Learning chemistry through kitchen resources: An educational perspective

Krishna Maya Devkota [1]; Dr. Narayan Prasad Timilsena [2]

1. Lecturer of Mahendra Ratna Campus, Department of science education, Tahachal, TU, Kathmandu, Nepal, krishna1devkota@yahoo.com +977-9841369254
2. Lecturer of central department of education, Department of science and environment education TU, Kirtipur, Kathmandu, Nepal, narayan12.timilsena@gmail.com, +977-9841631712

Abstract

This study was carried out to explore chemistry learning through kitchen resources and to perform an experiment by using kitchen resources at the school level. It also explores how kitchen resources can be used to teach chemistry in an educational context. A qualitative research methodology was used for this study. Twenty students of secondary level (about 16 years of age) were selected from the purposive sampling procedure. The information was gathered from the experiment performed by the students through kitchen resources, and the cooking experiences of participants were taken from the in-depth interview. It was found that with the use of familiar kitchen ingredients and cooking processes, students can see the practical applications of chemistry and develop a deeper understanding of the subject. Teachers can use these resources to create engaging, interactive lessons promoting critical thinking and problem-solving skills. The kitchen resources should be integrated into the secondary-level chemistry curriculum, which can be a fun and effective way to enhance chemistry learning.

Keywords: *Learning Chemistry, Kitchen Resources, Educational Perspective.*

INTRODUCTION

Education plays a vital role in community development. This education may be formal or informal, and it helps the transfer of social norms and values. Whether the school is in a rural or urban setting, research shows that the materials utilized in the classroom have a substantial impact (Nja & Obi, 2021). Similarly, Chemistry is a science subject taught in schools through activities. But due to the lack of science equipment in the school, most of the teachers do not follow the rules (Cheung, 2008). Chemistry studies matter, energy, and its interactions, which can be found worldwide. It is in the food we eat, the clothes we wear, the water we drink, medicines, air purifiers, and anything else we can think of because it relates to other sciences, such as biology, physics, geology, and environmental science. So, chemistry is frequently called the "central science"(Nja, 2021). According to Ausubel's (1958) theory of advanced organizers, concepts are relevant when the learner can visualize and incorporate them within the cognitive framework. This means that students already understand the material and recognize more general ideas that include the concept taught. Similarly, they may use previously known materials for unknown learning materials. According to Edgar's (1969) audiovisual model of teaching, learners recall just 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they hear and see, 70% of what they say, and 90% of what they say and do.

In Nepal, science is mainly taught in a theoretical way. Real-life situations are rarely introduced in the classroom setting. As a result, most science classrooms do not deal with basic concepts and do not connect with real-life problems (Cobb & Bowers, 1999). Classroom instructions do not generally address the practical parts of science, although those practical, hands-on exercises are the best way to internalize science learning. This shows that the logical approach to teaching science is widely used in schools in Nepal (Minner et al., 2010). The problems in the practice book and the prescribed texts are used to teach science. Most teachers begin their classes by selecting a problem from the exercise textbook and using one of the problems, generally the first, as a model to demonstrate how to complete a specific sort of issue and how to solve it (Valverde et al., 2002). Science textbooks are written with a rigid approach, resulting in the same types of problems being repeated over and over again. The teacher answers the majority of the problematic issues and "delivers" to the students as examples so that they can "learn" by heart and repeat the process with all the rest of the teaching and learning problems (Saeliet et al., 2011). When a chemistry teacher uses kitchen materials to teach chemistry, it can help students as an example in the teaching and learning process (Taber & Garcia-Franco, 2010).

Cooking is just chemistry. Many procedures, such as heating, freezing, mixing, and blending, are employed in the lab and the kitchen. The ingredients (i.e., chemicals) that go into cooking are transformed simultaneously by various physical and chemical processes. Respiration, digestion, photosynthesis, food preparation, burning fuels like coal and petroleum, washing clothes and household items, and many other activities are examples of how chemistry is used in daily life. We carry out each of these tasks daily, involving chemical processes. Kitchen chemistry helps to develop new scientific tools that make science teaching easier for teachers and more enjoyable for students. Kitchen tools promote collaborative learning, team building, and classroom activity and can challenge and help even the able students (Cecilia, 2013). Cooking materials are used for science experiments and projects when chemical resources are unavailable or expensive. It explains the science underlying cooking clearly and simply, allowing viewers to see how the kitchen functions as a chemistry laboratory and cooking as an experiment. Students can learn about sugar, carbohydrates, lipids, and protein, all typical chemical constituents in the kitchen (Vega et al., 2012). Chemistry is a fundamental subject essential for understanding many aspects of the world around us. However, students often struggle to grasp the concepts taught in traditional classroom settings (Mann, 2006). One way to enhance learning is by incorporating real-life examples into the curriculum. The kitchen may be an ideal place to teach chemistry because it is a familiar environment where students can see the practical application of concepts (Chirikure, 2021).Therefore, this article explores how kitchen resources can be used to teach chemistry in an educational context. So, the study's central question is how to teach chemistry using cheap materials found in the kitchen.

PROBLEM STATEMENT /RATIONALE

Many teachers and students say science is a complex subject in general and chemistry in particular (Edomwonyi-Otu, & Avaa, 2011). NASA reports (2017) show that students' achievements are below average. The PISA report (2016) also resonates with this issue. It is heard that science teaching is based on rote learning that cannot foster critical and creative thinking (Novak & Cañas, 2007). It does not focus on learning by doing and students' daily life experience. In that situation, kitchen resources may play a vital role in learning chemical concepts. Students' experiences with cooking ingredients may help practical activities and remove learning difficulty. It may help to develop a positive attitude of students towards chemistry learning. Therefore, Learning Chemistry through Kitchen Resources: An Educational Perspective is selected as the problem of the study. It is also relevant to the contemporary teaching-learning situation in Nepal and abroad.

MATERIALS AND METHODS

The researcher explored the kitchen activities, observation of cooking food, different stages of adding cooking ingredients, document collection, and analysis of documents thematically. Baking soda, vinegar, food colouring, glitter, pH strips, pH meter, lemon juice, baking powder, vegetable oil, sugar, salt, canning jars, fresh cucumbers, fresh strawberries, kitchen utensils like measuring cups, spoons, mixing bowls, etc.

Participants

The participants of this study were secondary school students in a chemistry class. The study included ten male and ten female students with an average age of 16 years.

Procedures

The study was conducted over four weeks. During the first week, students were introduced to the concept of chemistry in the kitchen and given a brief overview of the kitchen resources that would be used in the study. The students were then divided into two groups of 10 students each. As the first group, Group A was given a baking soda and vinegar experiment to learn chemical reactions in the kitchen. The students discussed how to react baking soda with vinegar. Then they were asked to observe and record their observations of the chemical reaction. As the second group, Group B was given a pH testing experiment to perform in the kitchen. The students were given pH strips and a pH meter and asked to test the pH of various kitchen ingredients such as lemon juice, vinegar, and baking powder. They were then asked to record their observations and compare their results. During the second and third weeks, the groups were switched, and the students in Group A performed the pH testing experiment while Group B performed the baking soda and vinegar experiment. In the fourth week, the students were assigned to create their investigation using kitchen resources to demonstrate a chemical reaction.

Data Analysis

The data collected from this study were qualitative and were analyzed using content analysis. The students' reports were reviewed and coded for themes related to their observations and understanding of chemical reactions. The data were then organized into categories based on the themes that emerged.

Ethical Considerations

This study was conducted with the approval of the school's Institutional Review Board. Informed consent was obtained from the participants and their parents/guardians. The study did not involve any risks to the participants. The data collected were kept confidential and were used only for the study.

Results and Discussion

The result and discussion were based on chemistry in the kitchen, using kitchen resources for learning, learning chemistry through kitchen resources, cooking as the chemical reaction, and experiments performed in the kitchen.

Chemistry in the Kitchen

The kitchen is a rich source of chemistry experiments. Cooking, baking, and preservation involve chemical reactions (Dabrowski & Manson McManamy, 2020). Based on the kitchen and chemistry, one of the participants says:

> *We can observe first-hand experience from the ingredients like salt, oil, turmeric, ginger, coriander, garlic, lemon, and vinegar from the kitchen. For example, students can see the chemical reactions when we mix. We learned about the chemical properties of kitchen ingredients, such as the acidity of lemon juice and the hydrophobicity of oil (interview recorded, 16 March 2022).*

The above statement participant interprets the kitchen as a rich source of chemicals that can be used to experiment whether there is a chemistry laboratory. These kitchen ingredients can be used as alternative chemicals to perform chemistry experiments and teach chemical reactions in schools.

Using Kitchen Resources for Learning

Many kitchen resources can be used to teach chemistry concepts. For the alternative chemicals for the preparation of carbon dioxide gas, the Research participant says as follows:

> *Participants give examples of using kitchen materials for chemistry learning, like Baking soda and vinegar. The experiment demonstrates the reaction between an acid (vinegar) and a base (baking soda) to create carbon dioxide gas, which produces vigorous effervesces (interview recorded, 16 March 2022).*

The above views of participants show that in the state of calcium carbonate and hydrochloric acid, baking soda and vinegar are used as alternative chemicals for producing carbon dioxide gas. This experiment can be enhanced by adding food colouring and glitter to the mixture to make it more visually appealing. pH testing students can test the acidity or alkalinity of various kitchen ingredients using pH strips or a pH meter. For example, they can test the pH of lemon juice, baking soda, and vinegar and compare the results. For food preservation students can learn about the science behind food preservation by making pickles and jams. Both processes involve using acid and sugar to preserve the food and prevent the growth of bacteria. There are several benefits to using kitchen resources to teach chemistry. First, it makes the subject more accessible and relevant to students by using real-life examples (Childs et al., 2015). Second, it can increase students' interest and engagement in the subject. Third, it allows students to see the practical applications of chemistry, which can help them understand the subject more deeply. Finally, it can help students develop critical thinking and problem-solving skills by encouraging them to experiment and observe the results.

Cooking as the Chemical Reactions

As the heating process proceeds, the starch granules absorb water and expand. The cell wall of the rice granule splits when a specific temperature, known as the gelatinization temperature, is achieved, and the starch granules either turn gelatinous or form amylase and amylopectin. Based on the cooking as the chemical reaction, a participant having the pseudo name Jeevan says as follows:

> *Rice also contains fiber and protein. When bonds break during chemical processes, they recombine with other chemicals uniquely to produce new chemical compounds. It is well known in thermochemistry that bonds must be broken with heat to be formed with heat. Even cooking gas requires heat to begin; this makes it an endothermic reaction, but once it is underway, the amount of heat it produces makes the reaction itself exothermic. Exothermic reactions occur when bonds break, while endothermic reactions occur when bonds form (interview recorded, 16 March 2022).*

The participant's overhead view indicated that cooking makes a chemical change in any food. When cooking chicken, fish, or any vegetable curry, we add a few spices, including salt and water. All spices have so many aromatic chemicals, and the smell is due to some volatile chemicals; for example, cinnamon has 12 aromatic chemicals, and cloves, curry leaves, coriander, chilli a lot more. The watery media helps the reactions; maybe it acts as an electrolyte. We never know most foods have a large percentage of water, but in cooking rice, one needs to add water, and then heat undergoes convection currents in supplying heat to rice grains. There is a temperature gradient as we cook the pot of rice on fire from the bottom to the top of the pot (Schiffer et al., 1994). There would be a moment when the temperature within the container was consistent if the lid was closed. It begins to foam and frequently falls within a few minutes. This is a critical stage of cooking. They then open it until it settles for a few minutes and then put the cover back. I've seen that most people check the water or whether the food is cooked by opening the lid. According to the experience of another participant:

> *If the lid is opened, the temperature gradient lowers, losing some heat and more heat in the top layer. Then, in some situations, we add cold water and occasionally stir the rice. What happens next? When partially cooked rice is combined with cooked rice, it sometimes cooks well but more frequently fails (interview recorded, 16 March 2022).*

The above surprise experience of the participant shows that they assumed the chemistry behind properly boiling rice while unaware of all the chemical interactions involved. Because chemical volatility is temperature dependent, some spices are put in a coarse form to control the release of chemicals. The more heat we apply, the quicker the chemicals come out. Some chemical bonds break in the presence of heat, spices, meat, and rice, whereas other chemical bonds keep the molecules together. When those ties are broken, the food becomes softer, which makes it easier to chew, give it a pleasant flavour, and digest.

Figure 1. Process of cooking rice

Experiment Perform in the Kitchen

Many experiments can be conducted in the kitchen. The students' baking soda, vinegar, and pH testing experiment is explored under this heading.

Baking Soda and Vinegar Experiment Performed In the Kitchen

The baking soda and vinegar experiment is a classic and fun way to teach about chemical reactions in the kitchen. Group A students performed the baking soda and vinegar experiment in the kitchen. They used materials like Baking soda, Vinegar, Bowl, a Spoon, Measuring spoons, etc. Students started by measuring one spoon of baking soda and placing it in a bowl. Next, measure 1/4 cup of vinegar and pour it over the baking soda. Observed the mixture begins to fizz and bubble! This is the chemical reaction happening. The baking soda (sodium bicarbonate) reacts with the vinegar (acetic acid) to produce carbon dioxide gas, which creates bubbles (Chan et al., 2021). They also added food colouring to the mixture to make it more visually attractive. They tried varying the baking soda and vinegar amounts to see what would happen. Students also tried to add other materials to the mixture, such as soap and salt, to see how they affected the reaction. This experiment helps teach about chemical reactions and the properties of different materials. It's also a fun and easy activity to do in the kitchen with school-level students for the science experiment. The picture of the reaction and testing performed in the kitchen are given as follows:

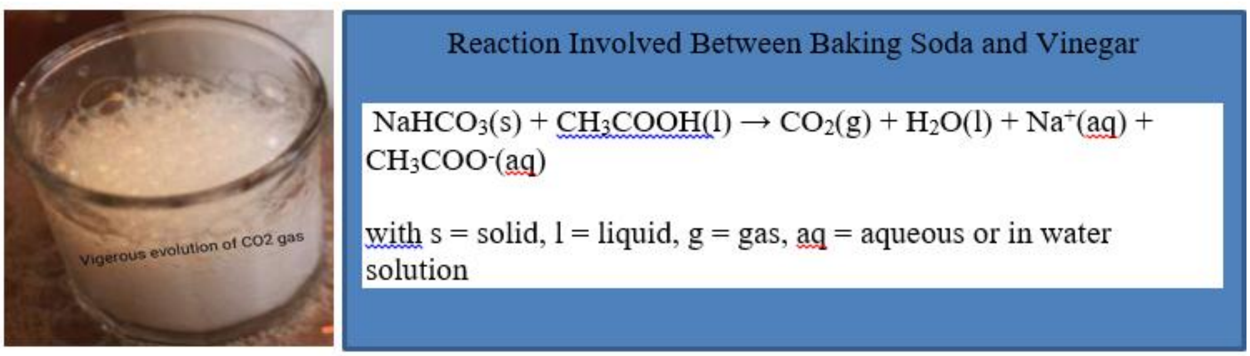

Figure2. The reaction between baking soda and vinegar

The above chemical reaction happens in two stages. Initially, acetic acid in the vinegar undergoes a double displacement reaction with sodium bicarbonate to produce sodium acetate and carbonic acid: $NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2CO_3$

Because it is unstable, carbonic acid undergoes a process that decomposes to produce carbon dioxide gas: $H_2CO_3 \rightarrow H_2O + CO_2$

Bubbles of carbon dioxide emerge from the fluid. Since the bubbles are heavier than the air, the carbon dioxide collects on the surface of the cup and overflows it.

pH testing Experiment to Perform in the Kitchen

Group B students performed a pH testing experiment in the kitchen using red cabbage juice as a natural indicator. To perform the pH test, students used materials like red cabbage, water, a strainer, a blender, a measuring cup, small bowls, lemon juice, baking soda, and vinegar. Students cut up red cabbage and blend it with two cups of water until it becomes a smooth crush. They strained the red cabbage squash through a strainer, collected the juice in a measuring cup, and poured a small amount of the red cabbage juice into a few small bowls. Added a few drops of the substance to the red cabbage juice and observed the colour change to test the pH of the substance. The red cabbage juice was turned pink, indicating the substance was acidic. The red cabbage juice turned blue or green indicates the substance is basic (Kuswandi et al., 2020). The pH of various kitchen substances like lemon juice, baking soda, and vinegar was tested, showing the different colours produced in the red cabbage juice. Red cabbage juice is a natural pH indicator that changes colour in response to acidic or basic substances. This experiment can be a fun and educational way to learn about pH and acidity in the kitchen. The pH testing experiment performed in the kitchen is given as follows:

Figure3. pH testing experiment performed in the kitchen

Preparation of Litmus Paper through Kitchen Resources

Litmus paper is a commonly used pH indicator that changes colour in response to the acidity or basicity of a substance (Jusayan, 2015). While litmus paper is unavailable in the school, it can also be prepared using simple kitchen resources and used in teaching-learning. Students used materials like red cabbage, white coffee filters, paper towels, scissors, a blender, a bowl, water, and vinegar to prepare the litmus. Based on these materials, participants prepare the litmus paper from kitchen resources in the following ways:

The red cabbage was cut into small pieces and placed in the blender. Add enough water to cover the cabbage and blend it until smooth. The cabbage mixture was poured into a bowl and let sit for at least 30 minutes. The coffee filters or paper towels were placed in the cabbage mixture, ensuring they were completely saturated. The filter paper was removed from the cabbage mixture and let them dry completely. Once dry, the filter paper was cut into small strips. To use the litmus paper, dip a strip into the substance being tested (note taken from participants' record file, 25 April 2022).

From the above procedure, the participant prepared the litmus paper and tested in the different kitchen ingredients. The litmus paper turned red in the presence of an acid and blue in the presence of a base. If desired, the paper can be dipped in vinegar and baking soda to confirm the colour changes.

Figure 4. Preparation of litmus from kitchen resources

Resources of Litmus Test

A litmus test is a simple and inexpensive way to determine the acidity or basicity of a substance. Several resources can be used in the kitchen to perform a litmus test; some are explored in these headings.

Red cabbage. Red cabbage contains a pigment called anthocyanin that changes colour in response to pH. To perform a litmus test with red cabbage, chop a small amount and boil it in water for about 10 minutes. Strain the liquid and use it as a pH indicator. The liquid will turn pink in the presence of an acid and blue or green in the presence of a base.

Lemon juice. Lemon juice is acidic and can be used to test for basicity. Simply add a few drops of lemon juice to the substance being tested. If the substance turns pink or red, it is basic.

Baking soda. Baking soda is a base and can be used to test for acidity. Mix a small amount of baking soda with water to form a paste. Apply the paste to the substance being tested. If the substance turns blue or green, it is acidic.

Litmus paper. Litmus paper is a type of pH indicator that is readily available in the instrumental shop. Dip the litmus paper into the tested substance and observe the colour change. The paper turned red in the presence of an acid and blue in the presence of a base. These are just a few examples of resources that can be used to perform a litmus test in the kitchen. It's important to remember that litmus tests are not always precise and may not give an exact pH value. However, they can be valuable for determining a substance's general acidity or basicity. Therefore, it can be helpful in acidic and basic pH testing. It was concluded that students can be prepared the litmus paper from kitchen ingredients.

Use of Salt before Turmeric in Cooking Vegetables.

Generally, we add salt after adding turmeric to cooking vegetables for colour and testing. Adding salt before turmeric when cooking vegetables can affect the colour and taste of the dish (Govindarajan & Stahl, 1980). Participants observe the cooking vegetables several times and draw the following inference.

> *Turmeric is a spice that gives a vibrant yellow colour to dishes. However, adding salt before turmeric can cause the colour to change and become cloudy. This is because salt can break down the pigments in turmeric, causing them to lose their colour intensity. Turmeric has a slightly bitter and earthy flavour that adds depth to dishes. When salt is added before turmeric, it can mask or overpower the flavour of the turmeric, making it less noticeable on the plate (note taken from participants' record file, 25 April 2022).*

The note-taking from the participant indicated that to avoid these issues, it's recommended to add turmeric to the dish before adding salt. This allows the spice to fully develop its color and flavor before the salt is added.

Figure 5. Adding salt before and after the turmeric when cooking vegetables

Reaction Occurs Between Ash and Turmeric

When ash is mixed with turmeric, the turmeric's colour changes. Ash is a basic substance, and turmeric is acidic. When an acid and a base are mixed, a neutralization reaction occurs, which can cause the colour to change (Caraballo et al., 2021). The participants explore that turmeric contains curcumin, which gives it a vibrant yellow colour. When curcumin comes into contact with an alkaline substance like ash, it can turn the turmeric from yellow to reddish-brown or brown. This is because the alkaline ash changes the pH of the turmeric, causing the curcumin to break down and lose its colour intensity. However, it's important to note that this colour change may vary depending on the type and amount of ash used and the amount of turmeric. In addition, the effect of the ash on the turmeric may be more noticeable in some recipes than in others. In general, it's best to avoid mixing ash with turmeric to preserve the vibrant yellow colour of the spice. Instead, use turmeric with other acidic ingredients to maintain its colour and flavour.

Use of Oil in the Cooking Vegetables

In our kitchen oil is widely used for cooking vegetables. But we don't feel why is it used and what reaction occur behind this? It doesn't discuss the classroom teaching and learning connected to the kitchen resources. For the discussion of this topic, student X says as follows:

> *In my kitchen oil is used in cooking vegetables to prevent burn. But I don't connect it with chemistry learning. I don't know what reaction occurs in oil and cooking vegetables. It is traditional work but it doesn't discuss the viewpoint of chemical reactions (interview recorded 25 April 2022).*

The above view of the participant shows that our teaching-learning process is not connected with kitchen resources. There is no provision to connect kitchen activities with chemistry learning. Cooking vegetables with oil can enhance their flavour and aroma by adding richness and depth to the dish. Oil can help create a crispy, heated exterior on vegetables while keeping the inside tender and juicy (Zhang et al., 2019). Oil is a good conductor of heat, which helps vegetables cook evenly and quickly. Some vitamins and nutrients in vegetables are fat-soluble, which means they need to be cooked with oil for the body to absorb them properly. When choosing an oil for cooking vegetables, it's essential to consider the smoke point, the temperature at which the oil begins to break down and smoke. Oils with higher smoke points, such as avocado and coconut oil, are better for high-heat cooking methods like stir-frying or roasting. In comparison, oils with lower smoke points, like olive oil and flaxseed oil, are better for lower-heat cooking methods like cooking or salad coverings.

Use of Species and Oil in Pickle Preparation

Oil and spices are used in making pickles. But we don't feel why is it used and what reaction occur in it? It is not connected to classroom teaching learning. For the exploration of this topic, student Y says as follows:

> *In my kitchen, oil and spices are used for making the pickle. But I don't connect it with chemistry learning. I don't know what reaction occurs in oil and spices within the pickle. It is prepared in a traditional process, but it doesn't explore the viewpoint of chemical reaction (interview recorded 25 April 2022).*

This view of the participant indicated that our teaching-learning process is not connected with kitchen resources. These concepts are not associated with kitchen activities with chemistry learning. Adding spices and oil to pickles enhances their flavour, aroma, and texture. Spices can provide a variety of flavours, such as tangy, spicy, or sweet, while oil can add richness and depth to the pickle (Mouritsen & Styrbaek, 2020). The oil and spices act as natural preservatives and help keep the pickles fresh for extended periods by inhibiting the growth of harmful bacteria. Some spices, such as ginger and cumin, have digestive properties that can aid digestion and alleviate digestive discomfort. Some spices and oils used in pickles have nutritional benefits. For example, turmeric contains curcumin, which has antioxidant and anti-inflammatory properties, while sesame oil is a good source of healthy fats and vitamin E. The specific spices and oil used in making pickles can vary depending on the region and the recipe. Common spices used in pickles include mustard seeds, cumin seeds, fenugreek seeds, fennel seeds, coriander seeds, and red chilli powder. Common oils used in pickles include mustard oil, sesame oil, and vegetable oil.

CONCLUSION

In conclusion, learning chemistry through kitchen resources can effectively engage students in science education. Kitchen resources can be used to provide a practical and accessible approach to teaching chemistry concepts and can help students connect abstract ideas with real-world applications. By using everyday life experience of kitchen items to demonstrate chemical reactions, students can develop a deeper understanding of chemistry and learn to appreciate science's role in their daily lives. Moreover, this educational perspective emphasizes the importance of active learning and hands-on experimentation instead of passive learning through lectures or textbooks. Kitchen resources provide a fun and engaging way to learn, which can help students develop a positive attitude toward science and increase their motivation to learn. While this approach may not replace traditional classroom teaching, it can complement and enhance it by providing a practical and accessible approach to learning chemistry. Therefore, educators should consider incorporating kitchen resources into their teaching strategies to provide a unique and effective way to teach chemistry. Overall, using kitchen resources can be valuable in promoting science education and fostering a love of learning in students.

REFERENCE

Caraballo, R. M., Saleh Medina, L. M., Gomez, S. G., Vensaus, P., & Hamer, M. (2021). Turmeric and RGB analysis: a low-cost experiment for teaching acid–based equilibria at home. *Journal of Chemical Education*, *98*(3), 958-965. https://doi.org/10.1021/ACS.JCHEMED.0C01165.

Cecilia, N. (2013). *Kitchen Resources Classroom Interaction and Academic Performance and Retention of SS2.Chemistry Students in Thermochemistry*. *4*(8), 169-173. https://www.researchgate.net/publication/333614475.

Chan, K., Madsen, L., Kashani, N., & Lee, R. (2021). Bubbling Baking Soda. *The Expedition*, *11*.

Cheung, D. (2008). Facilitating chemistry teachers to implement inquiry-based laboratory work. *International Journal of Science and Mathematics Education*, *6*(1), 107-130.

Childs, P. E., Hayes, S. M., & O'dwyer, A. (2015). Chemistry and everyday life: Relating secondary school chemistry to the current and future lives of students. In *Relevant chemistry education* (pp. 33-54). Brill.

Chirikure, T. (2021). Pre-service science teachers 'experiences of home-based practical work under emergency remote teaching. *Journal of Baltic science education*, *20*(6), 894-905.

Cobb, P., & Bowers, J. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational researcher*, *28*(2), 4-15.

Dabrowski, J. A., & Manson McManamy, M. E. (2020). Design of culinary transformations: A chemistry course for nonscience majors. *Journal of Chemical Education*, *97*(5), 1283-1288.

Edomwonyi-Otu, L., & Avaa, A. (2011). The challenge of effective teaching of chemistry: A case study. *Leonardo Electronic Journal of Practices and Technologies*, *10*(18), 1-8.

Fernandez-Cano, A. (2016). A methodological critique of the PISA evaluations. *Relieve*, *22*(1), 1-16.

Govindarajan, V. S., & Stahl, W. H. (1980). Turmeric—chemistry, technology, and quality. *Critical Reviews in Food Science & Nutrition*, *12*(3), 199-301.

Jusayan, S. (2015). pH indicator from kamias (Averrhoa bilimbi L.) flower extract. *WVSU Research Journal*, *4*(1), 30-40.

Kuswandi, B., Asih, N. P., Pratoko, D. K., Kristiningrum, N., & Moradi, M. (2020). Edible pH sensor based on immobilized red cabbage anthocyanins into bacterial cellulose membrane for intelligent food packaging. *Packaging Technology and Science*, *33*(8), 321-332.

Mann, R. L. (2006). Effective teaching strategies for gifted/learning-disabled students with spatial strengths. *Journal of Secondary Gifted Education*, *17*(2), 112-121.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry- based science instruction—what is it, and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(4), 474-496.

Mouritsen, O. G., & Styrbæk, K. (2020). Design and 'umamification'of vegetable dishes for sustainable eating. *International Journal of Food Design*, *5*(1-2), 9-42.

Novak, J. D., & Cañas, A. J. (2007). Theoretical origins of concept maps, how to construct them, and uses in education. *Reflecting education*, *3*(1), 29-42.

Poudel, L. N. (2017). A Review of the Results of National Assessments of Student Achievement in Nepal. *Educational Assessment*, *18*.

Saeli, M., Perrenet, J., Jochems, W. M., & Zwaneveld, B. (2011). Teaching programming in Secondary school: A pedagogical content knowledge perspective. *Informatics in education*, *10*(1), 73-88.

Schiffer, M. B., Skibo, J. M., Boelke, T. C., Neupert, M. A., & Aronson, M. (1994). New perspectives on experimental archaeology: surface treatments and thermal response of the clay cooking pot. *American Antiquity*, *59*(2), 197-217.

Taber, K. S., & García-Franco, A. (2010). Learning processes in chemistry: Drawing upon cognitive resources to learn about the particulate structure of matter. *The Journal of the Learning Sciences*, *19*(1), 99-142.

Valverde, G. A., Bianchi, L. J., Wolfe, R. G., Schmidt, W. H., & Houang, R. T. (2002). *According to the book: Using TIMSS to Investigate the Translation of Policy into Practice through the World of Textbooks*. Springer Science & Business Media.

Vega, C., Ubbink, J., & Van der Linden, E. (Eds.). (2012). *the kitchen as laboratory: Reflections on the science of food and cooking*. Columbia University Press.

Zhang, N., Sun, B., Mao, X., Chen, H., & Zhang, Y. (2019). Flavour formation in the frying process of green onion (Allium fistulosum L.) deep-fried oil. *Food Research International*, *121*, 296-306.