The Science of the Banana Cake; Development of Integrated Instruction on Science Knowledge and Skill by Using Hands-on Activities

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Abstract
The baking activity is a science teaching enhancement course that is focused around using food to engage students in many topics in chemistry. The purposes of this study are to develop ways of integrating science knowledge and skills by using hands-on activities and to find out the effectiveness of a baking activity for teaching of concepts of the biomolecule and chemical reactions. The results showed that the scores for the posttests which are statistically significant difference of the control group (CG) (M=6.98, SD=0.84) and experiment group (EG) (M=8.67, SD=1.60). In pretest and posttest students were also asked to self-assess their knowledge by answering the following questions with "I am sure" and "I do not know". The number of students in the CG that assessed "I am sure" stayed about the same with a decrease in the answer "I do not know" at both answers "Right" from 41.46% on the pretest to 17.31% on the posttest and from 2.69 % on the pretest to 0.45% on the posttest, respectively. In contrast with the EG students, there was substantial improvement. Especially, "I am sure", encouraging is to increase in the number of right answers and decrease in the number of wrong answers. In the same way, "I do not know" results showed that the right answer increased after they learned with a baking activity. The results show that a baking activity can enhance students' understanding about conceptual knowledge and encourage students to realize the link between food and chemistry.

Keywords: Hands-on activity; baking activity; biomolecule

Introduction

Many schools have developed teaching and learning methods which are the embodiment of various knowledge and skills necessary for the 21st century. For teaching methods, instructors have an important role to engage students to discover, explore, design and solve real life problems. Instructors will also go from lecturers and become the facilitators of learning. Hands-on learning, an active learning method, is one of the teaching methods (Capraro R.M., et al., 2013). This concept aims to help students build their own knowledge and learning skills by doing the activities themselves (Ainsworth S., et. al., 2011).

Also, this concept provides learners with experience and continuing education. The literature on education has explored that hands-on learning is one of the skills to reinforce 21st century learning skills. Hands-on learning is a concept designed to support students' learning through self-dependence (Cheung, T., et. al., 2016). Students are engaged in learning through research, exploration and starting to do, which will become a skill vital for lifelong learning and professional sources.

The fundamentals of chemistry is a topic that has been a part of the scientific curriculum at both junior and senior school levels. Many concepts in chemistry seem complicated and difficult for the students to understand in terms of scientific knowledge. One reason for such difficulty is that some concepts deal with chemistry on a microscopic level and so this cannot always be understood by just looking at it (Kelly, R., et. al., 2005). Hence, instructors must transform and simplify non-visual concepts into chemical models or symbols to help students understand them clearly. Moreover, many instructors applied various activities in courses such as games (Seungkeun K., et. al., 2014), art (Eisenkraft A., et. al., 2006), cartoon (Özmen H, 2012), cooking (Brunosson A., et.al., 2013) and baking (Amy C. R., et. al., 2010) et cetera. that help students of all ages to enjoy science. Therefore, the selection itself of an activity is important, as a well-selected activity can have a positive impact on students and help them understand concepts (Schwartz K., 2015).

Food can be a useful teaching tool to develop understanding of science concepts and engage students in active learning (Brunosson A., et.al., 2013 and Amy C. R., et. al., 2010). Students can then link and apply chemistry to everyday life. Food science-based activity allows for an interdisciplinary approach to learning including chemistry, biomolecule, chemical reaction, microbiology, engineering and mathematics (Amy c., et. al., 2010; Harvard. J. A., 2015; Sharon K., et. al., 2004). For example, according to Brunosson A., et.al. (2013), cooking is a subject of increasing interest, within both society and science. The cooking statements from the food and meal science students and teachers show that there is a great interest in food, its ingredients and how to prepare a meal by using different types of cooking processes to create delicious food and meals. Amy C. R., et al. (2010), scientific concepts in the context of a familiar food, pizza, might be used interactively as a demonstration where children act out the role of the molecules. At the end of the lecture, a professional pizza maker twirls pizza dough, and we even serve pizza so that everyone can experience the food they just learned about. Based on audience feedback, the presentation generates excitement and curiosity to continue asking questions about science in everyday life. Moreover, the skills learned in the activities would also be instantly transferable to the students' own cooking opportunities.

From the specific research questions which were how science could be enjoyable, and so easier to make students understand the topic on the "biomolecule". Therefore, the purposes of this study are to develop ways of integrating science knowledge and skills by using hands-on activities and to find out the effectiveness of a baking activity for teaching of concepts of the biomolecule and chemical reactions in secondary school.

Objective

1. To determine and compare the effect of food science-based instruction in high school and how it can enhance students' understanding of the biomolecule and chemical reaction concepts.
2. To investigate the effectiveness of teaching chemistry by integrating a baking activity into students' scientific knowledge.
3. To encourage students to realize the link between food and chemistry.
4. To apply scientific knowledge in everyday life.

Methodology

Participant and assessment

The research design included two groups which consisted of a control group (CG) and an experiment group (EG). The CG and EG were taught with lecture-based learning, hands-on based learning (food-science-based activity; baking activity) but with different to teaching approaches. Twenty-four students from the 12^{th} grade of CG and EG were investigated. Students participated in a series of lessons, and activities over eight weeks. A pretest and posttest were also administered to measure student learning in this course.

Course design

We are developing and integrating several teaching methods in an effort to improve students' attitudes toward understanding the biomolecule and chemical reaction concepts which involves a hands-on approach, including baking activities, question-based and lecture-based teaching. The course is designed based on 3 mainly expected outcomes which are 1. Understanding the biomolecule and chemical reaction concepts, 2. Understanding the meaning of food and chemistry and 3. Applying the scientific knowledge to everyday life. This course has also integrated 9 learning goals and soft skills. These are listed in below.

<u>Learning goals and soft skills related to biomolecule in the curriculum</u>

1. Learn the elements present in biomolecules and the difference between monomers and polymers.
2. List the four major complex biomolecules found in living cells, three of which are found on food labels and the basis for the grouping of biomolecules into those four groups.
3. For each group of biomolecules learn the name of its generic monomer (simple unit) and polymer (complex structure) and their function.
4. Carbohydrates:
    4.1 Identify their chemical elements and the difference between simple sugars and complex carbohydrates. On the food labels, what do sugar or sugar alcohol, and

fiber refer to?

4.2 Compare and contrast the structure and function of the following carbohydrates and where they are found: glucose, glycogen, starch, cellulose, chitin.

5. Proteins:

5.1 Identify their chemical elements and functional groups. Recognize the structure of an amino acid and the peptide bond that connects di-, tri, and polypeptides. Recognize the presence of 20 amino acids and that not all are essential amino acids.

5.2 Summarize the function of proteins and recognize the importance of the three dimensional shape of a protein on its function and the role of non-covalent bonds in maintaining the shape of a protein.

5.3 Explain protein denaturation and the effect of heat on protein structure and function.

6. Lipids:

6.1 Identify their chemical elements and learn their property of insolubility in water.

6.2 Identify the three groups of lipids.

6.3 Compare and contrast saturated and unsaturated fatty acids. Explain the importance of unsaturated fatty acids and why omega-3 and omega-6 fatty acids are considered essential. List sources of unsaturated fatty acids.

7. Develop a positive attitude and skill toward scientific experiments.
8. Understand and acknowledge links between science and food.
9. Develop capabilities in scientific thinking processes and practical skills.

Furthermore, the approach of the course design contains a variety of activities for the students to do. It is worthy to note that the instructor will attempt to integrate theory with practice during the teaching and learning process, and intends to keep some parts of the tasks as open-ended problems to challenge the students to study it themselves.

In the study, there were two groups of students: experimental group and control group. Both groups participated in the baking activity (seeing in figure 1.1 and 1.2). However, teaching approaches in each group were different. For the control group, the students were instructed with traditionally designed chemistry instruction. During the classroom instruction, the instructor used lecture and discussion methods and solved algorithmic problems to teach biomolecule concepts. For the experimental group, students participating in the baking activity were presented with lecture notes throughout this study. After that, the baking experience was used to strengthen the different chemistry concepts they were learning about. The posttest will be conducted immediately after they finish this final activity.

As seen from figures 1.1 and 1.2, the procedures of teaching consist of:

Pretest and posttest; Both the pretest and posttest were used before and after learning. The pretest was used to determine the students' background knowledge. It was very important to know students' background knowledge so it can then be used as a guideline to create suitable lessons. The posttest was also used to assess the students' gain in cognitive ability after learning through the new approach.

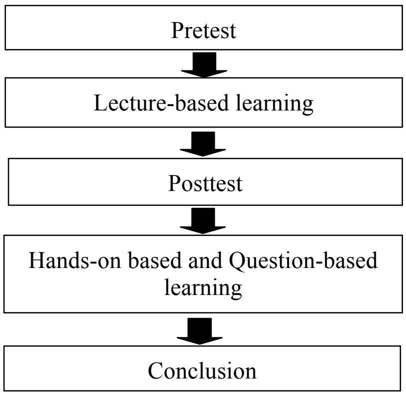

Figure 1.1 Course design of control group

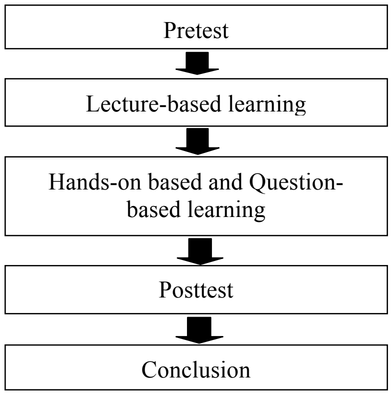

Figure 1.2 Course design of experiment group

The chemistry lecture; During the lessons, instructors tried to make a student-centered instruction based on discussions and oral explanations. The chemistry lecture process was used to explain the important concepts related to the biomolecule. The topics are listed below.

1) Carbohydrates
2) Proteins
3) Lipids

The learning activity (baking activity); This activity covered 2 approaches of teaching and learning processes. These are hands-on-based and question-based learning. The hands-on-based learning was used to attract students' attention and encourage students to learn chemistry concepts by using baking as an activity. Instructors combined chemistry concepts, the cooking activity and laboratory activity to engage students and improve students' understanding of the biomolecule concept. The teaching and learning processes for the baking activity were divided into 3 steps as follows.

1. Before the experiment.

All students were divided into 6 groups (6 experiments) which were;

• The baking temperature at 150 ° C (The large group A)

Group 1: took 10, 15, 20 minutes to bake, a regular recipe.
Group 2: took 10, 15, 20 minutes to bake, a regular recipe without lime.
Group 3: took 10, 15, 20 minutes to bake, a regular recipe without baking powder and baking soda.

• The baking temperature at 180 ° C (The large group B)

Group 4: took 10, 15, 20 minutes to bake, a regular recipe.
Group 5: took 10, 15, 20 minutes to bake, a regular recipe without lime.
Group 6 took 10, 15, 20 minutes to bake, a regular recipe without baking powder and baking soda.

The baking time and temperature have an impact on the morphology and the texture of cake and on its quality. This baking activity was to compare the influence of temperature with different functional ingredients (baking soda, lime and baking powder) and on the physical characteristics of a banana cake (color, weight, height and diameter).

2. Experimental procedure

Each group of students was allowed to make the banana cake according to the ingredients and description as follows.

The dry ingredients	
1. All purposes flour	115 g
2. Cake flour	115 g
3. Baking powder	2 teaspoons
4. Baking soda	1 teaspoon
5. Sugar	160 g
6. Salt	¼ teaspoon
7. Cream of tartar	¼ teaspoon

The wet ingredients	
1. Milk	¼ cup
2. Lemon juice	1 teaspoon
3. Unsalted butter	150 g
4. Ripe banana	300 g
5. Egg	3 eggs
6. Vanilla extract	1 teaspoon

Description: Preheat the oven to 150 ° C (No.1) and 180 ° C (No.2)

1) Whisk flour, baking powder, and baking soda together 2 times, set aside.
2) Separate the egg yolk from the white, set aside.
3) Add lemon juice to milk, set aside.
4) Using a handheld mixer to beat the butter on high speed until smooth and creamy about 1-2 minute.
5) Add the eggs yolk and the vanilla extract in No4. Beat by handheld mixer on medium-high speed until combined.
6) Add the banana in No.5.
7) Add No.1 and No.3 in No.6, stir until well mixed
8) Using a handheld mixer to beat the egg white with cream of tartar until smooth and creamy.
9) Add No.8 in No.7, stir until well mixed, set aside.
10) Scoop the No.9 into small cups, weight 30 g. Baked at the temperature and time specified in each group.

3. After the experiment

In question-based learning, the instructor tried to engage students with questions and class discussion. Instructors asked students to make observations about the physical characteristics of the banana cake (weight, height, diameter shape, color, texture, mechanism of forming, structure and properties of ingredients). Students brainstormed and took part in to asking the questions regarding the observation of the baking activity with recorded whole questions for discussion. Finally, they discussed and shared their previous and new knowledge together. They also helped each other respond to the questions. Moreover, the teacher emphasized important points of the biomolecule topics in order to help make students understand the topic more clearly.

Figure 2 Baking activity in Chemistry class

Result and Discussion

The baking activity is a science teaching enhancement course that is focused around using food to engage students in many topics in chemistry. In this section the results are shown for our teaching and learning activity consisting of 2 sections which are pre-posttests and questionnaire results. In pretest and posttest students were asked to self-assess their knowledge by answering the following questions with “I am sure” and “I do not know” that were as follows;

Question Topic	**Answer**	**Assessment**	
		I am sure	**I do not know**
What kind of biomolecules of cake flour, egg, unsalted butter, sugar and milk? (Protein, Carbohydrate or Fat etc.)			
How does it work of sugar, salt, unsalted butter, milk, lemon juice and egg in bakery products?			
What is the emulsion?			
Why is the wheat flour in the bakery products?			
What is the process of baking, protein denature?			
What is the similar and difference between fat and oil?			

The descriptive measures of tests for the control group (CG) and the experiment group (EG) are given in Table 1. One way (factor) ANOVA revealed no statistically significant difference between students’ mean scores of pretest for the CG (M=6.56, SD=1.14) and the EG (M=5.62, SD=2.25) at the p-value of 0.078 (> 0.05). This reflects similar backgrounds of both groups’ students in respect to biomolecule and chemical reactions knowledge before integrating the baking activity.

TABLE 1: Pretest and posttest score of on students' knowledge

Group	Test	Mean ± SD	N	p-value
Control	Pretest	6.56 ± 1.14[ab]	24	0.157
	Posttest	6.98 ± 0.84[b]	24	
Experiment	Pretest	5.62 ± 2.25[a]	21	0.000*
	Posttest	8.67 ± 1.60[c]	24	

** Values followed by the same letter in the same column are not significantly different (P > 0.05)*

The posttest score of students' knowledges also summarized in Table 1 were quite positive in each group. The mean score of posttests showed a statistically significant difference of the CG (M=6.98, SD=0.84) and EG (M=8.67, SD=1.60) with respect to the achieved chemistry knowledge ($p < 0.05$). This means that there was a significant mean difference between the students' knowledge in the CG and EG with respect to understanding of biomolecule and chemical reactions.

Many previous literature reviews reported that students who learned using hands-on manipulative activities had higher science achievement and science attitude scores than students who learned through traditional lecture, reading and discussion activities (Özmen H., 2012 and Capraro R.M., et al., 2013). In the lecture section, students learned chemistry concepts such as protein, carbohydrate and lipid. It was more abstract. Students could not visualize or understand the chemistry concept or application of the biomolecule. After the students had finished the learning activities, the results from students' discussion and posttest were presented which showed students understood the chemistry concepts more clearly. For example, students had more to discuss in terms of the different physical properties, which can be considered as characterizing the banana cake, the porosity is important not only for the mechanical properties of the crumb but also for moisture transfer within the product. Other aspects may also be considering how the ingredients interact with each other such as starch characteristics in the flour sifting process, dripping lemon juice into milk, butter beating, adding the eggs into the butter and sugar and et cetera. The hands-on activity can create a new learning environment that can help students to construct their knowledge. Moreover, question-based and lecture-based learning can also develop logical and inquiry skills.

In pretest and posttest students were also asked to self-assess their knowledge by answering the following questions with "I am sure" and "I do not know" as shown in Table 2 we present the self-assessment results in each group.

Group	**"I am sure"**						**"I do not know"**					
	Right		Half-Right		Wrong		Right		Half-Right		Wrong	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Control	41.46	17.31	26.43	31.27	32.11	51.42	2.69	0.45	13.71	19.54	66.94	63.34
Experiment	16.29	33.86	40.90	46.25	42.81	19.89	0.25	16.67	18.14	19.05	81.62	47.62

TABLE 2: Percentages of pretest and posttest score on students' assessment

The number of students in the CG that assessed “I am sure” stayed about the same with a decrease in the answer “I do not know” at both answers “Right” from 41.46% on the pretest to 17.31% on the posttest and from 2.69 % on the pretest to 0.45% on the posttest, respectively. While, the answers “I am sure” and “Wrong” at 32.11% on the pretest to 51.42% on the posttest. One possible explanation could be that students were not interested in the subject and so it was difficult for them to visualize. Another may be that some students did not enjoy the methods in which the lessons were taught, that is having only a chemistry lecture or lecture-based learning which could have had an impact on their interest. In contrast with the EG students, there was substantial improvement. Especially, “I am sure”, encouraging is to increase in the number of right answers (Pretest = 16.29%, Posttest = 33.86%) and decrease in the number of wrong answers (Pretest = 42.81%, Posttest = 19.89%). In the same way, “I do not know” results showed that the right answer increased after they learned with a baking activity (Pretest = 0.25%, Posttest = 16.67%). From students’ interviews, their confidence increased compared with before doing the activity. However, they were still not sure how to assess the “I am sure” answer. Moreover, the number of “I do not know” of wrong answers decreased. This means more confidence in the student’s ability to try and answer the question even if the answers were wrong. At this percentage it is more important to increase student’s confidence and excitement concerning the baking activity rather than getting all the answer 100% right. The majority of students felt this baking activity allowed them to increase their confidence in respect to the chemistry achievement from pretest to posttest. Özmen H., et. al. (2012) report that hands-on nature of the practical works and concept cartoons were particularly helpful for the students’ understanding of the concept of acid-based in chemistry. Moreover, a literature review gives us some information about active learning sometimes called inquiry learning, which engages the students and requires them to take part in the learning process through activities and student-driven studies. Passive learning consists of traditional lecture-based teaching. This includes practice problems or book questions. Passive learning may suit some learners some of the time, but it is ineffective for many learners much of the time (Michel N., et. al., 2009).

Conclusion

The results show that a baking activity can enhance students’ understanding about conceptual knowledge and encourage students to realize the link between food and chemistry. Students in EG performed better on the posttest compared to the students in CG. For example, students can conclude that the relation between the structure of the biomolecule and properties that a carbohydrate had more oxygen atom to improve solubility, whereas a lipid had less oxygen atoms. To mix them together, the phospholipid in egg yolk was used to emulsify them. Many recipes require fats and water-based liquids to come together in a solution, even though they repel each other. This kind of solution is called an emulsion.

The strength of this hands-on activity was that it allowed students to create something they could call their own. This in turn motivated the students to spend many hours outside of class baking banana cake which led them to ask higher level questions. The hands-on activity has a positive effect on students’ baseline knowledge. The use of hands-on activity in solving the real problems provided students with a great opportunity to use their chemistry curricula to illustrate concepts that were taught in the classroom and difficult for students to visualize. Therefore, this project sparked creativity in the students and motivated them to understand the chemistry behind baking banana cake. Students significantly improved their knowledge and skills.

Recommendation

Researchers may improve our approach to biomolecule concepts by integrating other food activities and new teaching methods. Moreover, researchers may also improve assessment methods by using pre and post-interviews to gather more information about students' views and conceptions related to biomolecule for improving their understanding about the actual concepts. This further step would be to both rework and refine the curriculum based on the posttest and interview results and then implement the curriculum into a larger setting in other schools.

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