relevant for chemistry instruction because it helps students relate chemical ideas to familiar materials, local practices, and daily phenomena.

Food-based contextual experiments represent a practical form of contextual chemistry learning. Food materials such as vinegar, baking soda, milk, salt, sugar, and fermented products are familiar, relatively accessible, and closely related to students' daily lives. Munro (2023) explains that food chemistry can directly connect course material to students' lives and can use materials that are safe and manageable in learning settings. Food and kitchen chemistry activities have also been reported as useful for hands-on learning because they allow students to make observations, test hypotheses, record evidence, and connect readings or concepts with experimental results. Schultz, Callahan, and Miltiadous (2020) further support the use of kitchen chemistry practical activities as an accessible alternative for conducting chemistry experiments with household materials.

In the topic of chemical reactions, food-based experiments can help students observe concrete evidence of reaction processes before interpreting them symbolically. For example, the reaction between vinegar and baking soda can demonstrate gas formation; the interaction between acid and milk can show coagulation; and fermentation processes can introduce students to chemical changes involving food products. These activities are expected to support students in identifying reactants and products, recognizing evidence of chemical reactions, understanding conservation of mass, classifying reaction types, and explaining factors that influence reaction processes. By using materials that are close to students' everyday experiences, learning can become more meaningful and less dependent on abstract explanation alone.

Based on these considerations, this study investigates the influence of food-based contextual experiments on Grade X students' understanding of chemical reaction concepts at Pondok Pesantren Nurul Hakim Kediri. The study focuses on whether students' conceptual understanding improves after participating in learning activities that use familiar food-related materials as experimental contexts. The findings are expected to contribute to chemistry education by providing empirical evidence on the use of simple, contextual, and accessible experiments to strengthen students' understanding of fundamental chemical reaction concepts.

METHOD

Research Design

This study employed a pre-experimental research design using a one-group pretest–posttest model. This design was used to determine the influence of food-based contextual experiments on students' understanding of chemical reaction concepts by comparing students' conceptual understanding before and after the instructional treatment. The design involved one group of students who were given a pretest, participated in learning activities through food-based contextual experiments, and then completed a posttest.

The research design can be illustrated as follows:

$$O_1 \rightarrow X \rightarrow O_2$$

where O_1 represents the pretest, X represents the implementation of food-based contextual experiments, and O_2 represents the posttest.

Participants

The participants of this study were 31 Grade X students at Pondok Pesantren Nurul Hakim Kediri. The participants were selected from one intact class that had studied or was scheduled to study the topic of chemical reactions. The use of one class was considered appropriate because the study focused on examining the change in students' conceptual understanding after the implementation of the learning treatment within a natural classroom setting.

Instructional Treatment

The instructional treatment consisted of chemistry learning activities using food-based contextual experiments. The experiments were designed to connect the concept of chemical reactions with familiar materials found in students' daily lives. The materials used in the learning activities included vinegar, baking soda, milk, salt, sugar, and fermented food products. These materials were selected because they are accessible, relatively safe, and closely related to students' everyday experiences.

During the learning process, students were guided to observe chemical phenomena, identify evidence of chemical reactions, discuss reactants and products, and relate experimental observations to chemical reaction concepts. For example, the reaction between vinegar and baking soda was used to help students observe gas formation as evidence of a chemical reaction. Other food-based examples were used to introduce changes in properties, reaction types, and factors that may affect reaction processes.

The learning activities were conducted through the following stages. First, students were introduced to contextual problems related to food and daily chemical changes. Second, students conducted simple experiments using food-related materials. Third, students recorded their observations and discussed the evidence of chemical reactions. Fourth, students connected their experimental findings with scientific explanations, including reactants, products, conservation of mass, reaction types, and factors affecting reactions. Finally, students were asked to reflect on the relationship between the experiments and the chemical concepts being studied.

Research Instrument

The instrument used in this study was a conceptual understanding test consisting of five items. The test was developed based on indicators of chemical reaction concepts. The same conceptual indicators were used in both the pretest and posttest to measure changes in students' understanding before and after the treatment. The indicators measured in the test were presented in Table 1.

Table 1. Indicator of Conceptual Understanding

No.	Indicator of Conceptual Understanding	Focus of Assessment
1	Evidence of chemical reactions	Students' ability to identify observable signs of chemical reactions
2	Reactants and products	Students' ability to distinguish substances before and after a reaction
3	Conservation of mass	Students' understanding that mass is conserved during chemical reactions
4	Reaction types	Students' ability to classify simple types of chemical reactions
5	Factors affecting reactions	Students' ability to explain factors that influence chemical reaction processes

Each item was designed to assess students' ability to explain chemical reaction concepts, not merely recall definitions. The test results were used to determine students' initial understanding and their understanding after participating in the food-based contextual experiments.

Data Collection Procedure

Data collection was carried out in three main stages. The first stage was the administration of the pretest to identify students' initial understanding of chemical reaction concepts. The second stage was the implementation of food-based contextual experiments as the instructional treatment. During this stage, students participated in experimental activities, classroom discussions, and concept reinforcement guided by the teacher. The third stage was the administration of the posttest to measure students' conceptual understanding after the treatment.

The pretest and posttest results were then compared to determine whether there was an improvement in students' understanding after learning through food-based contextual experiments.

Data Analysis

The data obtained from the pretest and posttest were analyzed using descriptive and inferential statistics. Descriptive statistics were used to determine the mean score, minimum score, maximum score, and standard deviation of students' pretest and posttest results. These results were used to describe the general pattern of students' conceptual understanding before and after the treatment.

Inferential analysis was conducted using a paired-sample t-test to determine whether the difference between pretest and posttest scores was statistically significant. The paired-sample t-test was considered appropriate because the data were obtained from the same group of students before and after the instructional treatment. The significance level used in this study was 0.05. If the significance value was lower than 0.05, it indicated that there was a significant difference between students' pretest and posttest scores.

Through this analysis, the study examined whether food-based contextual experiments had a significant influence on students' understanding of chemical reaction concepts.

RESULTS AND DISCUSSION

Results

The data in this study were obtained from the pretest and posttest scores of 31 Grade X students. The pretest was administered before students learned chemical reaction concepts through food-based contextual experiments, while the posttest was administered after the instructional treatment. The descriptive statistical results are presented in Table 2.

Table 2. Descriptive Statistics of Students' Pretest and Posttest Scores

Descriptive Statistics	Pretest	Posttest
N	31	31
Minimum Score	38	62
Maximum Score	69	93
Range	31	31
Mean	54.65	78.32
Median	56.00	79.00
Mode	51, 53, 56	79
Standard Deviation	7.09	8.19
Variance	50.24	67.03
Total Score	1694	2428

Table 2 shows that the mean pretest score was 54.65, while the mean posttest score was 78.32. This indicates an increase of 23.67 points after students participated in learning through food-based contextual experiments. The minimum score also increased from 38 in the pretest to 62 in the posttest, while the maximum score increased from 69 to 93. These results show that students' conceptual understanding of chemical reaction concepts improved after the treatment. The increase in the median score from 56.00 to 79.00 also supports the improvement in students' overall performance. In addition, the total score increased from 1694 in the pretest to 2428 in the posttest. This finding indicates that the improvement was not limited to only a few students but occurred generally across the class.

The paired-sample statistical results are presented in Table 3. Based on Table 3, the mean score increased from 54.65 before the treatment to 78.32 after the treatment. The increase of approximately 23.67 points indicates that students achieved better conceptual understanding after experiencing food-based contextual experiments. The standard deviation of the posttest score was slightly higher than that of the pretest, indicating that although students generally improved, there was still variation in the level of improvement among students.

Table 3. Paired Samples Statistics

Variable	N	Mean	Std. Deviation	Std. Error Mean
Pretest	31	54.65	7.09	1.27
Posttest	31	78.32	8.19	1.47

Table 4 shows that the correlation between pretest and posttest scores was 0.909 with a significance value of 0.000. This indicates a very strong and positive relationship between students' pretest and posttest scores. In other words, students who had relatively higher initial understanding tended to also obtain higher posttest scores. However, the increase in the posttest mean score shows that the learning treatment contributed to improving students' conceptual understanding.

Table 4. Paired Samples Correlations

Pair	N	Correlation	Sig.
Pretest and Posttest	31	0.909	0.000

The results of the paired-sample t-test are presented in Table 5. The paired-sample t-test results show that the mean difference between posttest and pretest scores was 23.68. The obtained t-value was 38.44 with 30 degrees of freedom, and the significance value was 0.000. Since the significance value was lower than 0.05, the null hypothesis was rejected and the alternative hypothesis was accepted. Therefore, there was a statistically significant difference between students' pretest and posttest scores. These results indicate that food-based contextual experiments had a significant positive influence on students' understanding of chemical reaction concepts.

Table 5. Paired Samples Test

Pair	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. 2-tailed
Posttest – Pretest	23.68	3.43	0.62	38.44	30	0.000

Discussion

The findings of this study indicate that food-based contextual experiments significantly improved students' understanding of chemical reaction concepts. The mean pretest score was 54.65, while the mean posttest score increased to 78.32, showing a mean gain of 23.68 points. The paired-sample t-test also confirmed a statistically significant difference between pretest and posttest scores, $t(30) = 38.44$, $p < .05$. This result suggests that students developed a better conceptual understanding after learning chemical reactions through experiments involving familiar food-based materials.

This improvement can be interpreted as evidence that students benefited from direct interaction with observable chemical phenomena. Chemical reactions are difficult for many students because they require understanding not only what can be observed, but also what happens at the particle level and how the process is represented symbolically. Taber (2013) emphasized that chemistry learning involves connections among macroscopic, submicroscopic, and symbolic representations, and students often struggle when these levels are taught separately. In this study, food-based experiments helped students begin with macroscopic observations, such as gas formation, changes in texture, or visible changes in substances, before relating these observations to reactants, products, and reaction equations.

The increase in students' scores also shows that contextual experiments can reduce the abstractness of chemical reaction concepts. Yan and Talanquer (2015) found that students' reasoning about chemical reactions is often influenced by their ability to explain why reactions happen and how substances change during the process. Similarly, Weinrich and Talanquer (2015) argued that students may use different conceptual modes when thinking about chemical reactions, including ideas about causality, mechanism, and control. In the present study, students were not only asked to memorize definitions of chemical reactions but were guided to observe evidence, identify substances before and after the reaction, and discuss why the changes occurred. This kind of learning experience is important because conceptual understanding in chemistry requires students to explain relationships among concepts rather than simply recall isolated facts.

The use of food-based materials was particularly relevant because the materials were familiar to students. Vinegar, baking soda, milk, salt, sugar, and fermented food products are closely related to daily life, making them useful contexts for introducing chemical change. Contextual learning helps students recognize that chemistry is not separate from everyday experience. Suryawati and Osman (2018) reported that contextual learning can support students' scientific attitudes and science performance, while Majid and Rohaeti (2018) found that context-based chemistry learning positively influenced students' achievement and attitudes. These studies support the finding that the use of familiar contexts can increase students' engagement and help them construct meaning from learning activities.

The result is also consistent with research on context-based chemistry learning. Koçak Altundağ (2018) showed that context-based chemistry teaching in laboratory settings improved achievement and metacognitive ability. Minata, Rahayu, and Dasna (2022), through a systematic literature review, also concluded that context-based chemistry learning generally has positive effects on students' cognitive, affective, psychomotor, and social aspects. In the present study, the contextual approach allowed students to connect chemical reaction concepts with concrete examples from their surroundings. As a result, students could understand chemical reactions not only as symbolic equations but also as real processes that occur in food and household materials.

Food-based contextual experiments also supported active learning. During the treatment, students observed reactions, discussed evidence, recorded results, and connected their observations with chemical concepts. This is in line with Supasorn and

Promarak (2015), who found that 5E inquiry combined with analogy learning improved students' conceptual understanding of chemical reaction rate because students explored evidence, constructed explanations, and evaluated their understanding. Kimberlin and Yezierski (2016) also reported that inquiry-based lessons using particulate-level models improved high school students' conceptual understanding of stoichiometry. These findings strengthen the interpretation that students understand chemistry more effectively when they are actively involved in observing, questioning, explaining, and representing chemical phenomena.

The improvement in students' posttest scores may also be explained by the role of multiple representations in the learning process. Students first observed visible evidence of reactions, then discussed the meaning of the observed changes, and finally related them to chemical concepts and equations. Milenković, Segedinac, and Hrin (2014) found that instructional strategies based on the interaction of multiple representation levels can improve chemistry performance and reduce cognitive load. Therefore, the food-based experiment approach in this study may have helped students process abstract ideas more easily because they were supported by concrete observations before moving to symbolic explanations.

The use of food and kitchen materials is also supported by previous studies in chemistry education. Schultz, Callahan, and Miltiadous (2020) showed that kitchen chemistry practical activities can be used as meaningful home-based chemistry experiments. Cheng, Ziffle, and King (2020) also developed food laboratory activities for chemistry learning, showing that food and cooking contexts can be used to support chemistry instruction. More recently, Munro (2023) reported that food chemistry courses with hands-on experiments can connect chemical concepts with students' daily lives. These studies support the present finding that food-based experiments are useful because they are accessible, familiar, and capable of making chemical ideas more meaningful.

Another important aspect is safety and accessibility. Food-based contextual experiments can be conducted using simple materials that are relatively safe, inexpensive, and easy to obtain. This is especially important in school contexts where laboratory facilities may be limited. Hidayah et al. (2023) showed that small-scale chemistry practicum approaches can support the design of laboratory activities, while Listyarini et al. (2019) emphasized that small-scale chemistry can reduce waste and support safer chemistry practicum for senior high school students. In this study, the use of familiar food-based materials provided opportunities for students to conduct experiments without relying heavily on complex laboratory equipment.

The strong positive correlation between pretest and posttest scores, $r = 0.909$, indicates that students' initial understanding was strongly related to their final achievement. Students with higher prior understanding tended to obtain higher posttest scores. However, the increase in the overall mean score shows that the treatment benefited the class as a whole. This suggests that food-based contextual experiments did not only help students who already had stronger initial knowledge but also supported students who initially had lower understanding. The instructional activities provided common concrete experiences that students could use as a basis for discussion and concept construction.

The statistical result also shows a strong practical improvement. Based on the mean difference and standard deviation of the paired differences, the effect size can be interpreted as very large. Lakens (2013) stated that reporting effect sizes is useful because statistical significance alone does not fully describe the practical magnitude of an intervention. In this study, the large difference between pretest and posttest scores indicates that the food-based contextual experiment approach had a meaningful effect on students' conceptual understanding.

Despite these positive findings, the results should be interpreted carefully because this study used a one-group pretest–posttest design without a control group. Therefore, the improvement cannot be compared directly with students who learned through conventional instruction or other learning models. Nevertheless, the significant increase in students' scores provides empirical evidence that food-based contextual experiments were effective in the observed classroom context. Future studies may use a quasi-experimental design with a control group, larger sample size, and more varied test items to strengthen the validity of the findings.

Overall, the findings show that food-based contextual experiments can improve students' understanding of chemical reaction concepts by linking abstract ideas with familiar daily-life phenomena. The approach helps students observe real evidence of chemical reactions, identify reactants and products, discuss conservation of mass, classify reaction types, and explain factors affecting reactions. Therefore, food-based contextual experiments can be considered an effective and practical instructional strategy for teaching chemical reactions, especially in contexts where teachers need simple, safe, and meaningful experimental activities.

CONCLUSION

This study concluded that food-based contextual experiments had a significant positive influence on students' understanding of chemical reaction concepts. The results showed an increase in students' mean score from 54.65 in the pretest to 78.32 in the posttest, with a mean difference of 23.68 points. The paired-sample t-test result also showed a significance value of 0.000, which was lower than 0.05. This indicates that there was a statistically significant difference between students' conceptual understanding before and after the treatment. The use of familiar food-based materials such as vinegar, baking soda, milk, salt, sugar, and fermented food products helped students connect abstract chemical reaction concepts with real phenomena in daily life. Through these experiments, students were able to observe evidence of chemical reactions, identify reactants and products, understand conservation of mass, classify reaction types, and explain factors affecting chemical reactions. Therefore, food-based contextual experiments can be considered an effective instructional strategy for improving students' conceptual understanding of chemical reactions.

RECOMMENDATION

Based on the findings of this study, chemistry teachers are encouraged to use food-based contextual experiments as an alternative learning strategy, especially when teaching abstract topics such as chemical reactions. The use of familiar and easily accessible materials can make chemistry learning more meaningful, practical, and connected to students' daily experiences.

Future researchers are recommended to conduct similar studies using a quasi-experimental design with a control group in order to compare the effectiveness of food-based contextual experiments with other instructional methods. Further research may also involve a larger sample size, different school contexts, and additional instruments such as observation sheets, student interviews, or questionnaires to obtain deeper information about students' learning processes, motivation, and attitudes toward chemistry.

In addition, future studies may develop more varied food-based experimental activities for other chemistry topics, such as acid-base reactions, oxidation-reduction reactions, reaction rates, colloids, and biochemistry-related concepts. This would help expand the application of contextual experiments in chemistry education.

ACKNOWLEDGMENT

The researcher would like to express sincere gratitude to Pondok Pesantren Nurul Hakim Kediri for providing permission and support during the implementation of this study. Appreciation is also extended to the Grade X students who participated actively in the learning activities and data collection process. The researcher also thanks the chemistry teacher and all parties who provided assistance, guidance, and encouragement throughout the research process. Their support contributed significantly to the completion of this study.

REFERENCES

Cheng, S. C., Ziffle, V. E., & King, R. C. (2020). Innovative food laboratory for a chemistry of food and cooking course. *Journal of Chemical Education, 97*(3), 659–667. https://doi.org/10.1021/acs.jchemed.9b00465

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

Hidayah, F. F., Imaduddin, M., Yuliyanto, E., Gunawan, Djunaidi, M. C., & Qomariyah, S. (2023). Strengthening pedagogical content knowledge in designing laboratory activity based on small-scale chemistry practicum approach. *European Journal of Educational Research, 12*(4), 1631–1644. https://doi.org/10.12973/eu-jer.12.4.1631

Holme, T. A., Luxford, C. J., & Brandriet, A. (2015). Defining conceptual understanding in general chemistry. *Journal of Chemical Education, 92*(9), 1477–1483. https://doi.org/10.1021/acs.jchemed.5b00218

Kimberlin, S., & Yezierski, E. (2016). Effectiveness of inquiry-based lessons using particulate level models to develop high school students' understanding of conceptual stoichiometry. *Journal of Chemical Education, 93*(6), 1002–1009. https://doi.org/10.1021/acs.jchemed.5b01010

Koçak Altundağ, C. (2018). Context-based chemistry teaching within the 4Ex2 model: Its impacts on metacognition, multiple intelligence, and achievement. *Journal of Turkish Science Education, 15*(2), 1–12. https://doi.org/10.12973/tused.10226a

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for *t*-tests and ANOVAs. *Frontiers in Psychology, 4*, Article 863. https://doi.org/10.3389/fpsyg.2013.00863

Listyarini, R. V., Pamenang, F. D. N., Harta, J., Wijayanti, L. W., Asy'ari, M., & Lee, W. (2019). The integration of green chemistry principles into small scale chemistry practicum for senior high school students. *Jurnal Pendidikan IPA Indonesia, 8*(3), 371–378. https://doi.org/10.15294/jpii.v8i3.19250

Majid, A. N., & Rohaeti, E. (2018). The effect of context-based chemistry learning on student achievement and attitude. *American Journal of Educational Research, 6*(6), 836–839. https://doi.org/10.12691/education-6-6-37

Milenković, D. D., Segedinac, M. D., & Hrin, T. N. (2014). Increasing high school students' chemistry performance and reducing cognitive load through an instructional strategy based on the interaction of multiple levels of knowledge representation. *Journal of Chemical Education, 91*(9), 1409–1416. https://doi.org/10.1021/ed400805p

Minata, Z. S., Rahayu, S., & Dasna, I. W. (2022). Context-based chemistry learning: A systematic literature review. *Jurnal Pendidikan MIPA, 23*(4), 1446–1463. https://doi.org/10.23960/jpmipa/v23i4.pp1446-1463

Munro, A. M. (2023). Food chemistry: An asynchronous course designed with hands-on experiments for undergraduate general education. *Journal of Chemical Education, 100*(9), 3347–3354. https://doi.org/10.1021/acs.jchemed.3c00130

Schultz, M., Callahan, D. L., & Miltiadous, A. (2020). Development and use of kitchen chemistry home practical activities during unanticipated campus closures. *Journal of Chemical Education, 97*(9), 2678–2684. https://doi.org/10.1021/acs.jchemed.0c00620

Supasorn, S., & Promarak, V. (2015). Implementation of 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for Grade 11 students. *Chemistry Education Research and Practice, 16*(1), 121–132. https://doi.org/10.1039/C4RP00190G

Suryawati, E., & Osman, K. (2018). Contextual learning: Innovative approach towards the development of students' scientific attitude and natural science performance. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(1), 61–76. https://doi.org/10.12973/ejmste/79329

Taber, K. S. (2013). Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice, 14*(2), 156–168. https://doi.org/10.1039/C3RP00012E

Weinrich, M. L., & Talanquer, V. (2015). Mapping students' conceptual modes when thinking about chemical reactions used to make a desired product. *Chemistry Education Research and Practice, 16*(3), 561–577. https://doi.org/10.1039/C5RP00024F

Yan, F., & Talanquer, V. (2015). Students' ideas about how and why chemical reactions happen: Mapping the conceptual landscape. *International Journal of Science Education, 37*(18), 3066–3092. https://doi.org/10.1080/09500693.2015.1121414