DESIGNING A PROCESS TO PREVENT APPLE'S BROWNING: A STEM ACTIVITY

Sevgi Aydın-Günbatar[1]

ABSTRACT

The purpose of this study is to present an activity based on integrated Science, Technology, Engineering, and Mathematics [STEM] approach, its implication, steps, and necessary documents. The activity started with a daily-life problem stated in the STEM literature. Later, activity worksheets were provided. Learners were asked to design a process to prevent or slow down apple's browning reaction. After the first designing step, groups' preventing processes were compared by the use of a rubric prepared previously. Then, groups were given a chance to re-design preventing apple's browning process. Finally, in light of the rubric, the most successful preventing process was determined. The activity can be used both in high school chemistry and biology courses. Teachers who implemented the activity stated that the participating learners enjoyed the lesson and came up with interesting ideas. Furthermore, they stated that the activity does not necessitate expensive materials, and can easily be applied.

Keywords: STEM, engineering design process, reaction rate, enzymatic reaction.

ELMANIN KARARMASININ ENGELLENMESİ: BİR FeTeMM ETKİNLİĞİ

ÖZ

Bu çalışmanın amacı günümüzde yaygın bir şekilde kullanılan bütünleşik Fen, Teknoloji, Mühendislik ve Matematik [FeTeMM] yaklaşımına uygun olarak tasarlanan bir etkinliği, etkinliğin uygulama basamaklarını ve gerekli dökümanları sunmaktadır. Tasarlanan etkinlik FeTeMM alan yazınında belirtilen günlük hayat problemine dayandırılarak başlatılmıştır. Daha sonra öğrencilere çalışma yaprağı verilmiş ve çeşitli basamaklardan geçerek elmanın kararmasını önlemeleri/yavaşlatmaları istenmiştir. İlk tasarımdan sonra grupların tasarladıkları kararma önleme süreçleri etkinliğin başında belirlenen kriterlere dayanarak tüm gruplar önünde incelenmiştir. Daha sonra gruplara tekrardan tasarlama basamağında tasarımlarını modifiye etme ya da isterlerse yeniden tasarlama şansı verilmiştir. Finalde, elmanın kararmasını en çok yavaşlatan grubun tasarımı yine kriterler yardımıyla ve tüm grupların katılımı ile birinci seçilmiştir. Etkinliğin hem lise kimya hem de lise biyoloji dersinde uygulanabileceği düşünülmektedir. Etkinliği uygulayan öğretmenler öğrencilerin etkinliği zevkle gerçekleştirdiğini ve farklı fikirler ortaya attığını belirtmiştir. Ayrıca, etkinliğin çok masraflı olmaması ve bütün okullarda rahatlıkla uygulanabilir olması da yine avantajları arasında belirtilmiştir.

Anahtar kelimeler: FeTeMM, STEM, mühendislik tasarım süreci, reaksiyon hızı, enzimatik reaksiyon.

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[1] Assoc. Prof. Dr., Van Yüzüncü Yıl University, Faculty of Education, Department of Mathematics and Science Education, sevgi.aydin45@hotmail.com, ORCID: https://orcid.org/0000-0003-4707-1677

INTRODUCTION

Integrated Science, Technology, Engineering, and Mathematics [STEM] education arose in the United States [US] and have had an influence in many other countries. Many factors, such as global economic race among the US, China, and Russia, the US's goal of being leader, and the decrease in the STEM job preference revealed in the reports, resulted in embracement of integrated STEM approach. Although the starting point of STEM is the US, it has been adopted by Turkey, Australia, and Far East Countries and has been applied (Akgündüz et al., 2015; Aydeniz, 2017; Sanders, 2009).

In the related literature, there are different STEM definitions (Brenier, Harkness, Johnson, & Koehler, 2012). For instance, according to Johnson (2013) STEM is "an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21st century interdisciplinary themes and skills" (p. 367). In another definition, STEM was defined as "an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real world problems." (Stohlmann, Moore, & Roehrig, 2012, p. 30). The reports published in the US stated that STEM approach includes design process and that learners should take an active participation to this process (National Research Council [NRC], 2012; Next Generation Science Standards [NGSS], 2013). Additionally, it has been highlighted that STEM is an approach that learners make design to solve daily-life problems, analyze the problem, collect data, brainstorm for solutions, provide creative ideas, and provide a prototype, and test the prototype by the use of criteria set at the beginning (NGSS, 2013; NRC, 2012).

Although there is not a consensus about what STEM is, the most prominent properties of STEM are stated by Moore, Johnson, Peters-Burton, and Guzey (2015) as follows.

- Including a context that motivates learners,
- Including an engineering design challenge,
- Providing learning opportunity from failure,
- Based on science/mathematics curriculum objectives,
- Being learner-centered,
- Including group work and communication through the whole engineering design process.

Due to the fact that STEM approach is different from traditional discipline-based approach regarding integration of four disciplines, it should be implemented in an altered way both in school and out of school contexts. Related to this point, researchers mentioned two different ways of integration in STEM education; namely, context integration and content integration (Roehrig, Moore, Wang, & Park, 2012). In the context integration, the STEM disciplines are harmonized in a unit or in an activity. The focus is a topic that is under one of the STEM disciplines. Other STEM disciplines are used to make the topic be more understandable. The content integration, however, "allows a teacher to teach content from each discipline and highlight how these disciplines are all needed to solve a problem in this area." (Roehrig et al., 2012, p. 35). The activity described in this paper is an example of context integration. The main focus of the preventing apple browning activity is chemistry and biology, in other words, topics under science discipline of STEM (i.e., rate of reaction and enzymes activity) whereas engineering design process and technology are used in order to form a context for the activity. If learners plan to keep apple slices in solution with different pH, mathematics is also included during the activity. Many STEM activities in the literature are related to physics topics. This activity related to both chemistry and biology fields is supposed to fill this gap and to contribute the literature.

In STEM approach applications, in order to frame engineering design process, there are different models with different steps. In this paper, a six-step model proposed by Wheeler Whitworth, and Gonczi (2014) was preferred. The reason behind this preference is its guidance on engineering design challenge by providing questions for each step. The steps in the model are explained below.

1. Brain Storming: The step through which learners are asked to write what comes to their mind about the materials and methods used to address design challenge.
2. Research: The step through which learners determine what they want to know in order to address the design challenge, write research questions, and conduct research in the light of the research questions determined.
3. Design: After receiving necessary information from research conducted, learners list the materials, construct their designs by drawing or telling their designs to the teachers to get approval.
4. Construction and Testing: The steps through which learners construct their designs formed through initial ideas and research, test their designs, and collect data about the success of their designs.
5. Redesign: The step through which learners redesign to eliminate failure or missing points in their design or to increase its performance.
6. Evaluation: The step through which learners discuss to what extend redesign process work well and evaluate the design by the use of the criteria set earlier.

The activity worksheet prepared in the light of the model and the guiding questions for each step is provided in Appendix 1.

Browning Reaction in Apples and Other Fruits

When an apple is cut or falls, the cells are bruised. As in apple case, many other fruit cells' vacuole includes phenol derivative compounds. Those chemicals react with enzymes in apple cytoplasm, then polymerize, and form compounds with brown color. Oxygen is necessary for this reaction to occur. Compounds in different parts of the apple cells contact and react with each other due to cutting, hitting, or biting in the presence of oxygen. Then, browning reaction occurs. The enzyme that accelerates this reaction is Polyphenol oxidase (PPO). Enzymes are biological catalysts that accelerate slow reactions (Ioannou & Ghoul, 2013).

The curriculum standards related to the activity are as the following:

Biology, Grade 9:
9.1.2.1.g. Experiments related to factors influencing enzyme activity are provided (Ministry of National Education, [MoNE], 2018a, p. 16).

Chemistry, Grade 11:
11.5.2. Factors affecting rate of reaction
11.5.2.1. Learners are expected to explain factors affecting rate of reaction.
a. Nature of reactants, concentration, temperature, catalyst (Restriction: No mention to enzymes) and surface area (Restriction: No mention to Arrhenius equation) (MoNE, 2018b, pp. 31-32).

In addition to these standards, the activity is also consistent with the general purposes and goals stated in the chemistry curricula:

- "Learners are expected to use the knowledge and skills acquired in Chemistry course to explain daily-life, health, industry, and environmental events." (MoNE, 2018b, p. 11).
- "Learners are expected to be aware of the contribution of chemistry to society, social life, economy, and technology." (MoNE, 2018b, p. 11).
- "Learners are expected to collect data through experimenting, inferring and interpreting the data collected, and making generalizations." (MoNE, 2018b, p. 12).

ACTIVITY IMPLEMENTATION

The activity was conducted with two teachers and 10 learners in a Science and Art Center after receiving necessary permissions. The learners worked in small groups with two or three peers. The activity implementation took about 3 hours.

Equipment and Materials

The list presented below was prepared in the light of the activity implementation. In future implementations of the activity, different learners may come up with different designs and materials. In order to guide learners who have different design ideas, it would be helpful for teachers to conduct some research about the browning reaction, enzymes, and designs for eliminating fruits' browning before activity implementation. Many papers have been written about the topic. For instance, the paper published by Ioannou and Ghoul (2013) is a comprehensive summary of prevention methods for fruits' browning. A figure summarizing the prevention types was formed in the light of the paper and was provided in Appendix 2.

- apples (at least an apple for each group),
- honey,
- lemon,
- pine apple,
- orange,
- vinegar,
- table salt,
- knife,
- stretch film,
- heater,
- pH strips,
- paper towels,
- pencil,
- watch,
- camera (or cell phone).

The activity will be described step by step. At the beginning of the activity, the problem is introduced to the learners:

- ➢ In food industry, fruits' browning is a big problem during storage and food processing. This problem is getting more attention day by day.
- ➢ This (enzymatic) browning reduces quality of appearance and taste of fruits.
- ➢ In the fruit juice factory, where you serve your internship as a person who has necessary chemistry and biology knowledge, they ask you to solve the browning problem. To prevent or at least slow down the reaction, what would you plan and design?

After the problem introduction, the activity worksheet that was prepared by using the engineering design model proposed by Wheeler et al. (2014) is distributed to the learners (Appendix 1).

1. Brainstorming

In the brainstorming step, the first one in Wheeler et al.'s model (2014), learners were asked what they could do to prevent apples' browning. They were asked to write down the necessary materials according to brainstorming that they did in their group. This step may take about 15 minutes according to the academic level of the learners. Groups take notes about the ideas on the activity worksheet. In the current implementation, covering with stretch film, keeping in water, and keeping in a cold container were the very first ideas that learners had.

2. Research

In this step, learners are supposed to conduct research in the light of ideas they came up with in the previous step. Depending on the learners' level, 20-30 minutes are necessary for research phase. It can be possible to conduct research either by the use of technology and the internet or by the use of textbooks or other journals, etc. Teachers may provide different textbooks and written documents. If there is a shortage of time, homework for researching apple's browning reaction can be given before the class. To guide learners' research, the following questions can be used.

- ➢ What do you want to know to prevent apple's browning?
- ➢ What are the ideal materials to prevent apple's browning?
- ➢ Which re/sources may be useful for you?
- ➢ What is necessary for you to solve this problem? Please write down the questions about which you want to research.
- ➢ After conducting research, if you learn something new, write it down with a different color on activity worksheet.

Some examples written on the activity worksheets in the current implementation were:

- *What is the pH of lemon?*
- *To what extend does covering apple with stretch film prevent browning?*
- *Is the antioxidant amount of avocado enough for preventing browning?*

- *Do hot or cold applications prevent browning?*

3. Design

In this step, the groups write the necessary materials and equipment to design the process that they decided to try. Then, they show their design and materials to the teachers and get feedback about their design and materials. Although it depends on the number of the groups, this step takes about 15 minutes.

4. Construction and Testing

In this step, learners start to construct their design after getting approval from their teacher. Before that, the teacher asks: "How can you determine whether your design works well or not? In other words, how do you understand your design is successful in preventing the browning?" Learners are guided to think about the questions and realize that they need a reference point. After a short discussion, an apple is chosen as a reference point and is cut into four pieces. Learners observe these pieces and determine browning duration. Browning takes about 10 minutes after slicing. However, the type of the apple, its freshness, and many other factors may affect the duration. Therefore, a reference point should be determined for each group. Or, the teachers may take the very similar apples to the class and distribute them to the groups. After deciding about a reference point, the groups go on studying with the same apple slices.

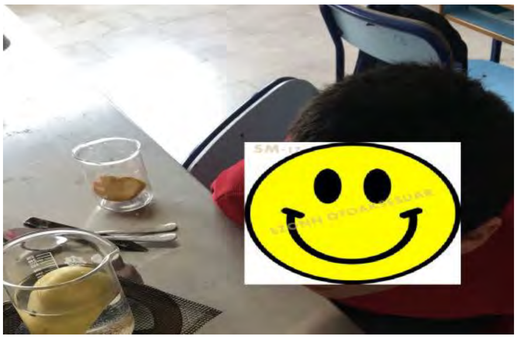
The categories for preventing browning can be listed as follows.

- Precautions for preventing contact with air (conservation in water or covering with stretch film).
- Precautions for slowing down the browning reaction (decreasing the temperature).
- Lowering the enzyme activity (heating to 80°C, which causes decrease in enzyme activity, but also results in taste loss).
- Changes in pH cause decrease in enzyme activity.
- Precautions related to decreasing oxygen amount of the atmosphere (modified atmosphere packing).

To control whether their designs prevent/slow down the browning or not, learners take a photo every 10 minutes for 4 or 5 times. For this step, 40-50 minutes are necessary. Examples from this step are provided below (Photos 1-4).

Photograph 1. Preventing Browning by the Use of Antioxidants (Antioxidant Source is Avocado)

Photograph 2. Preventing Browning by the Use of Antioxidants (Antioxidant Source is Honey)



Photograph 3. Preventing Browning with Heating

Photograph 4. Groups' Designs

5. Redesign

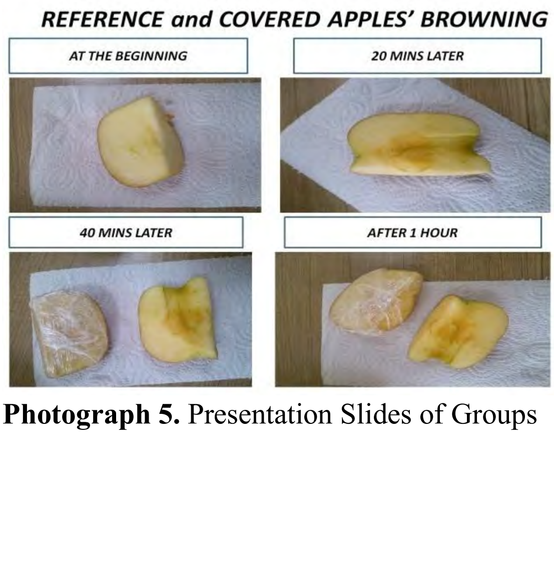
All groups present and explain their design to other groups. The best design is determined by the use of the criteria set at the beginning. Later, redesign opportunity is given to the groups. For a better guidance, the following questions can be asked to the learners:

- What can you do to improve your design? Try something new and write it down with a different color on activity worksheet.
- By taking account the initial design and modification made, redesign to eliminate browning.
- Give details about the final version of your design.

In the current implementation, groups whose design did not work well decided to try the successful groups' ideas in redesign step. For instance, due to the fact that more browning occurred than they expected, one of the groups decided to redesign by the use of lemon juice. Or another group stated that they would try different fruits (e.g., pineapple) containing antioxidant in addition to avocado. This part takes about 15 minutes.

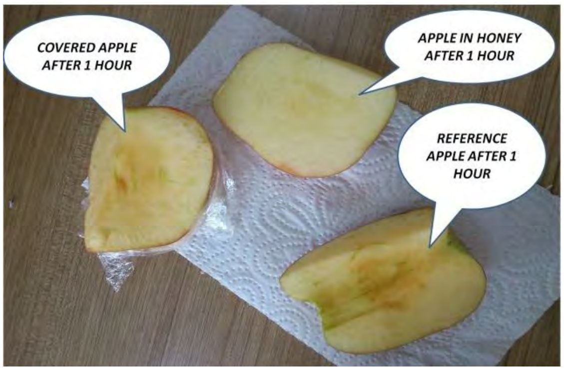
6. Evaluation

Finally, the best final design is determined altogether by the use of the criteria set at the beginning. The criteria are presented in Appendix 3. At this step, in order to encourage technology use and to compare the groups' designs, groups are asked to prepare a presentation by the use of photos and data (generally presentation software is preferred) (Photo 5).



Photograph 5. Presentation Slides of Groups

This step takes about 30 minutes. However, it may change depending on the group number in the class. If you cannot take photos, you can also decide the best design through observing (Photo 6).



Photograph 6. Comparing the Designs through Observing to Determine the Best Design

CONCLUSIONS and SUGGESTIONS

The teachers implemented the activity stated that it was pleasant to apply. Additionally, they thought that the materials and equipment are easy to find and cheap to buy. Furthermore, it is safe to implement due to the use of daily-life chemicals. Finally, teachers said that the activity is great regarding opportunities for learners to research and determine the research questions that they are curious about, which supports science process skills.

When the learners' activity worksheets were examined, it was observed that the learners used a scientific inquiry to design for preventing browning reaction. For instance, in the research step, the questions determined by the learners showed that they learned browning is an enzymatic reaction (i.e., owing to the research that they conducted). Additionally, they learned that oxygen is necessary for reaction to occur. Examples of the research questions that the learners determined:

- *Why does apple get brown?*
- *What are the factors preventing browning?*
- *Does the type of the apple influence browning?*
- *Which foods are rich regarding antioxidant?*
- *Is pH of lemon enough for preventing browning?*

In addition to those listed above, when the activity worksheets were examined, it was also seen that the learners focused on factors influencing enzyme activity. Due to the research that they conducted, they learned the concept of antioxidant although it is not in the curriculum. Furthermore, they realized that they can change enzyme activity through heating apple slices in water and pH. In the related literature, Apedoe, Reynolds, Ellefson, and Schunn (2008) found that STEM approach supported learners' conceptual learning. Another result that can be inferred from the activity sheets of learners is that the groups tried to prevent browning from a Biology perspective (i.e., enzyme structure and activity) except the group focused on covering apple slice with stretch film to decrease the amount of oxygen (this could be thought as concentration affecting rate of reaction) that is necessary for reaction. Finally, one of the groups compared their design both on green and red apples, indicating that they followed scientific inquiry steps. Literature also showed that STEM approach is useful regarding science process skills development (Gokbayrak & Karisan, 2017).

During the implementation, teachers should give opportunity to learners to conduct research with peers and to design on their own way. Teachers should be a guide through the activity, and provide support through asking guiding questions when necessary. Regarding research opportunity, the literature revealed that learners have a tendency to skip research step and jump into the design and construction steps (Whitworth & Wheeler, 2017). Therefore, teachers should be aware of this situation and take necessary measures.

An interesting situation was experienced while preparing for the activity. To be ready for the activity, the author bought some apples from a supermarket and cut one of them into slices to determine the approximate amount of time for browning. It was planned to take photos every 10 minutes. However, although 24 hours passed after slicing, no browning occurred. Slices became dehydrated and plasmolysis was observed. Although the author did not conduct any scientific analysis, she inferred that the apples bought might be genetically modified (i.e., genetic is one of the methods used for prevention browning) or produced through natural reclamation. Therefore, it would be better to test apples before implementing the activity in class.

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Appendix 1

Activity Worksheet

1. **Brainstorming:**

What do you think about the materials that can be used to prevent apple's browning? Write any ideas come to your mind.

2. **Research:**

What do you want to know about to design for preventing apple's browning?

Which materials/equipment can be the ideal for preventing browning?

Which re/sources may be useful for you?

What are the ideal materials to eliminate apple's browning?

What is necessary for you to solve this problem? Please write down the questions about which you want to research.

After conducting research, if you learn something new, write it down with a different color on the activity sheet.

3. **Design:**

Design your process to prevent browning and note the necessary materials. Get feedback from your teacher about your design.

4. **Construction and Testing:**

After constructing, wait about 40-50 minutes. **Before testing**, take notes about to what extend your design address the criteria determined earlier.

5. **Redesign:**

What can you do to improve your design? Try something new and write it down with a different color on the activity sheet.

By taking account the initial design and modification made, redesign to eliminate browning.

Give details about the final version of your design.

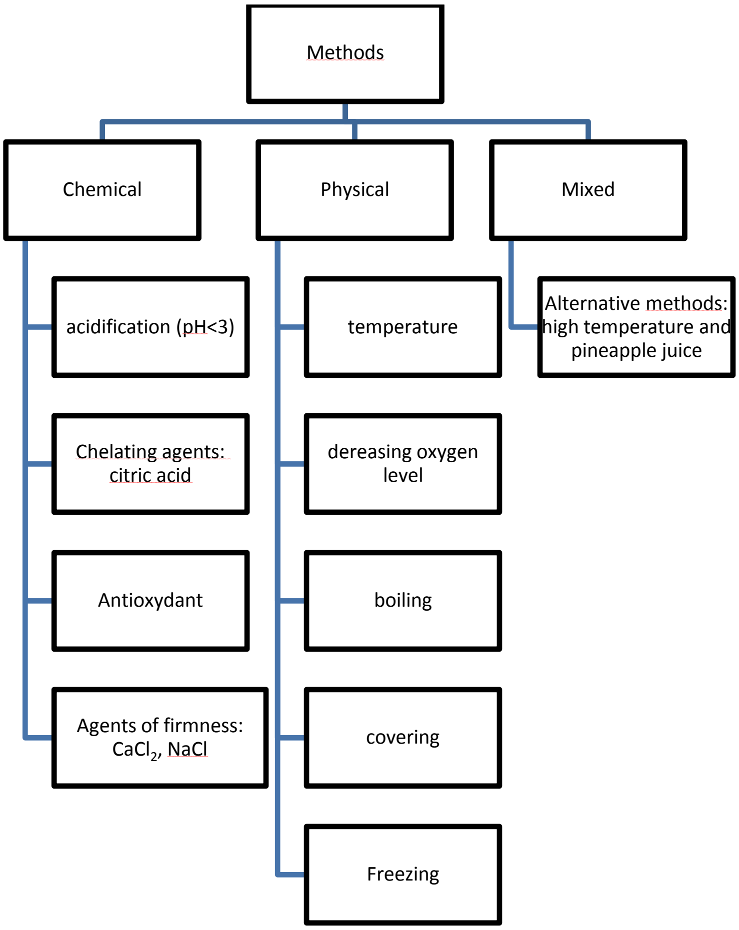
6. **Evaluation:**

Evaluate your design by the use of the criteria list given.

Compare and contrast initial and final designs. Discuss the developments.

Appendix 2

Summary of theMethods Eliminating Browning (Ioannou & Ghoul, 2013)



Appendix 3

Criteria Used (Rubric)

Criteria	Excellent	Good	Bad
Including non-hazardous materials			
Taste lost			
Duration for elimination			
Economy			
Creativity			