BURÇİN ARSLAN YILMAZ

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APPLICATION OF FOOD FERMENTATION PRACTICAL WORK
IN CLASSES

BURÇİN ARSLAN YILMAZ

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FOR

THE DEGREE OF MASTER OF ARTS

IN

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To my family…

Application of Food Fermentation Practical Work in Classes

The Graduate School of Education

of

İhsan Doğramacı Bilkent University

by

Burçin Arslan Yılmaz

In Partial Fulfilment of the Requirements for the Degree of

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İHSAN DOĞRAMACI BILKENT UNIVERSITY

GRADUATE SCHOOL OF EDUCATION

Application of Food Fermentation Practical Work in Classes

Burçin Arslan Yılmaz

July 2021

I certify that I have read this thesis and have found that it is fully adequate. in scope and in quality. as a thesis for the degree of Master of Arts in Curriculum and Instruction.

Asst. Prof. Dr. Armağan Ateşkan (Advisor)

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instruction.

Asst. Prof. Dr. Jennie Farber Lane (Examining Committee Member)

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Curriculum and Instrucion.

Prof. Dr. Gaye Teksöz, METU (Examining Committee Member)

Approval of the Graduate School of Education

Prof. Dr. Orhan Arıkan (Director)

ABSTRACT

APPLICATION OF FOOD FERMENTATION PRACTICAL WORK

IN CLASSES

Burçin Arslan Yılmaz

M.A. in Curriculum and Instruction

Advisor: Asst. Prof. Dr. Armağan Ateşkan

August 2021

This study investigates the integration of food fermentation practical work into national and international curricula and teachers' perceptions of its implementation in classes. Content analysis was used to determine the incorporation of food fermentation practical work into IBDP, IGCSE, MoNE biology and MoNE science curricula to develop a framework. Furthermore, a food fermentation workshop is organized for teachers and their curriculum integration study in the workshop used for triangulation. After the workshop, semi-structured interviews were used to gather data about teachers' perceptions on the application of practical work of food fermentation in classes. Food fermentation practical work was found to be applicable in 75% of the MoNE biology curriculum units, and in 67% and 62% of the IBDP and IGCSE biology curricula, and 36% of the MoNE science curriculum. The findings suggest that all teachers' views about the use of food fermentation practical work in classes were positive in terms of contribution of practical work on learning, making abstract topic more permanent, improving students' recall level and eliminating misconceptions of the topic, and improving students' manipulative, creativity, communication, responsibility skills. It is found that teachers who have resources such as laboratories, allowed time in curriculum for practical work, the support of school administrations, availability of ready-made materials and in-service trainings on practical work, are more willing to implement food fermentation practical work in their classes. Moreover, practical studies of food fermentation were found appropriate for extracurricular activities and interdisciplinary projects by the teachers.

Keywords: Food fermentation practical work, Science education, Biology education, National curriculum, International curriculum, Teacher perceptions

ÖZET

GIDA FERMENTASYONU DENEYLERİNİN SINIFLARDA UYGULANMASI

Burçin Arslan Yılmaz

Yüksek Lisans, Eğitim Programları ve Öğretim

Tez Danışmanı: Dr. Öğr. Üyesi Armağan Ateşkan

Ağustos 2021

Bu çalışma, gıda fermantasyonu uygulamalı çalışmalarının ulusal ve uluslararası öğretim programlarına entegrasyonunu ve öğretmenlerin sınıflarda uygulanmasına ilişkin algılarını incelemektedir. Bir çerçeve geliştirmek için, gıda fermantasyonu uygulamalı çalışmalarının IBDP, IGCSE, MEB biyoloji ve MEB fen bilimleri öğretim programlarına entegre edilmesini araştırmak amacıyla içerik analizi kullanılmıştır. Ayrıca, öğretmenler için gıda fermantasyonu atölyesi düzenlenmiş ve öğretmenlerin atölyedeki öğretim programı ile ilgili analiz çalışmaları üçgenleme için kullanılmıştır. Atölye çalışmasından sonra, öğretmenlerin gıda fermantasyonu çalışmalarının sınıflarda uygulanmasına ilişkin algıları hakkında veri toplamak için yarı yapılandırılmış görüşmeler yapılmıştır. Gıda fermantasyonu uygulamalı çalışmalarının MEB biyoloji eğitim programı ünitelerinin %75'inde, IBDP ve IGCSE biyoloji eğitim programlarının %67 ve %62'sinde ve MEB fen bilimleri eğitim programının %36'sında uygulanabilir olduğu bulunmuştur. Bulgular, gıda fermantasyonu uygulamalı çalışmalarının derslerde kullanımına ilişkin tüm öğretmenlerin görüşlerinin; uygulamalı çalışmaların öğrenmeye katkısı, soyut konuları daha kalıcı hale getirmesi, öğrencilerin hatırlama düzeylerini artırması ve konuyla ilgili kavram yanılgılarını gidermesi ve öğrencilerin el, yaratıcılık, iletişim, sorumluluk becerilerini geliştirme açısından olumlu olduğunu göstermektedir. Laboratuvar gibi kaynaklara sahip olan, öğretim programında uygulamalı çalışmalar için zamanı olan, okul yönetimlerinin desteğini alan, hazır materyallerin bulunması ve uygulamalı çalışmalara yönelik hizmet içi eğitimler gibi kaynaklara sahip olan öğretmenlerin; gıda fermantasyonu çalışmalarını sınıflarında uygulamaya daha istekli oldukları tespit edilmiştir. Ayrıca gıda fermantasyonu ile ilgili uygulamalı çalışmalar, öğretmenler tarafından ders dışı etkinlikler ve disiplinler arası projeler için uygun bulunmuştur.

Anahtar kelimeler: Gıda fermentasyonu uygulamalı çalışmaları, Fen bilimleri eğitimi, Biyoloji eğitimi, Ulusal öğretim programı, Uluslararası öğretim programı, Öğretmen algıları

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CHAPTER 1: INTRODUCTION

Education is more than teaching content knowledge. Developing skills and fostering responsible behaviors are also important components. Moreover, students can learn ways to improve their well-being and lifestyles in their daily lives. One way to do this is for teachers to help students learn more than the content of the lessons through hands-on activities such as experiments. Through these activities, teachers can share their personal knowledge and real-life experiences and increase students' awareness of different values, skills, and ways of thinking. Regarding improving students' well-being and lifestyles, these activities can offer students the opportunity to examine their living and eating habits. In particular, they can explore aspects of nutrition such as carbohydrate consumption, food choices, and food processing. They can also learn about the history and future of food preparation and storage. Among the topics related to food storage is the fermentation. This chapter provides background about food fermentation and its potential for use as a practical work in educational settings. This is followed by the problem, purpose, research questions, significance, limitations, and definition of key terms, in order.

Background

In the book of *Handbook of Fermented Functional Foods*, Prajapati and Nair (2003, Chapter 1) stated that fermentation is the oldest food preservation method in the world. In early civilizations, humans fermented food to ensure that it would be available throughout the winter months. Over time, fermented foods became favored for their richer tastes. The authors explain that in the middle of the nineteenth century, Louis Pasteur identified the roles of microbes in the fermentation process by proving that there was a variety of types of fermentation. The fermentation process consists of converting carbohydrates to alcohol or organic acids by using yeast and bacteria. Modern researchers have learned that the fermentation process enhances the nutritional and therapeutic value of food by enriching its rich probiotic content. The concept of probiotics which are live microorganisms that have health benefits when consumed, was discovered by Elie Metchnikoff, who was the winner of Nobel Prize around 1900s. She was among the first who presented the benefits of probiotics (Parvez et al., 2006). These beneficial microorganisms, or probiotics, are self-augmented during the fermentation process and keep us healthy in many ways. Therefore, people have started to prefer to consume fermented foods because they like the flavor and understand that is healthy. According to the *Global Fermented Food and Ingredients Market 2019-2023 report*, the global fermented food and ingredient market is expected to reach $ 689.34 billion by 2023, due to the increasing population, income per capita, and awareness about health (Research and Markets, 2021).

One of the ways eating fermented foods keeps us healthy is to take advantage of their probiotic-rich content and reduce the intake of processed sugars. The strongest risk factor for type 2 diabetes is overweight and obesity (World Health Organization [WHO], 2016). One of the largest impacts has been the rise of type 2 diabetes is urbanization (moving from rural areas to cities) which causes to change in people's lifestyles and food consumption (Piemonte, 2019). Research shows that more than 340 million children between 5 and 19 years old were overweight or obese in 2016. From 1995 to 2016, the prevalence of obesity around the world has nearly tripled (WHO, 2018).

The rise of diabetes in today's children is being contributed to their food consumption habits. On the other hand, eating fermented foods may help to prevent and treat some diseases such as obesity and type 2 diabetes. Kim et al. (2011) worked with overweight and obese patients and applied a fermented kimchi (a traditional Korean food) diet to the one group and fresh kimchi diet to the other group. They found that the group who ate fermented kimchi showed improvements in terms of systolic and diastolic blood pressures, percent body fat, fasting glucose, and total cholesterol than another group. Kwon et al. (2010) evaluated the literature in their study that was related to the treatment and prevention of type 2 diabetes using fermented soybean from animal studies. They mentioned that fermented soy products are better than non-fermented soybean products for preventing and retarding type 2 diabetes. Ejtahed et al. (2012) proved that probiotic yogurt consumption improved fasting blood glucose and antioxidant status in type 2 diabetic patients.

These health benefits are among the reasons why we should make and eat fermented foods. One way to increase the consumption of fermented foods is by improving education about the concept of fermentation in the school curriculum. In one of the research, Hussain et al. (2007) suggested that increasing physical activity and reducing consumption of energy-dense foods should be encouraged in food consumption and education policy, with the involvement of governments and research by specifically targeting school children and young people. In particular, biology and science curricula include relevant concepts; however, its instruction and associated learning expectations may be limited. There are so many advantages to integrate the topic of fermented foods in education, especially in science students' practical work.

Practical work is the most important part of science education which helps students to understand scientific concepts and learn how to apply theoretical knowledge in real life. Composing a starter culture (living microorganisms which are ferment foods) and providing appropriate environment for sustainability of these starter culture, then making fermented products with these starter cultures are the basic steps of the food fermentation practical work (Elabd, 2016). By doing activities and experiments related to fermented foods, students can gain many manipulative skills and can use all five senses, which may not be possible in other experiments.

Problem

The food fermentation process can be used in different units in high school curriculum like microbiology in biotechnology unit, anaerobic respiration, and symbiotic relationship in ecology unit. Also, it can also be used for middle school students to teach scientific method through safe practical work and to make connections to many different topics. It is included in the national and international curricula, but this does not mean that students experience the topic effectively by applying practical work and utilize its benefits as much as possible. Each curriculum has different handicaps in terms of teaching and learning the subject in the most effective way.

Turkey's Ministry of National Education (MoNE) features fermentation within the respiration unit of its grade12 biology curriculum. Students in this grade are preparing for the university entrance exam, and unfortunately time restrictions may prevent them from participating in practical work related to fermentation. The same situation occurs in MoNE middle school science education: Fermentation is included in the 8th grade of the MoNE science curriculum as a part of the *Energy transformation* unit (MoNE, 2018b, p. 52), but this unit is taught at the end of the semester before the high school entrance exam it may be limited or excluded.

Besides, international programs also pose some obstacles in learning the fermentation topic effectively. The International Baccalaureate Organization (IBO) discusses anaerobic respiration of yeast during baking as part of its *Cell respiration* unit for its Diploma Programme students (IBO, 2014a, p. 46). In addition, its *Biotechnology and bioinformatics* unit is directly connected with fermentation by including applications. However, this unit is designed as an *Option* and it may not be selected and covered by some schools (IBO, 2014a, pp. 119-120). Another international education program, the International General Certificate of Secondary Education (IGCSE) includes aerobic respiration of microorganisms in its *Respiration* and *Biotechnology and genetic engineering* units of biology curriculum. Students receive only a basic education of fermentation as the learning outcomes include low-order thinking skills such as *state* and *explain* according to Bloom's taxonomy (Cambridge International Examinations, 2016, pp. 23, 41).

Clearly, very little of what can be taught by food fermentation is included in national and international curricula, and what is included may not be fully learned due to facing learning barriers from different curricula. Another reason for this may be that teachers are unaware or uncomfortable with the implementation of these studies. Curriculum content analysis in all subject areas is needed to integrate the practical work of food fermentation into the curriculum and to encourage its application in classes. Especially, science and biology teachers can use food fermentation practical work for teaching related topics effectively.

According to Songer and Mintzes (1994), understanding the chemical processes of fermentation is not easy for students. Since fermentation involves many chemical reactions, students may have difficulties to learn this topic. More practice in connection with daily life can be helpful to engage students and teach the basic fermentation processes. While doing food fermentation practical work, it is possible to observe or measure so many factors such as CO_2 outgassing, changes in pH, microbial culture, alcohol, and amount of sugar which make easier to understand these processes. On the other hand, doing fermented foods as a practical work at school cost effective than other fermentation experiments and setting up the experiment to take little time than other experiments (Collins & Bell, 2004). All these features can be counted as valid reasons why practical studies on food fermentation should be promoted.

Purpose

The main purpose of this qualitative study is to develop an integration framework about food fermentation practical work to promote its application into classes. The integration framework includes themes derived from a content analysis of biology and science curricula, a manual for teachers, and teachers' perceptions on the integration of practical studies of food fermentation. The themes developed through the content analysis involved examining MoNE, IBDP, IGCSE biology, and MoNE science curricula for ways to incorporate food fermentation practical. The manual provides teachers with ideas about how food fermentation practical work can be integrated into the curriculum. Teacher perceptions were derived after a food fermentation workshop. This workshop was designed and conducted as part of this study to provide teachers within opportunity to experience food fermentation. Teachers who participated in the workshop were interviewed to gain insights into their perspectives and experiences regarding the integration of food fermentation practical work into their programs. Furthermore, they provided recommendations for the integration of food fermentation concepts into the curriculum through a content analysis of different curricula (MoNE, IGCSE, IBDP biology, and MoNE science).

The overall purpose of the study was to help teachers raise awareness among students, to disseminate applied food fermentation studies, and to contribute to their nutritional habits by promoting healthy food choices.

Research Questions

This study addressed the following questions:

1. How can food fermentation practical work be incorporated into IBDP, IGCSE, MoNE biology, and MoNE science curricula?
2. How do teachers perceive application of food fermentation practical work in classes?
    a. What kind of resources encourage and prepare the teachers to apply practical work about food fermentation in their classes?
    b. What are the teachers' opinions about use of practical work while teaching fermentation topics in the classroom?
    c. Into which units and subjects can food fermentation practical work be integrated in science curricula and interdisciplinary projects?

Significance

The health benefits of the food fermentation have been proven by many researchers, especially when consider the rich generation of probiotic content (Ejtahed, 2012; Kim et al., 2011; Kwon et al., 2010; Parvez et al., 2006; Piemonte, 2019). To spread awareness about the health benefits of fermented foods and promote sustainability among our community members with sharing cultures (microorganism which are ferment foods) can be supported by this study. Promoting fermented foods in the classrooms and teaching how to make these foods can help keep students healthy. The students may learn and apply this method and benefit in many ways, especially to improve their health. To applying food fermentation practical works in the classrooms would support teaching and learning process. The students have a chance to use their five senses in this laboratory work in comparison with other laboratory studies. Furthermore, this method can improve their manipulative skills and learning level of fermentation.

This study intends to share examples of food fermentation practical studies with workshop that may motivate and prepare teachers to apply into the science and biology classrooms with their students. The teachers who are participated the food fermentation workshop, were interviewed. Their experiences and perceptions will bear a torch to other teachers and literature for further studies. Moreover, curricula content analysis will help the teachers in the matter of how they can integrate food fermentation practical work into different topics and units. The participant teachers' curriculum analysis work, ideas, and experiences at the fermentation workshop and during the interview will also give suggestions to all teachers for interdisciplinary studies with other subject field teachers such as group 4 projects (see Chapter 2 IBDP biology curriculum) at IB Diploma Programme.

Limitations

This study took place in Ankara, so it does not represent the whole country. The teachers are selected purposively. Also, they may attend the study because of their interest. So, their responses may include some biases. All participants were female. Moreover, they did not have a chance to apply food fermentation practical work in their classrooms because of the timing of the research. Their responses may change after the implementation of the practical work. This study was conducted with twelve teachers. The number of teachers also another limitation of this study. Only limited number of curricula were analysed for this study which are IBDP, IGCSE, MoNE biology, MoNE and IBMYP science curricula. The content analysis and the integration ideas are done according to the knowledge of the researcher.

Definition of Key Terms

Fermentation: A chemical process in which sugar molecules are broken down anaerobically by microorganism such as bacteria and yeasts (Encyclopedia Britannica, n.d.).

Probiotic: Probiotics are live microorganisms that are nonpathogenic and beneficial for microflora and digestive system (Williams, 2010).

Starter culture: Starter cultures are microorganisms such as bacteria, yeast, or mold, that are essential components of the fermentation process and causes changes in the finished products. (Durso & Hutkins, 2003; Elabd, 2016) In some foods starter culture necessary for fermentation is naturally present and be activated in the right conditions but, in some ferments, starter culture must be added externally such as culture of Kombucha (Elabd, 2016).

Ginger bug: Ginger bug is a starter culture that can be used as a wild yeast to start fermenting alcoholic beverages such as ginger beer or other products. It is made by grated ginger, sugar, and water and activates within a week (Katz, 2003, p. 139).

SCOBY: A starter culture for Kombucha tea which contains the symbiotic consortium of bacteria and yeasts in a cellulose biofilm (Laavanya et al., 2021).

Kombucha: Kombucha is a fermented beverage made by sweetened tea by adding its starter culture, SCOBY (Villarreal-Soto et al., 2018).

Practical work: Practical work is a teaching and learning activity in which students involve the any or whole process of observing, conducting experiments, manipulating variables by using scientific inquiry skills (Millar, 2010).

IBDP: An education program designed by the International Baccalaureate Organization for students aged 16-19 as a two-year pre-university program called Diploma Programme (IBO, 2014a, p. 2).

IBMYP: A middle years education program offered by the International Baccalaureate Organization for students aged 11-16 for preparation to IBDP program throughout five years (IBO, 2014b, p. 2).

IGCSE: An international education program offered by the Cambridge International Examinations for students 14-16 aged for two years to international qualification (Cambridge Assessment International Education, 2019).

MoNE: The Ministry of National Education in Turkey whose responsibility carry out national education services, establish programs, plans and duties. All national curriculum is developed and implemented by MoNE in Turkey.

Perception: Perception can be defined as a belief or opinion of a person according to how things seem to this person (Cambridge Dictionary, n.d.).

CHAPTER 2: REVIEW OF RELATED LITERATURE

Introduction

Teachers use variety of media for teaching each topic effectively. Besides subject area knowledge, it is important to know how to teach each topic with appropriate medium. One of the mostly used and accepted media is practical work in science education. Practical work is the most important, significant, and unique part of science education to improve students' conceptual knowledge and personal abilities such as cognitive and manipulative skills (Gilbert, 1994; Hofstein & Lunetta, 1982; Millar & Abrahams, 2009; Tobin, 1990).

This study focused on application of food fermentation practical work in science classes. While teaching science, food fermentation practical work can be integrated in many topics. It may open the way of transitions between units and connections between key concepts of science teaching. Also, food fermentation practical studies can be used by other field teachers. Interdisciplinary works may help to students to comprehend the big picture of living things.

Practical Work

Practical work is a broad term which is more than laboratory work to involve short and long-term lab exercises, different student projects with interaction of students with materials and active involvement (Hodson, 1993, 1998; Lunetta et al., 2007). In this study, food fermentation practical work involves composing starter culture (microorganisms), conducting experiments with active student involvement, setting up controlled experiments by students and observing whole process of fermentation from starter culture to end-product of fermentation, measuring variables with variety of equipment, tasting, smelling, touching, feeding cultures (microorganisms) regularly and sharing with social circle for sustainability (Elabd, 2016). Also, it includes short-term and long-term individual projects (individual investigations for IBDP students), group projects such as Group 4 Project (see IBDP biology curriculum below) as a part of IBDP program or extracurricular activities (clubs, bazaars etc.).

Practical Work in Science

Scientific knowledge, according to many researchers, is best learned through practical work (Abrahams & Millar, 2008; Hofstein & Lunetta, 1982; Tobin, 1990). There has been a lot of research on practical work in the literature from the past decades. In an important study was conducted by Kerr (1963) to learn science teachers' views about the use of practical work in science. He sent a questionnaire survey to 912 science teachers and 393 responses being received from 151 schools which are following traditional grammar type curriculum in England and Wales (Kerr, 1963, as cited in Abrahams & Saglam, 2010).

According to findings of the study, Kerr (1963) identified ten motives for deploying practical work in school science:

- to encourage accurate observation and careful recording
- to promote simple, common-sense, scientific methods of thought
- to develop manipulative skills
- to give training in problem-solving
- to fit the requirements of practical examination regulations
- to elucidate theoretical work so as to aid comprehension
- to verify facts and principles already taught
- to be an integral part of the process of finding facts by investigation and arriving at principles

- to arouse and maintain interest in the subject
- to make biological, chemical, and physical phenomena more real through actual experience (Kerr, 1963, as cited in Abrahams & Saglam, 2010, p. 755)

Kerr’s ten motivates has accepted with only a few minor changes since 1963 (Hodson, 1998). Abrahams and Saglam (2010) followed Kerr’s (1963) research to investigate difference between the teachers’ views on practical work after all these years from 1963 to 2010. They sent questionnaires to investigate science teachers’ views to the head of science department to four different school types which includes Comprehensive, Grammar, Independent and Specialist school teachers. Then they analysed and compared the data with Kerr’s research results. They found two substantial changes out of Kerr’s (1963) ten aims of practical work. The authors evaluated these changes as a result of government led changes to the assessment procedures may affect on teachers' views. During the last 56 years; it seems Kerr’s (1963) ten motivates generally still acceptable despite many changes in educational policies, educational system, and technological developments (Abrahams & Saglam, 2010). The effectiveness of practical work in school science can be evaluated by Kerr’s ten motivates.

On the other hand, practical work sometimes can be inefficacious if the teachers do not select appropriate activities with learning objectives. Also, if practical work is over-used and under-used, it can be cause unproductive work. Hodson (1996) stated three related purposes to prevent ineffective practical work, as follows:

- to help students learn science—acquire and develop conceptual and theoretical knowledge;

- to help students learn about science—develop an understanding of the nature and methods of science and an awareness of the complex interactions among science, technology, society, and the environment;
- to enable students to do science—engage in and develop expertise in scientific inquiry and problem solving (p. 756).

Teachers' role is very important while managing practical work. They should have adequate knowledge about each practical work that is unlikely possible for all activities. Tobin (1990) stated that teachers should be the professionals to make appropriate decisions relating to which activities are best matched to desired learning outcomes. Professional development of teachers can be supported by different events such as workshops, courses, conferences etc. According to Hofstein and Lunetta (1982), few teachers in secondary schools are competent to use the laboratory effectively. Therefore, pedagogical content knowledge (PCK) is another important factor on success of teachers about practical work. In a study, Wei et al. (2018) investigated which sources have effect on development of science teachers' practical knowledge of teaching through practical work. The results of the study showed that *personal teaching practices and reflection* and *informal exchanges with colleagues* are two important factors for the development of teachers' PCK of teaching through practical work (Wei et al., 2018).

Teachers' Views about Practical Work

The perceptions of teachers on practical work have long been researched by several studies (Abrahams & Saglam, 2010; Danmole, 2012; Ghartey-Ampiah et al., 2004; Sani, 2014; Shim et al., 2014) and it is one of the important components of this research. A study conducted to investigate the views of secondary school biology teachers on practical work in Nigeria (Danmole, 2012). Participants of the study selected through purposive sampling (N=96) and a questionnaire used for data collection. The findings of the study indicated that practical work is found important and essential for understanding biology concepts by all participating teachers. Furthermore, majority of the teachers agreed that biology cannot be taught effectively without practical work (Danmole, 2012).

Another research driven by Ghartey-Ampiah et al. (2004) in Ghana to explore the teachers' views on the role of practical work in science teaching and learning. Fifty senior secondary school science teachers were surveyed using a questionnaire. According to the research findings, the teachers expressed the reasons for organising practical work as contributing to a better understanding of theory and concepts, verification of facts, and the development of laboratory skills such as observation and manipulative skills. On the other hand, most respondents indicated that students are not allowed to design their own experiments due to the limited time allocated for the curriculum followed, the overloaded content of the curriculum, crowded class sizes, lack of equipment, and the WAEC science practical examination does not include such questions. That is showed that the development of cognitive skills is less emphasized by teachers (Ghartey-Ampiah et al., 2004).

Shim et al. (2014) investigated the purposes of using practical work of secondary school science teachers in South Korea and administered a survey to collect views of teachers (N=152). The questionnaire includes four domains determined by considering the educational objectives of the Science National Curriculum of Korea and these are *Scientific inquiry, Scientific knowledge, Science-related attitude,* and *STS (science-technology-society)*. The findings of the study determined that Korean secondary school science teachers' responses were positive towards these four domains of practical work, especially for the scientific inquiry skills. It has been found that high school teachers are more willing to apply practical work to develop scientific inquiry skills through practical work, and middle school teachers to the usage for acquiring scientific knowledge due to the content of the curriculum (Shim et al., 2014). Also, Shim et al. (2014) suggested that, given that teachers have the greatest influence on students' science learning, training programs should be provided to increase teachers' positive attitudes and facilitate practical work for student engagement.

Sani (2014) conducted a case study with six Malaysian lower secondary level science teachers to identify aims and practices in implementing practical work. Data collected from in-depth and semi-structured interviews. Teachers' purposes categorized under conceptual, procedural, and affective domains. All teachers in the study revealed that they aim to develop procedural knowledge that have manipulative skills, follow instructions, and obtain desired results. In addition, all participants expressed that the development of procedural knowledge is very important for safety of students in order to prevent accidents during practical work. Half of the teachers mentioned that they aim to develop conceptual knowledge, while a few teachers stated that they aimed at the affective domain which prompt students' interest towards science (Sani, 2014). Besides, from the data Sani reported that all of the teachers preferred to conduct structured practical activities because of they believe that students do not have the abilities to plan and manage their own investigations. Only a few teachers indicated that students could improve their scientific skills by manipulating some parts of the practical work on their own. According to Sani (2014), "Such control takes away all learner autonomy and may lead some students to not engage in the practical work at all". (p. 1019)

In these studies, the importance of practical work in science learning has been expressed by all science teachers, and there is consistent evidence of similarity in their intention to use practical work. Mostly, teachers aimed to apply practical work for improve students' scientific and conceptual knowledge by verifying facts and obtaining expected results, and to develop scientific inquiry and laboratory skills. Even though some teachers pointed to other purposes, such as the cognitive and affective components of practical work, by giving more autonomy to students to design and engage with their investigations; it could not be applied in classes because of lack of recourses such as time, equipment, or students' ability to apply.

Students' Views about Practical Work

Students' perceptions on learning science topics with practical work also important component of this study. In 2011, a study was conducted in which 29 students between the ages of 13 and 16 participated in order to find out the students' views on practical work (Toplis, 2011). Data collected from lesson observations and in-depth interviews with participants listed three main reasons why practical work is important for students in science lessons. These are interest and activity which involves students' participation, trust, and autonomy; different teaching medium rather than always doing same type of activities, and a way of learning that helps comprehension, memorization and recall by visualizing the scientific concepts. Toplis (2011) stated that practical work offers students opportunities in terms of inquiry-based learning, but more research is needed to evaluate its effectiveness as it is a complex issue.

Another research driven by Osborne and Collins (2001) investigated students' perspectives on science education to explore the reactions they experienced in school science. Data were obtained from 144 16-year-old students using the focus group method. The findings of the study determined that for the majority of students, relevance and personal autonomy were important missing parts. Also, students emphasized that scientific concepts are more accessible and easier to remember when supported by practical work regardless of the results of the experiment (Osborne & Collins, 2001). According to the Osborne and Collins (2001), practical work offers students a greater sense of autonomy and if school science is linked to students' daily lives, students engage with it. According to these studies (Osborne & Collins, 2001; Toplis, 2011), the importance of practical work for students is that it provides personal autonomy and facilitates to recall by visualizing the topics.

Earlier, a study was conducted by Çimer (2012) in Rize, Turkey, in order to determine the reason why high school students have learning difficulties in biology subjects and effective learning ways. Qualitative and quantitative data were collected from 207 11th grade students through a questionnaire. Anaerobic respiration is the one of the topics out of 38 topics covered in the questionnaire. Students' views revealed that matter cycles, endocrine system and hormones, aerobic respiration, cell division, and genes and chromosomes are the five most difficult biology topics. The reasons of students why they found these topics difficult is categorized under five issues. The first one is the nature of biology that includes lots of concepts with Latin words and also most are abstract topics which based on memorization as a learning strategy. The other one is teaching strategies based on teacher-centered education which lacks of connections with daily life and practical work. Besides, teacher competencies on topics, lack of resources such as laboratories and teaching materials, and allocated time for the subject are the other issues. Also, students' attitudes found negative towards subject because of all listed items that effects their motivation and studying habits (Çimer, 2012). Lastly, the usage of visual materials, implementing practical work, connecting topics with daily life, different teaching and learning techniques to make the subject interesting, alleviate the content while increasing the number of questions in the university entrance exam, are purposed by students to overcome the difficulties of learning for the difficult topics of biology (Çimer, 2012).

Later, the other study conducted to discover in which biology topics of National curriculum of Lagos State in Nigeria, senior secondary school students have difficulties in learning (Etobro & Fabinu, 2017). A questionnaire was administered to 400 students to obtain both qualitative and quantitative data. Anaerobic respiration or cellular respiration was not one of the fourteen major topics listed in the curriculum; only respiratory system was included. Five major topics determined out of fourteen topics as difficult to learn which are nutrient cycling in nature, ecological management, conservation of natural resources, pests and diseases of crops and reproductive system in plants. In addition, abstractness, complexity, misconception of topics, unavailable instructional materials, poor attitude of teachers to teaching, lack of practical classes and students poor study habits are the facts listed by the students as to why they perceive the topics as difficult. Also, it is suggested by students as a solution of the problem to use appropriate materials and instructional strategies such as hands-on and minds-on activities and to integrate of daily life into biology concepts (Etobro & Fabinu, 2017).

These two studies driven in different countries (Çimer, 2012; Etobro & Fabinu, 2017) that follow the similar methodology show positive correlation in terms of students' perceptions on difficulties in learning biology, their reasons, and suggestions. Although the subject of fermentation or anaerobic respiration is not listed in these studies among the subjects that are difficult for the students; the abstractness of the subject, the misconceptions about microorganisms and the chemical processes based on memorization coincide with the features that the students stated to have difficulties. Moreover, the solutions suggested by students to overcome the learning difficulties match with the characteristics of food fermentation practical work in terms of its connection with daily life, allowing to comprehend the process by visualizing it, providing a chance to touch, smell, taste, and allow more autonomy in terms of being open to manipulation of variables.

Food Fermentation Practical Work

Contrary to some studies (Çimer, 2012; Etobro & Fabinu, 2017), a specific study that analyzed conceptual challenges about cellular respiration revealed that college level biology students had problems understanding anaerobic respiration and the role of yeast in fermentation (Songer & Mintzes, 1994). One of the parts of the study involves fermentation and the data collected from 100 students by concept maps and structured interviews used for further investigation on fermentation. In the second phase of the study, a bread task was given to students to explore their difficulties on fermentation in depth. Ingredients needed for breadmaking were told to students, then the role of yeast and the fermentation process were questioned. It has been found that majority of the students responded correctly to the role of yeast, however less than half of advanced biology students could successfully explain the fermentation process. Even Songer and Mintzes (1994) reported that some students, who are more than 25% of the participants, stated that yeasts are dead when used, they are enzymes, make dough sticky, release oxygen, expand when combined with ingredients, they are bacteria, and dough rises as they multiply.

Another research driven by Yip (2000) explores year 11 students' understandings about the nature and the role of anaerobic respiration in humans based on their performances in the biology paper of Hong Kong public examination. A structured question asking the word equation of the lactic acid process and the importance of the process was analyzed in the papers of 400 students selected by random sampling among 37,254 candidates. The findings of the study revealed that less than one third of the students correctly wrote the equation of anaerobic respiration in skeletal muscle. More than one third of the students included carbon dioxide as an end-product, most likely because of the confusion with alcoholic fermentation or aerobic respiration. Yip (2000) proposed a flow diagram to solve students' conceptual understanding problems due to the oversimplified structure of textbooks. Also, it is stated that the practical work of winemaking, an alcohol fermentation, as another learning method, would increase students' motivation and understanding of the biochemical process involved (Yip, 2000).

In 2002, a study was conducted to examine the effects conceptual change instruction and traditional instruction on 11th grade students' understanding of cellular respiration concepts and their perceptions of biology subject (Çakir et al., 2002). The data were collected with a test containing 23 multiple choice questions from 84 11th grade students in the experimental and control group, who were instructed 4-weeks by these two different instructional methods. Some parts of the study related to fermentation reveal that more than half of the students in the control group instructed by the traditional method thought that the end products of fermentation reactions are the same. In addition, half of the students in the experimental group and one fifth of the students in the control group chose the correct answer about cellular respiration types of yeast and plants. Moreover, 39% of the control group students thought that in the presence of light yeasts make photosynthesis. The findings of the study suggest that if conceptual change instruction is well designed, it is more useful in eliminating misconceptions but there is no significant effect on students' perceptions of biology subject (Çakir et al., 2002).

Fermentation is an important part of microbiology, and it is taught in an undergraduate microbiology course as research experience (Lyles & Oli, 2020). An investigation driven by Lyles and Oli (2020) planned to identify probiotic species from different types of kefirs, and to focused on the students' learning on fermentation, the human microbiome, probiotics, the gut–brain axis, and health benefits of consuming fermented products. According to the pre and post survey responses of university students (N=267), research stated that students' knowledge and skills about the topic improved after the participation in the "Fermentation revival in the classroom" course module. In addition, Lyles and Oli (2020) suggested that this module can be applicable in many levels of education due to its adaptability, minimum and accessible equipment requirement, and easy implementation.

In the literature, there are some studies focusing on microorganisms, which can be directly associated to fermentation. It is discussed high school students' knowledge and thoughts about microorganisms and its place in the National curricula (MoNE biology) in Turkey (Aydın, 2015). Data collected with descriptive survey model from 160 science high school students by random sampling within volunteers and the researcher's review of the biology curricula. The findings of the study suggests that although microorganisms do not have a significant place in the followed curricula, students' ideas about microorganisms are positive and they are knowledgeable. If the responses of the students are examined in depth in terms of the fermentation relationship, the results also found out 33% of the students did not indicate where the microorganism located as everywhere, instead they mentioned only specific locations such as human body, soil, dirty places, yogurt, and so on. In addition, fungi only mentioned by almost 23% of students as the microorganisms they known and most of the participants indicated bacteria and viruses. Majority of the students (69%) responded microorganisms can be both harmful and beneficial, however, approximately 34% of the students mentioned that they cause diseases and only 27% of the students stated that microorganisms are used as yeast (Aydın, 2015). Furthermore, as noted by Simard (2021), microorganisms have been considered disease-causing and harmful for decades, this perception may be enhanced by the pandemic (Covid-19) and lead to difficulties in teaching and learning for future microorganism education.

All in all, practical work is most important part of the science education. There are many benefits of teaching subjects which are abstract and difficult in learning for students by implementing practical work. Also, practical work contributes improving students' scientific inquiry skills, manipulative skills, understanding on subject, personal autonomy, engagement in activity and so on. Several studies have shown evidence that students have difficulty in learning the topic of fermentation since the topic is abstract, includes metabolic processes that are difficult to understand and recall, and misconceptions about microorganisms (Çakir et al., 2002; Simard, 2021; Songer & Mintzes, 1994; Yip, 2000). According to Byrne (2011), 11-year-old students can explore the fermentation process by making yoghurt or ginger beer that helps to understand benefits of microorganisms or harmful effects in unsterilized conditions. Children at 14 years old are capable of further practical work to enhance their understanding of fermentation processes (Byrne, 2011). This study aims to develop an integration framework to promote the application of food fermentation practical work in classes to enhance students' learning by visualizing metabolic processes and connecting with daily life, develop students' several personal and scientific skills, disseminate health benefits, help connections between topics and subjects, and engage students with science.

National and International Curricula

Ministry of National Education (MoNE) Biology Curriculum

Public and private high schools in Turkey are obligated to follow and fulfil the requirements of the Ministry of National Education curriculum for students aged 14-18 to successfully complete the high school education. It is a four-year high school program which is compulsory education for all children in Turkey.

In the MoNE biology curriculum, there are a total of 12 units, also called as *Unit* in the syllabus. The time allocated for this four-year program is 432 teaching hours. The total teaching hours required for the 9th and 10th grades are 72 hours for each, and the total teaching hours for the 11^{th} and 12^{th} grades are 144 hours for each (MoNE, 2018a, p. 13). In this curriculum, no extra or separate time has been specifically set for extra activities or practical work.

The structure of the course content begins with name of the *Unit* and followed by name of the *Topic*. Below the topic name, *Key terms* are listed related with each topic. After, *Learning outcome* is given which expresses the level of knowledge and skills that students are expected to achieve. This is followed by *Learning outcome explanations*, which explains the limitations of the content, the dimensions of the learning outcome, the points to be considered, and the methods and practices that can be used in teaching (MoNE, 2018a, p. 15).

In this study, *Learning outcome* and *Learning outcome explanations* are accepted as learning outcomes. As the structure of the learning outcome is very general and contains limited details, the learning outcome explanations give an idea of the dimensions of the outcome that students are expected to learn. This would also give teachers a detailed idea of which parts of the topic the food fermentation practical work can be embedded in.

Ministry of National Education (MoNE) Science Curriculum

Public and private middle schools in Turkey are obligated to follow and fulfil the requirements of the Ministry of National Education curriculum for students aged 10-14 to successfully complete the middle school education. It is a four-year middle school program which is compulsory education for all children in Turkey before moving to the high school.

In the MoNE science curriculum includes a total of 28 units, seven for each year of the program. The time allocated for implementation of the curriculum at each grade level from the 4^{th} grade to the 8^{th} grade is 144 teaching hours per year. In other words, 576 teaching hours are allocated to complete the middle school science curriculum in 4 years (MoNE, 2018b, pp. 12-13).

The structure of the syllabus begins with the name of *Unit*, followed by explanations of students' learning expectations from the unit. The next heading is *Topic* and then *Recommended time* indicates the time allotted for teaching the topic. The heading *Topic / Concepts* below presents specific scientific terminology and concepts related to the topic. Finally, the *Learning outcomes* that students are expected to learn throughout the topic are listed. In the curriculum integration analysis of the research, only the *Learning outcomes* section was used for this curriculum.

Another component of the MoNE science curriculum is Science, engineering and entrepreneurship applications, where students are expected to present their products at the end of year science festival at their schools. First of all, students are expected to define a daily life need or problem for the development of a solution and their product in the school environment. During the development of the product, students should conduct practical work and apply all scientific inquiry processes. Lastly, they should plan and use different strategies for the promotion of their products in order to the develop of their entrepreneurial skills (MoNE, 2018b, p. 10). These applications are not a graded component of the curriculum but are intended to be implemented as extracurricular activities to enhance student learning and engagement in science.

International Baccalaureate Diploma Programme (IBDP) Biology Curriculum

The IBDP program is a 2-year pre-university program implemented in the last two years of high school education. There are 58 schools in Turkey which follow the IBDP program for students aged 16-19. The program includes six academic areas, one of which is sciences. Students are required to select at least one subject from each academic area, including sciences. In addition, the program offers students two levels, Standard level (SL) and Higher level (HL). Basically, although these levels aim for the same goals, HL includes more depth and breadth. Students must decide to take at least 3 and at most 4 higher level (HL) subjects (IBO, 2014a, p. 3).

The IBDP biology curriculum consists of 11 units in total, categorized under six core, five additional higher level (AHL), four option units. For the IBDP biology curriculum, "The recommended teaching time is 240 hours to complete HL and 150 hours to complete SL courses as stated in the document General regulations: Diploma Programme for students and their legal guardians (2011) (page 4, Article 8.2)" (IBO, 2014a, p. 20). These teaching times include 40 hours for SL and 60 hours of HL students for practical work that includes practical activities, individual investigation, and group 4 project. These are the compulsory part of the program, and all students must complete their individual investigation (IA) and group 4 project. Individual investigation includes a scientific investigation and a written report that worth 20% of the final score of the program (IBO, 2014a, p. 153). The group 4 project is an interdisciplinary activity where students focus on cooperation, scientific investigation, development of relationships between the subjects (IBO, 2014a, p. 161). As can be seen from the components of the curriculum, practical activities cover an important part of the IBDP biology curriculum.

The format of the syllabus begins with *Topic* or *Option*, which are the most general headings in the curriculum and are equivalent to *Unit* when compared to other curricula. This is followed by the *Sub-topic* and is equivalent to the *Topic* in other curricula when compared. Below each sub-topic, there are *Essential idea* which described as "... an enduring interpretation that is considered part of the public understanding of science" (IBO, 2014a, p. 21). The next section is the *Nature of science*, which guides teachers about the general theme to be addressed by giving examples. Below the Nature of science, there are two columns that includes *Understandings, Applications and skills, Guidance, International mindedness, Theory of knowledge, Utilizations,* and *Aims.* The *Understandings* section presents the main ideas to be taught. This is followed by *Applications and skills*, which lists specific applications and the skills that students are expected to acquire. The other listed sections offer ideas to teachers for the implementation of all the required components of the sub-topic.

In this study, topics and options are considered as units and sub-topics are accepted as topics. Also, the items listed below the *Understandings* and *Applications and skills* sections are accepted as the learning outcomes listed for students. The content analysis carried out by the researcher was made in the light of these information.

International General Certificate of Secondary Education (IGCSE) Biology Curriculum

Forty-three high schools in Turkey implement the IGCSE program designed for students aged 14-16. It is a two-year program implemented in the first two years of high school education in Turkey. In the biology syllabus of the program, there are 21 topics that equivalent to units when compared with other curricula. The topic is followed by sub-topic which is equivalent to topic. Below this main information, the subject content includes *Core* and *Supplement* sections. These sections are described in the syllabus as follows:

> All candidates should be taught the Core subject content. Candidates who are only taught the Core subject content can achieve a maximum of grade C. Candidates aiming for grades A* to C should be taught the Extended subject content. The Extended subject content includes both the Core and the Supplement. (Cambridge International Examinations, 2016, p. 7)

As noted above, the *Core* and *Supplement* sections are the parts that students are expected to learn and were considered as learning outcomes for this study. In addition, the allocated time for the curriculum reported as, “The estimated number of guided learning hours for this syllabus is 130 hours over the duration of the course. The total qualification time for this syllabus has been estimated to be approximately 200 hours” (Cambridge International Examinations, 2016, p. 55).

The IGCSE curriculum allows students opportunity to carry out practical work and investigations, and improve their practical skills, in all 21 topics of the syllabus (Cambridge International Examinations, 2016, p. 7). Moreover, students must take a practical test based on experimental skills, which affects the final grade by 20%, to complete the program. Students are expected to have grasped the learning outcomes listed below in the practical assessment:

- demonstrate knowledge of how to safely use techniques, apparatus, and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements, and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements (Cambridge International Examinations, 2016, p. 49)

It can be concluded that practical work is an important part of the IGCSE biology curriculum. Curriculum integration analysis was conducted considering all learning outcomes listed under the *Core* and *Supplement* sections of the syllabus.

International Baccalaureate Middle Years Programme (IBMYP) Science Curriculum

In Turkey, 12 schools follow the IBMYP program for students aged 11-16, but most schools implement this program only at the middle school level, for 11-14 years old students. The main reason behind that is the 4+4+4 education system in Turkey. High schools are generally independent from middle schools and curriculum arrangements may differ. In addition, all schools affiliated to MoNE must follow the national curriculum as well as the IBMYP program.

The recommended teaching time in each year of IBMYP program is minimum 50 hours for middle school level. IBMYP sciences program provides a framework-based curriculum to guide students for being independent and collaborative during investigations, experiments, and research by connecting science with daily life. For this purpose, “In every year of MYP sciences, all students must independently complete a scientific investigation that is assessed against criterion B (inquiring and designing) and criterion C (processing and evaluating)” (IBO, 2014b, p. 18). It is important for the program to improve students' scientific inquiry, critical and creative thinking skills by giving them autonomy to design and conduct their own investigations. Also, conceptual learning is one of the important components of the IBMYP program, which requires the involvement of key and global concepts by teachers in the developing the curriculum (IBO, 2014b, p. 20).

Moreover, “MYP schools are responsible for engaging students in at least one collaboratively planned interdisciplinary unit for each year of the programme integrating disciplines either within or across subject groups” (IBO, 2014b, p. 15). In the guide, it is indicated that interdisciplinary teaching and learning connects curriculum for the developmental needs of students and further academic studies (IBO, 2014b, p. 15).

As noted above, due to the framework-based design of the IBMYP curriculum, there are no learning outcomes listed in the guide. Schools following the IBMYP program in Turkey mostly apply the requirements of the program, taking into account the listed learning outcomes of the MoNE science curriculum. For this reason, the IBMYP curriculum could not be analyzed in the curricula content analysis conducted in the study and the MoNE science integration rate was accepted as valid for this program as well.

CHAPTER 3: METHOD

Introduction

The main purpose of this study is to develop an integration framework of food fermentation practical work to promote its application in classes. The content analysis methodology is used to answer the research questions. This chapter discusses the research design, context, participants, instrumentation, method of data collection and analysis.

Research Design

This study used content analysis methodology as a qualitative research design. As a stated by Hsieh and Shannon (2005), qualitative content analysis is used to analyse text data for the subjective interpretation of the content by coding and identifying themes or patterns through the systematic classification. There are two main research questions in this study that are:

1. How can food fermentation practical work be incorporated into IBDP, IGCSE, MoNE biology, and MoNE science curricula?
2. How do teachers perceive application of food fermentation practical work in classes?

The data were collected from teachers' curriculum integration study during the food fermentation workshop, curriculum analysis driven by researcher, and the semi-structured interviews with the teachers who participated to the workshop. To explore and analyse the research questions to develop an integration framework for promoting food fermentation practical work in science and biology classrooms, three data sources were analysed using content analysis. Qualitative analysis of content can be used to analyse various types of written text data (Wildemuth, 2016). Hsieh and Shannon (2005) identified three distinct approaches of qualitative content analysis that are conventional, directed, and summative approaches.

> In conventional content analysis, coding categories are derived directly from the text data. With a directed approach, analysis starts with a theory or relevant research findings as guidance for initial codes. A summative content analysis involves counting and comparisons, usually of keywords or content, followed by the interpretation of the underlying context. (p. 1277)

The curriculum analysis driven by the researcher and teachers' curriculum integration study were analysed by using summative approach. The researcher identified learning objectives that can be related with food fermentation practical work by latent content analysis from each curriculum and the teachers' integration framework. These learning objectives were used to deduce keywords (codes) with the purpose of determine the themes for food fermentation practical work. A summative approach to qualitative content analysis is more than word counts to include latent content analysis which is the process of interpretation of content (Holsti, 1969). To integrate food fermentation practical work in IBDP, IGCSE, MoNE biology, and MoNE science curricula, the themes of the identified keywords were categorized by the researcher.

Therefore, semi-structured interviews were transcribed before analysis. In this part of the study, inductive approach was followed. This is defined as an approach based on detailed reading of raw data by the researcher to derive concepts or themes (Thomas, 2006). The method used for semi-structured interview analysis is inductive thematic analysis. This is a method which identifies, analyses and reports patterns within data (Braun & Clarke, 2006). The transcribed interviews were read several times by the researcher to identify the patterns of the teachers' perceptions of food fermentation practical work. All of the results obtained from analysis were used to develop a framework to support teachers and to promote their interest, motivation, and preparation.

Context

Prior to the data collection, the food fermentation workshop was organized for science and biology teachers. There is a need to inform teachers about application of food fermentation in classes and options of implementation before getting their perceptions. For trustworthy of the data, participants should know what they will evaluate.

Food Fermentation Workshop

In this research, the food fermentation workshop was organized for science and biology teachers at a non-profit university on May 25, 2019. It was all day workshop and lasted six and half hours from 9 a.m. to 3:30 p.m. The workshop had three parts. In the first part, teachers learned theoretical knowledge about food fermentation practical work.

Figure 1

The Researcher Talking about Food Fermentation

The second part of the workshop was practical, the teachers applied three different practical that they can apply in their classrooms. These applications were sourdough bread, Kombucha tea (fermented beverage) and ginger ale (fermented beverage).

Figure 2

The Teachers Making Sourdough Bread in the Workshop

The last part was an investigation of the curriculum to find out chances for integration of food fermentation which is called teachers' curriculum integration study.

Figure 3

The Teachers' Curriculum Integration Study in the Workshop

Teachers used different curricula during the study which they teach at their current schools. These are IBDP biology curriculum, MoNE biology curriculum, IGCSE biology curriculum, IBMYP science curriculum and MoNE science curriculum. The IBMYP curriculum was analyzed underneath the MoNE Science curriculum because MYP does not have prescribed curriculum. IBMYP is concept-based curriculum and MYP teachers are following MoNE science curriculum's learning objectives in Turkey. Consequently, four curricula were examined into deeply by the teachers for specifying learning objectives that food fermentation practical work can be used (Table 1). Also, these teachers' represented curricula were used by researcher for further analysis.

Table 1

Curricula Analysed in the Study

Curriculum Name	Information about the Curriculum
IBDP Biology curriculum	International Baccalaureate Organization, 2014. Diploma Programme Biology guide. United Kingdom.
IGCSE Biology curriculum	Cambridge International Examinations, 2017. Syllabus Cambridge IGCSE® Biology 0610, Version 3. England, Wales and Northern Ireland as a Cambridge International (QN: 500/5871/X).
MoNE Biology curriculum	T.C. Milli Eğitim Bakanlığı, 2018. Orta Öğretim Biyoloji Dersi Öğretim Programı. Ankara.
MoNE Science curriculum	T.C. Milli Eğitim Bakanlığı, 2018. Fen Bilimleri Dersi Öğretim Programı. Ankara.

Participants

In total, 12 teachers participated to this study from nine different public and private schools in Ankara. Five participants were biology teachers who were working at five different high schools. One of the high schools is public school and the others are different private schools. Seven participants were science teachers who were working at four different middle schools. Four of the middle school teachers were working at the same public school. One of the middle school teachers was working at different public school and the other two teachers were working at different private schools. All the participants were selected by convenience sampling method. According to Fraenkel and Wallen (1993), “A convenience sampling is a group of individuals who (conveniently) are available for study” (p. 87). The invitation letter was sent via e-mail. The teachers accepted the invitation voluntarily according to their interest of the topic and convenience. The main reason for working with teachers is that they reach many students and can spread to implementation of food fermentation practical work. All volunteer teachers were female. Participants’ demographic information are shown in Table 2.

Table 2

Background of Participant Teachers

Teacher	Age	School Type	School Level	Curriculum that the School Follows	Total Teaching Experiences	Cultural Background about Fermentation
T1	45	Private	Middle	IBMYP, MoNE	22	No
T2	42	Private	Middle	MoNE	14	Yes
T3	36	Public	Middle	MoNE	11	Yes
T4	32	Public	Middle	MoNE	9	Yes
T5	47	Public	Middle	MoNE	24	Yes
T6	48	Public	Middle	MoNE	24	Yes
T7	60	Public	Middle	MoNE	38	Yes
T8	27	Private	High	IBDP, IBMYP, MoNE	1	No
T9	32	Private	High	IBDP, IGCSE	8	Yes
T10	29	Private	High	IBDP, MoNE	2	No
T11	30	Private	High	MoNE	6	Yes
T12	35	Public	High	MoNE	11	Yes

Instrumentation

At the third part of the workshop, teachers prepared curriculum integration outlines as a result of curriculum study. They wrote learning objectives from each curriculum one-by-one on the paper. Then, all three groups presented their fermentation framework to other teachers for giving an idea. After presentations, teachers' curriculum integration outlines were collected by the researcher. These findings were shifted to an Excel table. The table has units, topics, and learning objectives columns. The learning objectives written by teachers will be analyzed using conventional content analysis.

In addition, the researcher used content analysis of selected curricula (IB, IGCSE, and MoNE) and blended her findings with teachers' framework for data triangulation. In the study, the application and combination of several research methodologies for the same phenomenon called as triangulation (Denzin, 2006). For content analysis part, the researcher formed Excel table with three columns which consists of units, topics, and learning objectives same as teachers' curriculum integration table. Afterwards, new Excel table was created by using only determined learning objectives and their dependence units. The second Excel table composed of four columns that are units, learning objectives, keywords (codes), and how to use sections. These determined learning objectives were checked from two teachers, who are experts in science education field, for detection of any missing or irrelevant objectives. Teachers' curriculum integration study and researcher' curriculum analysis tools were used to answer the first research question of the study.

After the workshop, semi-structured interview which questions are prepared by researcher, were used. The interview questions were sent to two teachers who did not participate the workshop, before the interviews for a pilot study. Interview questions consisted of two parts. The first part has 11 questions and was designed to collect demographic data. This part was filled on paper by teachers. The second part consisted of 27 semi-structured questions; as the interview was flexible, a few times extra questions were asked for in-depth interviews. These extra questions asked if found necessary by the researcher for understanding the opinions of teachers transparently. In the second part of the interview, the first 12 questions are related to resources which may affect teachers' enthusiasm to apply a practical work in their classes. After resources questions, rest of the interview questions were about fermentation topic for an attempt to understand teachers' opinions about the application of food fermentation practical work in their classes.

During the interviews, the voices of participants were recorded and transcribed for further analysis. Semi-structured interview tool was used to answer second research question and it is sub-questions (Appendix A).

Method of Data Collection

The proposal of this research was prepared, and it was sent to the department in charge of the Ministry of Education in 2019, April 2nd. After the permission slip was taken, the researcher started to organize food fermentation workshop. The invitation letters were sent via e-mail to teachers.

The food fermentation workshop was carried out on May 25, 2019 at a non-profit university. At the end of the workshop, curriculum integration study frameworks created by teachers. The teachers were separated into three groups according to the education level they are teaching. Two groups consisted of science teachers and the other one consisted of biology teachers. For the curriculum integration study, the teachers used IBDP biology curriculum, MoNE biology curriculum, IGCSE curriculum, and MoNE science curriculum. They used the educational learning outcomes and their experiences to identify where the food fermentation practical work can be integrated. Therefore, three frameworks were created by three groups. These written frameworks were split up two groups as middle school frameworks and a high school framework. Each levels' contents were analyzed separately.

All participants of the food fermentation workshop were interviewed between on May 30 to June 28. Interviews were conducted one-by-one at the schools of the participant teachers or different locations that the teachers adjusted. Because, it was important to teachers feel comfortable. Each interview lasted between 20 to 50 minutes. All interviews were recorded and transcribed before the analysis.

Methods of Data Analysis

The curriculum analysis driven by researcher were analyzed using specified curricula which are IBDP, IGCSE, MoNE biology, and MoNE science. Each unit and each topic were listed into an Excel file one-by-one from the IBDP, IGCSE, MoNE biology, and MoNE science curricula's online versions with using computer. Then, all curricula were read by researcher for deducing underlying meanings of the content and determined learning outcomes were recorded the pairing row of each topic. The lines without any value that include only the dashes (-) indicate that there were no learning outcomes which cover food fermentation practical work. All findings were recorded on the same Excel file.

Each learning outcome that is appropriate to use food fermentation practical work were copied to the second Excel table. The first column in the second table indicates the unit of the related learning outcome. The second column shows the learning outcomes which had primary level codes. The third column shows the keywords (codes) which were found out from learning outcomes were used to create themes. In addition to that the researcher generated fourth column to clarify the usage of food fermentation practical work in each learning outcome by using coding system from one to five. The themes and the usage of food fermentation practical work are constituents of the developed framework. Table 3 demonstrates the meanings of the codes which illustrate the usage of the food fermentation practical work.

Table 3

Coding System for Application of Food Fermentation Practical Work

Coding System	How to Use
1	As an example
2	For making a comparison
3	As a part of a process
4	As a whole process (starting from culturing to making end-product)
5	As an addition

On the other hand, the framework created in the curriculum integration study carried out by the participating teachers of the workshop includes learning outcomes. Three different columns created by using Excel for each following the curricula which are IBDP biology curriculum, MoNE biology curriculum, IGCSE curriculum, and MoNE science curriculum. The first column indicates the unit of the topics. The second column shows the topics and the third column shows the learning outcomes which were determined by teachers. Each learning outcome was written on the computer beside the related unit and topic row. Then, the units which cover these learning outcomes were analyzed. Moreover, the determined learning outcomes were compared with the researchers' curriculum analysis findings for data triangulation.

In the next stage of the analysis, the six phases of thematic analysis outlined by Braun and Clarke (2006) are followed. These are familiarizing yourself with your data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report (Braun & Clarke, 2006, p. 87). First of all, the semi-structured interview answers from the 12 participants were translated from Turkish to English after transcription. Each participants' answers were read several times to procure coding categories directly from the text data. Specific and repeated codes highlighted in the written text to determine the themes in the next phase of the analysis. Besides, same question's answers of all participants were read one after the other for detecting patterns (themes) of answers given each question. The themes that emerged later formed the main headings in the interview results. Lastly, the findings of the study reported and discussed in the following chapters of the study.

CHAPTER 4: RESULTS

Introduction

This chapter presents the data gathered from different sources, the results of the analysis and interpretation of the qualitative findings of the study. There are three different data sources in this study.

- Curricula content analysis by the researcher
- Teachers' curricula integration study
- Semi-structured interviews with the teachers

The results of the analysis are given respectively in the related sections. The first section presents the results of the curricula content analysis made by researcher. It also includes the ideas about how to use food fermentation practical work for each topic and examples of its applications for some learning outcomes. The second section shares results of the teachers' curricula integration study analysis were driven in the joint workshop. Third section introduces the perceptions of participant teachers about application of food fermentation practical work in classes. All analysis were carried out to develop an integration framework to promote the practical work of food fermentation in science classrooms and extracurricular activities.

Curricula Content Analysis

The content analysis of the national and international curricula was conducted to answer the first research question asking to determine the units that food fermentation practical work can be integrated. The following curricula by the participant teachers are selected for this study. The curricula's last published versions: IBDP Biology guide (2014), IGCSE Biology syllabus (2019), MoNE Biology curriculum (2018), and MoNE Science curriculum (2018) were analyzed by the researcher. Determining related units for each curriculum, deducing codes from related units, constructing themes, and stating how to use of food fermentation practical work for each unit were the steps of the process followed for curriculum content analysis.

Units Related with Food Fermentation Practical Work

In the first stage of the curricula content analysis; the researcher determined the topics underneath each unit which are related with practical work of food fermentation by sifting through each learning outcome in all selected curricula. For each topic within each unit, the learning outcomes which food fermentation practical work can be incorporated are listed and the topics with inapplicable learning outcomes are showed with "-".

Analyzed Units of IBDP Biology Curriculum

For IBDP biology guide, *Understandings* and *Application and skills* sections are considered as learning outcomes. Action verbs are not used in the *Understandings* section of IBDP biology curriculum, but the main ideas are expressed as points to understand. In the guide, these sections are described as follows:

> Under the overarching Nature of science theme there are two columns. The first column lists "Understandings", which are the main general ideas to be taught. There follows an "Applications and skills" section that outlines the specific applications and skills to be developed from the understandings. (IBO, 2014a, p. 21)

Therefore, the points that should be understood were accepted as learning outcomes in this study. The content analysis of 15 units of IBDP biology curriculum is presented below. Table 4 shows this list of incorporated learning outcomes for *Cell biology* unit in IBDP biology curriculum.

Table 4

The Incorporation of Learning Outcomes for Cell Biology Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Cell biology	1.1 Introduction to cells	According to the cell theory, living organisms are composed of cells.
		Organisms consisting of only one cell carry out all functions of life in that cell.
		Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. (Practical 1)
	1.2 Ultrastructure of cells	Prokaryotes have a simple cell structure without compartmentalization.
		Eukaryotes have a compartmentalized cell structure.
		Prokaryotes divide by binary fission.
	1.3 Membrane structure	-
	1.4 Membrane transport	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)
	1.5 The origin of cells	Cells can only be formed by division of pre-existing cells.
		The origin of eukaryotic cells can be explained by the endosymbiotic theory.
		Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.
	1.6 Cell division	Mitosis is division of the nucleus into two genetically identical daughter nuclei.

There are six topics for this unit and five of them are appropriate to application of food fermentation practical work except *membrane structure* topic (Table 4). Food fermentation practical studies can also be used for meeting the requirements of Practical 1 and Practical 2 in *Cell biology* unit.

Below, Table 5 is the visual representation of integrability of learning outcomes according to topics.

Table 5

The Incorporation of Learning Outcomes for Molecular Biology Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Molecular biology	2.1 Molecules to metabolism	Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism.
		Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions.
		Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.
	2.2 Water	-
	2.3 Carbohydrates and lipids	-
	2.4 Proteins	-
	2.5 Enzymes	Temperature, pH and substrate concentration affect the rate of activity of enzymes.
		Enzymes can be denatured.
		Methods of production of lactose-free milk and its advantages.
		Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes.
		Experimental investigation of a factor affecting enzyme activity. (Practical 3)
	2.6 Structure of DNA and RNA	-
	2.7 DNA replication, transcription and translation	-
	2.8 Cell respiration	Cell respiration is the controlled release of energy from organic compounds to produce ATP.
		ATP from cell respiration is immediately available as a source of energy in the cell.
		Anaerobic cell respiration gives a small yield of ATP from glucose.
		Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.
	2.9 Photosynthesis	Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.
		Design of experiments to investigate the effect of limiting factors on photosynthesis.

In *Molecular biology* unit, out of nine topics, the food fermentation practical work can be integrated into four topics including *molecules to metabolism*, *enzymes*, *cell respiration* and *photosynthesis*. The learning outcomes of the five topics are not related to the food fermentation practical work (Table 5).

Table 6 shows the list of learning outcomes in which food fermentation practical studies can be incorporated.

Table 6

The Incorporation of Learning Outcomes for Genetics Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Genetics	3.1 Genes	Comparison of the number of genes in humans with other species.
		Use of a database to determine differences in the base sequence of a gene in two species.
	3.2 Chromosomes	Prokaryotes have one chromosome consisting of a circular DNA molecule.
		Some prokaryotes also have plasmids but eukaryotes do not.
		Comparison of genome size in T2 phage, Escherichia coli, Drosophila melanogaster, Homo sapiens and Paris japonica.
	3.3 Meiosis	-
	3.4 Inheritance	-
	3.5 Genetic modification and biotechnology	DNA profiling involves comparison of DNA.
		Analysis of examples of DNA profiles.

In the *Genetics* unit, there are five topics. Practical work of food fermentation can be integrated into three of them comprising *genes*, *chromosomes*, and *genetic modification and biotechnology* (Table 6).

Table 7 shows the learning outcomes of *Ecology* unit for application of food fermentation practical work.

Table 7

The Incorporation of Learning Outcomes for Ecology Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Ecology	4.1 Species, communities and ecosystems	Species are groups of organisms that can potentially interbreed to produce fertile offspring.
		Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).
		Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.
		A community is formed by populations of different species living together and interacting with each other.
		A community forms an ecosystem by its interactions with the abiotic environment.
		The supply of inorganic nutrients is maintained by nutrient cycling.
		Ecosystems have the potential to be sustainable over long periods of time.
		Classifying species as autotrophs, consumers, detritivores or saprotrophs from a knowledge of their mode of nutrition.
	4.2 Energy flow	Chemical energy in carbon compounds flows through food chains by means of feeding.
		Energy released from carbon compounds by respiration is used in living organisms and converted to heat.
	4.3 Carbon cycling	Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.
		Construct a diagram of the carbon cycle.
	4.4 Climate change	-

As seen in the Table 7, food fermentation practical work can be embedded three topics within four. It was not found related with learning outcomes of *climate change* topic. The most frequently integrable topic is the *species, communities and ecosystems* with eight learning outcomes.

Table 8 shows that the topic of *classification of biodiversity* is the only one out of four topics in the *Evolution and biodiversity* unit, which food fermentation practical work can be integrated three learning outcomes of the topic.

Table 8

The Incorporation of Learning Outcomes for Evolution and Biodiversity Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Evolution and biodiversity	5.1 Evidence for evolution	-
	5.2 Natural selection	-
	5.3 Classification of biodiversity	When species are discovered they are given scientific names using the binomial system.
		All organisms are classified into three domains.
		Natural classifications help in identification of species and allow the prediction of characteristics shared by species within a group.
	5.4 Cladistics	-

Table 9 shows related learning outcomes with practical work of food fermentation.

Table 9

The Incorporation of Learning Outcomes for Human Physiology Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Human physiology	6.1 Digestion and absorption	-
	6.2 The blood system	-
	6.3 Defence against infectious disease	-
	6.4 Gas exchange	-
	6.5 Neurons and synapses	-
	6.6 Hormones, homeostasis and reproduction	Causes and treatment of Type I and Type II diabetes.
		Testing of leptin on patients with clinical obesity and reasons for the failure to control the disease.

Human physiology unit of IBDP biology curriculum has six topics. In *hormones, homeostasis and reproduction* topic, food fermentation practical work can be used for covering two of the learning outcomes (Table 9). The other five topics are not found related with food fermentation studies.

In *Nucleic acids* unit, there is no learning outcome suitable for food fermentation practical work. Below, Table 10 is the visual representation of incorporation of learning outcomes according to topics.

Table 10

The Incorporation of Learning Outcomes for Metabolism, Cell Respiration and Photosynthesis Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Metabolism, cell respiration and photosynthesis	8.1 Metabolism	Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.
		Metabolic pathways can be controlled by end-product inhibition.
	8.2 Cell respiration	Cell respiration involves the oxidation and reduction of electron carriers.
		Phosphorylation of molecules makes them less stable.
		In glycolysis, glucose is converted to pyruvate in the cytoplasm.
		Glycolysis gives a small net gain of ATP without the use of oxygen.
	8.3 Photosynthesis	-

The food fermentation practical work can be implemented six learning outcomes of *metabolism* and *cell respiration* topics. However, there is no related learning outcomes in *photosynthesis* topic (Table 10).

Plant biology, *Genetics and evolution*, *Animal physiology*, and *Neurobiology and behaviour* units are not found relevant for the application of food fermentation practical work. There is no learning outcome corresponding to applied food fermentation studies in these units.

As seen in the Table 11, *Biotechnology and bioinformatics* unit has five topics and food fermentation practical work can be incorporated 18 learning outcomes in *microbiology: organisms in industry* and *environmental protection* topics.

Table 11

The Incorporation of Learning Outcomes for Biotechnology and Bioinformatics Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Option B: Biotechnology and bioinformatics	B.1 Microbiology: organisms in industry	Microorganisms are metabolically diverse.
		Microorganisms are used in industry because they are small and have a fast growth rate.
		Pathway engineering optimizes genetic and regulatory processes within microorganisms.
		Pathway engineering is used industrially to produce metabolites of interest.
		Fermenters allow large-scale production of metabolites by microorganisms.
		Fermentation is carried out by batch or continuous culture.
		Microorganisms in fermenters become limited by their own waste products.
		Probes are used to monitor conditions within fermenters.
		Conditions are maintained at optimal levels for the growth of the microorganisms being cultured.
		Deep-tank batch fermentation in the mass production of penicillin.
		Production of citric acid in a continuous fermenter by *Aspergillus niger* and its use as a preservative and flavouring.
		Biogas is produced by bacteria and archaeans from organic matter in fermenters.
		Production of biogas in a small-scale fermenter.
	B.2 Biotechnology in agriculture	-
	B.3 Environmental protection	Microorganisms are used in bioremediation.
		Cooperative aggregates of microorganisms can form biofilms.
		Biofilms possess emergent properties.
		Microorganisms growing in a biofilm are highly resistant to antimicrobial agents.
		Microorganisms in biofilms cooperate through quorum sensing.
	B.4 Medicine	-
	B.5 Bioinformatics	-

The learning outcomes of *biotechnology in agriculture*, *medicine*, and *bioinformatics* topics are not found related with food fermentation practical studies (Table 11).

Table 12 shows the learning outcomes of *Ecology and conservation* unit for application of food fermentation practical work.

Table 12

The Incorporation of Learning Outcomes for Ecology and Conservation Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Option C: Ecology and conservation	C.1 Species and communities	Community structure can be strongly affected by keystone species.
		Each species plays a unique role within a community because of the unique combination of its spatial habitat and interactions with other species.
		Interactions between species in a community can be classified according to their effect.
		Two species cannot survive indefinitely in the same habitat if their niches are identical.
		Local examples to illustrate the range of ways in which species can interact within a community.
	C.2 Communities and ecosystems	-
	C.3 Impacts of humans on ecosystems	-
	C.4 Conservation of biodiversity	-
	C.5 Population ecology	Modelling the growth curve using a simple organism such as yeast or species of Lemna.
	C.6 Nitrogen and phosphorus cycles	-

Practical work of food fermentation is found integrable into two topics of the unit. *Species and communities* is the most applicable topic with five learning outcomes (Table 12).

The related learning outcome of *Human physiology* unit can be seen in Table 13 below.

Table 13

The Incorporation of Learning Outcomes for Human Physiology Unit into IBDP Biology Curriculum

Unit	Topics	Understandings and Application and Skills
Option D: Human physiology	D.1 Human nutrition	Overweight individuals are more likely to suffer hypertension and type II diabetes.
	D.2 Digestion	-
	D.3 Functions of the liver	-
	D.4 The heart	-
	D.5 Hormones and metabolism	-
	D.6 Transport of respiratory gases	-

Human nutrition topic is found related with food fermentation practical work in terms of diseases like hypertension and type II diabetes that are arising from unhealthy food consumption. It can be incorporated one of the learning outcomes of the topic which is listed in Table 13 above.

Analyzed Units of IGCSE Biology Curriculum

In IGCSE biology syllabus, *Core* and *Supplement* sections are considered for analyzing the learning outcomes. The content analysis of the 21 units of the IGCSE biology curriculum is presented below. Table 14 shows the learning outcomes of *Characteristics and classification of living organisms* unit for application of food fermentation practical work.

Table 14

The Incorporation of Learning Outcomes for Characteristics and Classification of Living Organisms Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Characteristics and classification of living organisms	1.1 Characteristics of living organisms	Describe the characteristics of living organisms by defining the terms
	1.2 Concept and use of a classification system	State that organisms can be classified into groups by the features that they share

Table 14 (cont'd)

The Incorporation of Learning Outcomes for Characteristics and Classification of Living Organisms Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
		Define species as a group of organisms that can reproduce to produce fertile offspring
		Define and describe the binomial system of naming species as an internationally agreed system in which the scientific name of an organism is made up of two parts showing the genus and species
	1.3 Features of organisms	List the main features used to place all organisms into one of the five kingdoms: Animal, Plant, Fungus, Prokaryote, Protoctista
	1.4 Dichotomous keys	-

As seen in Table 14, food fermentation practical work can be integrated five learning outcomes of three topics of the unit. The learning outcomes of *dichotomous keys* topic are not found related with practical studies of food fermentation (Table 14).

Organisation of the organism unit are not found relevant for the application of food fermentation practical work. There is no learning outcome corresponding to applied food fermentation studies within three topics of the unit.

Table 15 shows the list of learning outcomes in which food fermentation practical studies can be incorporated.

Table 15

The Incorporation of Learning Outcomes for Movement in and out of Cells Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Movement in and out of cells	3.1 Diffusion	-
	3.2 Osmosis	Investigate and describe the effects on plant tissues of immersing them in solutions of different concentrations
	3.3 Active transport	-

One of the learning outcomes of *osmosis* topic is related with food fermentation practical work (Table 15). While making a pickle such as Sauerkraut (fermented cabbage), cabbage leaves release their water due to salt concentration and this can be used as an example of osmosis. The other topics, *diffusion* and *active transport* are not found related with food fermentation practical work (Table 15).

There is no learning outcome of *Biological molecules* unit related with application of food fermentation studies. The two related learning outcomes of *Enzymes* unit are shown in the Table 16 below.

Table 16

The Incorporation of Learning Outcomes for Enzymes Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Enzymes	5.1 Enzymes	Investigate and describe the effect of changes in temperature and pH on enzyme activity
		Explain the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation

Enzymes play an active role in fermentation process therefore all food fermentation practical work can be used to investigate and explain the effects on enzyme activity in this unit.

In the Table 17, there is only one learning outcome in *photosynthesis* topic is related with food fermentation practical work.

Table 17

The Incorporation of Learning Outcomes for Plant Nutrition Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Plant nutrition	6.1 Photosynthesis	Define the term limiting factor as something present in the environment in such short supply that it restricts life processes
	6.2 Leaf structure	-
	6.3 Mineral requirements	-

Table 18 shows that *diet topic* in *Human nutrition* unit is related with practical work of food fermentation with two learning outcomes.

Table 18

The Incorporation of Learning Outcomes for Human Nutrition Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Human nutrition	7.1 Diet	State what is meant by the term balanced diet for humans Describe the effects of malnutrition in relation to starvation, constipation, coronary heart disease, obesity and scurvy
	7.2 Alimentary canal	-
	7.3 Mechanical digestion	-
	7.4 Chemical digestion	-
	7.5 Absorption	-

There is no related learning outcome of *Transport in plants* and *Transport in animals* units with food fermentation applications. In *Diseases and immunity* unit, only one learning outcome of the topic is found related with food fermentation practical work (Table 19).

Table 19

The Incorporation of Learning Outcomes for Diseases and Immunity Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Diseases and immunity	10.1 Diseases and immunity	Define pathogen as a disease-causing organism

Food fermentation practical work cannot be incorporated in *Gas exchange in humans* unit. Below, Table 20 is the visual representation of integrable learning outcomes according to topics of *Respiration* unit.

Table 20

The Incorporation of Learning Outcomes for Respiration Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Respiration	12.1 Respiration	State that respiration involves the action of enzymes in cells
	12.2 Aerobic respiration	-
	12.3 Anaerobic respiration	Define anaerobic respiration as the chemical reactions in cells that break down nutrient molecules to release energy without using oxygen
		State that anaerobic respiration releases much less energy per glucose molecule than aerobic respiration
		State the balanced chemical equation for anaerobic respiration in the microorganism yeast as $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Food fermentation practical work is not found applicable to the learning outcomes of *Excretion in humans*, *Coordination and response* and *Drugs* units in IGCSE biology curriculum. Table 21 shows that *asexual reproduction* topic out of seven topics in *Reproduction* unit, is found related with food fermentation practical work.

Table 21

The Incorporation of Learning Outcomes for Reproduction Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Reproduction	16.1 Asexual reproduction	Identify examples of asexual reproduction from information provided
	16.2 Sexual reproduction	-
	16.3 Sexual reproduction in plants	-
	16.4 Sexual reproduction in humans	-
	16.5 Sex hormones in humans	-
	16.6 Methods of birth control in humans	-
	16.7 Sexually transmitted infections (STIs)	-

In the Table 22, there are five topics among these, practical work of food fermentation can be incorporated one of the learning outcomes of *mitosis* topic.

Table 22

The Incorporation of Learning Outcomes for Inheritance Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Inheritance	17.1 Inheritance	-
	17.2 Chromosomes, genes and proteins	-
	17.3 Mitosis	State the role of mitosis in growth, repair of damaged tissues, replacement of cells and asexual reproduction
	17.4 Meiosis	-
	17.5 Monohybrid inheritance	-

In *Variation and selection* unit of IGCSE biology curriculum, *variation* topic is found related with food fermentation practical work (Table 23).

Table 23

The Incorporation of Learning Outcomes for Variation and Selection Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Variation and selection	18.1 Variation	Define variation as differences between individuals of the same species
	18.2 Adaptive features	-
	18.3 Selection	-

Below, Table 24 is the visual representation of integrable learning outcomes to three topics of *Organisms and their environment* unit.

Table 24

The Incorporation of Learning Outcomes for Organisms and Their Environment Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Organisms and their environment	19.1 Energy flow	-
	19.2 Food chains and food webs	State that energy is transferred between organisms in a food chain by ingestion
		Define consumer as an organism that gets its energy by feeding on other organisms
		Define decomposer as an organism that gets its energy from dead or waste organic material
	19.3 Nutrient cycles	Describe the carbon cycle, limited to photosynthesis, respiration, feeding, decomposition, fossilisation and combustion
	19.4 Population size	Define population as a group of organisms of one species, living in the same area, at the same time Identify and state the factors affecting the rate of population growth for a population of an organism, limited to food supply, predation and disease
		Define community as all of the populations of different species in an ecosystem
		Define ecosystem as a unit containing the community of organisms and their environment, interacting together, e.g. a decomposing log, or a lake
		Explain the factors that lead to each phase in the sigmoid curve of population growth, making reference, where appropriate, to the role of limiting factors

As seen in Table 24, there are four topics in *Organisms and their environment* unit and nine different learning outcomes from three topics is found related with food fermentation practical work. *Energy flow* topic is not found relevant with application of food fermentation.

Table 25 shows six learning outcomes of two topics of *Biotechnology and genetic engineering* unit are found related with food fermentation practical work.

Table 25

The Incorporation of Learning Outcomes for Biotechnology and Genetic Engineering Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Biotechnology and genetic engineering	20.1 Biotechnology and genetic engineering	State that bacteria are useful in biotechnology and genetic engineering due to their rapid reproduction rate and their ability to make complex molecules
		Discuss why bacteria are useful in biotechnology and genetic engineering, limited to:
	20.2 Biotechnology	Describe the role of anaerobic respiration in yeast during production of ethanol for biofuels
		Describe the role of anaerobic respiration in yeast during bread-making
		Describe the role of the fungus Penicillium in the production of the antibiotic penicillin
		Explain how fermenters are used in the production of penicillin
	20.3 Genetic engineering	-

Table 26 shows that *Human influences on ecosystems* unit is related with practical work of food fermentation with three learning outcomes.

Table 26

The Incorporation of Learning Outcomes for Human Influences on Ecosystems Unit into IGCSE Biology Curriculum

Unit	Topics	Core and Supplement
Human influences on ecosystems	21.1 Food supply	Discuss the social, environmental and economic implications of providing sufficient food for an increasing human global population
	21.2 Habitat destruction	-
	21.3 Pollution	-
	21.4 Conservation	State that products can be reused or recycled, limited to paper, glass, plastic and metal Define the term sustainable development as development providing for the needs of an increasing human population without harming the environment

Human influences on ecosystems is one of the very important issue in 21st century. Food fermentation studies are supported sustainability in different ways such as usage of products again and again or continuity of the cultures (microorganisms) in production of food. Practical work of food fermentation can be incorporated *food supply* and *conservation* topics while covering listed learning outcomes above in Table 26.

Analyzed Units of MoNE Biology Curriculum

In MoNE biology curriculum, *Kazanım* (learning outcome) and *Kazanım Açıklaması* (learning outcome explanation) sections are considered as learning outcomes. The content analysis of the 12 units of the MoNE biology curriculum is presented below.

Table 27 is the visual representation of listed learning outcomes that are found related with food fermentation practical work in *Life science biology* unit of MoNE biology curriculum.

Table 27

The Incorporation of Learning Outcomes for Life Science Biology Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Life science biology	9.1.1. Biology and common characteristics of living things	Examine the common features of living things.
		a. The meaning of biology today and how it is used is briefly stated through the concept of living things. b. Cellular structure, nutrition, respiration, excretion, movement, reaction to stimuli, metabolism, homeostasis, adaptation, organization, reproduction, growth and development features of living things are emphasized.
	9.1.2. The basic compounds found in living things	Explain the organic and inorganic compounds that make up the structure of living things.
		a. The importance of water, minerals, acids, bases and salts for living beings is stated. c. The structure, function and importance of carbohydrates, lipids, proteins, nucleic acids, enzymes are stated. ç. It is emphasized that DNA is found in all living species and contains the same nucleotides. d. The importance of ATP and hormones for living things is questioned without including chemical formulas. f. Students are provided to conduct experiments to detect the presence of carbohydrates, lipids and proteins in foods. g. It is provided to conduct experiments related to factors affecting enzyme activity.
		Establish the relationship of lipids, carbohydrates, protein, vitamins, water and minerals with healthy nutrition. a. Insulin resistance, diabetes and obesity are addressed in the context of healthy eating. b. Students are provided to prepare a weekly healthy diet program for their age group.

In *Life science biology* unit, the food fermentation practical work can be incorporated all three learning outcomes and some of their sub-explanations (Table 27).

Table 28 shows the list of learning outcomes of *Cell* unit related with food fermentation studies.

Table 28

The Incorporation of Learning Outcomes for Cell Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Cell	9.2.1. Cell	Explain cell structures and functions.
		a. Parts of prokaryotic cells are shown.
		b. The structure of eukaryotic cells and the parts that make up this structure are shown. ç. Cell samples are examined with a microscope.
		Conduct a controlled experiment on the move across of particles through the cell membrane. a. The scientific method steps before the experiment on the move across of particles through the cell membrane are explained with an example.
		c. A controlled experiment is performed on one of the factors (surface area, concentration difference, temperature) affecting the move across of particles through the cell membrane.

As seen in the Table 28, food fermentation practical work can be embedded two learning outcomes and five of their sub-explanations. Table 29 shows that *World of living things* unit's related learning outcomes with food fermentation practical work.

Table 29

The Incorporation of Learning Outcomes for World of Living Things Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
World of living things	9.3.1. Diversity and classification of living things	Explain the importance of classification in understanding the diversity of living things.
		Explain the categories used in the classification of living things and the hierarchy between these categories with examples. c. Considering the hierarchical categories, binary naming examples are given about living species to be selected from the environment. ç. Students are provided to create a video or a product from photos taken / acquired about the world of living things.
	9.3.2. Kingdoms of living things and characteristics	Explains the kingdoms used in the classification of living things and the general characteristics of these kingdoms.

Table 29 (cont'd)

The Incorporation of Learning Outcomes for World of Living Things Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
		a. Examples are given by explaining the general characteristics of bacteria, arcs, protists, plants, fungi, animals. Classification of other kingdoms is not included except the animal kingdom.
		Explain the contribution of living things to biological processes, economy and technology with examples.

Food fermentation practical work can be incorporated all four learning outcomes of two topics of the unit (Table 29). The integrability of food fermentation practical work to learning outcomes of *Cell divisions* unit is shown in Table 30.

Table 30

The Incorporation of Learning Outcomes for Cell Divisions Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Cell divisions	10.1.1. Mitosis and asexual reproduction	Explain the necessity of cell division in living things.
		a. Cell division is explained by associating it with reproduction, growth and development in living things.
		Explain asexual reproduction with examples.
		a. Binary fission, budding, spore production, regeneration, parthenogenesis and vegetative reproduction samples are given in the context of asexual reproduction. In spore reproduction, only examples are given, fertilization is not mentioned.
	10.1.2. Meiosis and sexual reproduction	-

In *Cell divisions* unit, practical work of food fermentation can be embedded two learning outcomes of *mitosis and asexual reproduction* topic. The learning outcomes of the *meiosis and sexual reproduction* topic are not related with the food fermentation practical work (Table 30).

General principles of inheritance unit is not found related with the food fermentation practical studies. Below, Table 31 shows incorporation of food fermentation practical work to *Ecosystem ecology and current environmental problems* unit's learning outcomes.

Table 31

The Incorporation of Learning Outcomes for Ecosystem Ecology and Current Environmental Problems Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Ecosystem ecology and current environmental problems	10.3.1. Ecosystem ecology	Explains the relationship between biotic and abiotic components of the ecosystem.
		a. The relationship between population, community and ecosystem is explained by examples. b. Possible consequences in the system of any changes that may occur in the ecosystem are emphasized.
		c. Students are provided to prepare a presentation introducing an ecosystem of their choice.
		Explains the mode of nutrition in living things with examples.
		Analyzes the flow of matter and energy in the ecosystem.
		a. The role of producers, consumers and decomposers in the flow of matter and energy is examined.
		b. Matter and energy flow in ecosystems is exemplified by associating it with the food chain, the food web and the food pyramid. ç. Students are provided to construct a food web showing the nutritional relationships between living things.
		Interrelates the cycles of matter and the sustainability of life. a. Nitrogen, carbon and water cycles are reminded.
	10.3.2. Current environmental problems and human	Offers solutions for the prevention of environmental pollution in the local and global context.
		b. It is provided to discuss human activities that harm the environment locally and globally. c. Examples are given about how biology is associated with other disciplines in preventing environmental pollution.
	10.3.3. Natural resources and biodiversity conservation	Explains the importance of sustainability of natural resources.

As seen in Table 31, food fermentation practical work can be incorporated all three topics of the unit. The most common topic for the application of these studies is the *ecosystem ecology* with four learning outcomes and several annotations. Table 32 shows the integrability analysis with the food fermentation applied study of *Human physiology* unit.

Table 32

The Incorporation of Learning Outcomes for Human Physiology Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Human physiology	11.1.1. Supervisory and regulatory system, sensory organs	-
	11.1.2. The musculoskeletal system	-
	11.1.3. Digestive system	Explains digestive system disorders.
		Students make inferences about what needs to be done to protect the health of the digestive system.
	11.1.4. Circulatory system	-
	11.1.5. Respiratory system	-
	11.1.6. Urinary system	-
	11.1.7. Reproductive system and embryonic development	-

Food fermentation practical studies is found related with only *digestive system* topic of the unit. Other six topics are not associated with these practical studies (Table 32). The list of learning outcomes that can be integrated with the practical work of food fermentation of the *Community and Population Ecology* unit is shown in Table 33 below.

Table 33

The Incorporation of Learning Outcomes for Community and Population Ecology Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Community and population ecology	11.2.1. Community ecology	Explain symbiotic relationships between species in the community with examples. a. Parasitism and mutualism are associated with human health (lice, fleas, ticks, tapeworms, intestinal flora).
	11.2.2. Population ecology	Analyzes the factors affecting population dynamics. b. Different growth curves (S and J) are drawn for population growth.

There are two topics in this unit and food fermentation practical work can be embedded all two learning outcomes of these topics (Table 33). Table 34 is the visual representation of incorporation analysis of *From gene to protein* unit.

Table 34

The Incorporation of Learning Outcomes for From Gene to Protein Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
From gene to protein	12.1.1. Discovery and importance of nucleic acids	-
	12.1.2. The genetic code and protein synthesis	Evaluates the effects of genetic engineering and biotechnology applications on human life.

Food fermentation practical work is found related with the *the genetic code and protein synthesis* topic. But there is no corresponding learning outcome in *discovery and importance of nucleic acids* topic with these studies (Table 34).

In Table 35, the integrability analysis of food fermentation practical work to the learning outcomes of *Energy transformations in living things* unit is shown below.

Table 35

The Incorporation of Learning Outcomes for Energy Transformations in Living Things Unit into MoNE Biology Curriculum

Unit	Topics	Learning Outcomes and Explanations
Energy transformations in living things	12.2.1. Vitality and energy	Explains the necessity of energy for the continuation of life.
		a. The structure of the ATP molecule is explained.
		b. Phosphorylation types are briefly mentioned.
	12.2.2. Photosynthesis	-
	12.2.3. Chemosynthesis	-
	12.2.4. Cellular respiration	Explains cellular respiration.
		c. It is emphasized in all living things that glucose is broken down into pyruvic acid by a chain of reactions. Intermediate steps and intermediate products up to pyruvic acid are not mentioned. ç. Ethyl alcohol and lactic acid fermentation is explained and examples from daily life are given. d. In anaerobic respiration, it is stated that the electron is transferred to a molecule (sulfate, sulfur, nitrate, carbon dioxide, iron) other than oxygen. e. The reasons of higher energy efficiency than fermentation in aerobic respiration are emphasized. f. Cellular respiration processes are explained using visual elements, graphic organizers, e-learning object and applications.

As seen in Table 35, two of the four topics of the *Energy transformations in living things* unit are associated to the practical work of food fermentation. It was not found related with the learning outcomes of *photosynthesis* and *chemosynthesis* topics. The topic that can be incorporated most is *cellular respiration* with five sub-annotated learning outcomes (Table 35).

Plant biology and *Living things and the environment* units have not corresponding learning outcomes with the applied studies of food fermentation.

Analyzed units of MoNE Science Curriculum

In MoNE science curriculum, *Kazanım* (learning outcome) and *Kazanım Açıklaması* (learning outcome explanation) sections are considered as learning outcomes. The learning outcomes were analyzed by considering from year 5 to year 8 which is equivalent to the secondary school level. The content analysis of 28 units of MoNE science curriculum is presented below.

The learning outcomes of *Sun, earth, and moon* unit in MoNE science curriculum were not found related with food fermentation practical work. Table 36 shows that the only topic of *World of living things* unit is found associated with practical work of food fermentation.

Table 36

The Incorporation of Learning Outcomes for World of Living Things Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
World of living things	F.5.2.1. Getting to know the living things	Gives examples to living things and classifies them according to their similarities and differences. a. Living things are classified as plants, animals, fungi and microscopic organisms. c. Examples of microorganisms (bacteria, amoeba, euglena and paramecium) and mushrooms are given, but structural details are not mentioned. ç. Observes the presence of microorganisms with the help of a microscope. d. Students are warned not to eat poisonous mushrooms.

Food fermentation practical work is not found applicable to the learning outcomes of *Measurement of force and friction*, *Matter and change* and *Propagation of light* units in MoNE science curriculum.

Table 37 shows incorporation of the learning outcomes of *Human and environment* unit for application of food fermentation practical work.

Table 37

The Incorporation of Learning Outcomes for Human and Environment Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Human and environment	F.5.6.1. Biodiversity	-
	F.5.6.2. Human and environment relationship	Students provide suggestions for the solution of an environmental problem in their immediate environment or in our country.
	F.5.6.3. Destructive natural phenomena	-

Food fermentation practical work is found integrable into only one of the three topics. There are no learning outcomes corresponding to these studies in other two topics of the unit (Table 37).

Electrical circuit elements, *Solar system and eclipses*, *The systems of the human body*, *Force and motion*, *Matter and heat*, and *Sound and properties of sound* units are not found relevant for the application of food fermentation practical work.

Table 38 shows the integrability analysis of *Human body systems and its health* unit in food fermentation practical studies.

Table 38

The Incorporation of Learning Outcomes for Human Body Systems and Its Health Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Human body systems and its health	F.6.6.1. Supervisory and regulatory systems	-
	F.6.6.2. Sense organs	Students demonstrate the relationship between sense of smell and taste with an experiment they designed.
	F.6.6.3. Health of systems	Discusses what needs to be done for the health of human body systems based on research data.

As seen in Table 38, food fermentation applied studies can be incorporated into the learning outcomes of two of the three topics. *Supervisory and regulatory systems* topic is not found related with these studies (Table 38).

Transmission of electricity and *Solar system and beyond* units are not found related with food fermentation practical work. Table 39 shows the learning outcomes of the *cell* and *mitosis* topics in which the food fermentation practical studies can be applied and the *meiosis* topic which is not related to fermentation studies.

Table 39

The Incorporation of Learning Outcomes for Cell and Divisions Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Cell and divisions	F.7.2.1. Cell	Compares animal and plant cells in terms of their basic parts and functions.
	F.7.2.2. Mitosis	Explains the importance of mitosis for living things.
	F.7.2.3. Meiosis	-

Force and energy unit has no corresponding learning outcome with food fermentation practical work. Below, Table 40 shows the incorporation of learning outcomes with the food fermentation practical work for *Pure substances and mixtures* unit.

Table 40

The Incorporation of Learning Outcomes for Pure Substances and Mixtures Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Pure substances and mixtures	F.7.4.1. The particle theory of matter	-
	F.7.4.2. Pure substances	-
	F.7.4.3. Mixtures	Students give examples by classifying mixtures as homogeneous and heterogeneous.
	F.7.4.4. Separation of mixtures	-

Table 40 (cont'd)

The Incorporation of Learning Outcomes for Pure Substances and Mixtures Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
	F.7.4.5. Domestic wastes and recycling	Distinguishes substances that can be recycled and not recycled in domestic waste.
		Designs projects for the recycling of domestic solid and liquid wastes.
		Students develop projects to convey its reusable items to those in need.

Two topics out of five is found related with practical work of food fermentation in *Pure substances and mixtures* unit (Table 40).

Food fermentation studies is not found related with *Interaction of light with matter* unit. Table 41 shows the incorporation of learning outcomes of *Reproduction, growth and development in living things* unit with food fermentation practical studies.

Table 41

The Incorporation of Learning Outcomes for Reproduction, Growth and Development in Living Things Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Reproduction, growth and development in living things	F.7.6.1. Reproduction, growth and development in human	-
	F.7.6.2. Reproduction, growth and development in plants and animals	Compares reproduction types in plants and animals.
		Explains the growth and development processes in plants and animals by giving examples. a. An experiment involving dependent, independent and controlled variables is provided regarding the factors affecting seed germination.
		Explains the main factors affecting growth and development in plants and animals.
		Students take care of a plant or animal and reports its development process.

As seen in Table 41, *reproduction, growth and development in human* topic has no related learning outcome with fermentation studies. Four learning outcomes of the *reproduction, growth and development in plants and animals* topic have been found suitable for the implementation of the practical study of food fermentation (Table 41).

Electric circuits and *Seasons and climate* units are not found related with food fermentation practical studies. There is no learning outcome corresponding to applied food fermentation studies in these units. Below, Table 42 is the visual representation of incorporation of learning outcomes according to topics of the *DNA and genetic code* unit.

Table 42

The Incorporation of Learning Outcomes for DNA and Genetic Code Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
DNA and genetic code	F.8.2.1. DNA and genetic code	-
	F.8.2.2. Inheritance	-
	F.8.2.3. Mutation and modification	-
	F.8.2.4. Adaptation (Adaptation to the environment)	-
	F.8.2.5. Biotechnology	Discusses the beneficial and harmful aspects of these practices with the dilemmas created within the scope of biotechnological applications.

Among the five topics, only the *biotechnology* topic is found to be related to the practical study of food fermentation. There is no learning outcome in which fermentation studies can be applied in four other topics (Table 42).

Below, the related learning outcome of *Pressure* unit can be seen in Table 43.

Table 43

The Incorporation of Learning Outcomes for Pressure Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Pressure	F.8.3.1. Pressure	Students give examples of applications of pressure properties of solids, liquids and gases in daily life and technology.

Table 44 shows the learning outcomes of *Matter and industry* unit for application of food fermentation practical work.

Table 44

The Incorporation of Learning Outcomes for Matter and Industry Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Matter and industry	F.8.4.1. Periodic system	-
	F.8.4.2. Physical and chemical changes	Explains the differences between physical and chemical changes by observing various events.
	F.8.4.3. Chemical reactions	-
	F.8.4.4. Acids and bases	Refers to the general properties of acids and bases.
		Gives examples of acids and bases from daily life.
		Make inferences about the acidity and alkalinity of the substances by using PH values.
		It is ensured that they make inferences by doing experiments on the subject.
	F.8.4.5. Interaction of matter with heat	-
	F.8.4.6. Chemical industry in Turkey	-

As seen in Table 44, two topics of the unit within six topics is found related with food fermentation practical work. Five learning outcomes of the unit can be addressed by applying the practical study of food fermentation (Table 44).

Simple machines unit is not found related with practical work of food fermentation. Table 45 shows the list of learning outcomes of the *Energy* *transformations and environmental science* unit in which food fermentation practical studies can be incorporated.

Table 45

The Incorporation of Learning Outcomes for Energy Transformations and Environmental Science Unit into MoNE Science Curriculum

Unit	Topics	Learning Outcomes and Explanations
Energy transformations and environmental science	F.8.6.1. Food chain and flow of energy	Gives examples to producers, consumers and decomposers in the food chain.
	F.8.6.2. Energy transformations	Indicates the importance of respiration in living things. c. Aerobic and anaerobic respiration are given without entering stages, but the amount of energy released is not specified numerically. ç. Specifies the name of ATP without entering the structure.
	F.8.6.3. Matter cycles and environmental problems	Explains cycles of matter by showing them on the diagram.
		Interrogates the importance of matter cycles for life.
	F.8.6.4. Sustainable development	Designs projects for economical use of resources.
		Explains the importance of separating solid wastes for recycling.

Food fermentation practical work can be incorporated in all four topics of the *Energy transformations and environmental science* unit. Six learning outcomes of the unit is found appropriate for the implementation of these studies (Table 45).

Food fermentation practical work is not found related with the learning objectives of *Electric charge and electrical energy* unit.

Conclusion

The number of units containing learning outcomes in which food fermentation practical work can be incorporated was determined by adding up. Table 46 compares the number and percentage of units that can be integrable for each curriculum.

Table 46

Sample Frequency of Integrable Units According to the Content Analysis

Analyzed Curricula	Number of Units	Number of Units can be Integrated	%
IBDP Biology	15	10	67
IGCSE Biology	21	13	62
MoNE Biology	12	9	75
MoNE Science	28	10	36

As seen in Table 46, practical work of food fermentation can be incorporated more than two thirds of the units in IBDP biology curriculum (67%). The integrable units of the IGCSE biology curriculum found almost the same as IBDP biology curriculum with 62%. Three quarters of the MoNE biology curriculum units is found to be integrable with the food fermentation practical work, which is higher than the other two biology curricula. The lowest incorporation percentage could be seen in the MoNE science curriculum with 36%, in all curricula. Overall, the proportion of integrable units that all biology curricula average is 68%, which is nearly double than the science curriculum percentage (36%).

Codes from Learning Outcomes Related with Food Fermentation Practical Work

In the second stage of the curricula content analysis; the researcher removed the learning outcomes that are not related with food fermentation practical work. With using related learning outcomes, the keywords as known as codes were deduced and listed. All deduced codes from related learning outcomes of the analyzed curricula were included in Appendix B.

Deduced Codes from IBDP Biology Curriculum

The 10 units out of 15 of IBDP biology curriculum is analyzed for deducing codes from learning outcomes that are related with food fermentation practical work

(Appendix B). As an example of the analysis made in this section, Table 47 shows the keywords deduced from eight learning outcomes of *Cell biology* unit that are found related with food fermentation practical work.

Table 47

The List of Codes Deduced from Cell Biology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Cell biology	According to the cell theory, living organisms are composed of cells.	cell, cell theory
	Organisms consisting of only one cell carry out all functions of life in that cell.	organisms, functions of life
	Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. (Practical 1)	structure of cells
	Prokaryotes have a simple cell structure without compartmentalization.	prokaryotes, cell structure
	Eukaryotes have a compartmentalized cell structure.	eukaryotes, cell structure
	Prokaryotes divide by binary fission.	prokaryotes, binary fission
	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)	osmolarity
	Cells can only be formed by division of pre-existing cells.	pre-existing cells
	The origin of eukaryotic cells can be explained by the endosymbiotic theory.	origin of eukaryotic cells, endosymbiotic theory
	Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.	Pasteur's experiments, generation of cells
	Mitosis is division of the nucleus into two genetically identical daughter nuclei.	mitosis, cell division

Deduced Codes from IGCSE Biology Curriculum

The 13 units out of 21 of IGCSE biology curriculum is analyzed for deducing codes from learning objectives that are related with food fermentation practical work (Appendix B). As an example of the analysis made in this section, Table 48 shows the keywords deduced from five learning outcomes of *Characteristics and classification of living organisms* unit that are found related with food fermentation practical work.

Table 48

The List of Codes Deduced from Characteristics and Classification of Living Organisms Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Characteristics and classification of living organisms	Describe the characteristics of living organisms by defining the terms	characteristics of living organisms, living organisms
	State that organisms can be classified into groups by the features that they share	organisms, classification
	Define species as a group of organisms that can reproduce to produce fertile offspring	species, organisms, reproduce, fertile offspring
	Define and describe the binomial system of naming species as an internationally agreed system in which the scientific name of an organism is made up of two parts showing the genus and species	binomial system, organism, genus, species
	List the main features used to place all organisms into one of the five kingdoms: Animal, Plant, Fungus, Prokaryote, Protoctista	organisms, kingdoms, Fungus, Prokaryote

Deduced Codes from MoNE Biology Curriculum

The nine units out of 12 of MoNE biology curriculum is analyzed for deducing codes from learning outcomes that are related with food fermentation practical work (Appendix B). As an example of the analysis made in this section, Table 49 shows the keywords deduced from three learning outcomes of *Life science biology* unit and their explanations that are found related with food fermentation practical work.

Table 49

The List of Codes Deduced from Life Science Biology Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Life science biology	Examine the common features of living things.	common features of living things
	a. The meaning of biology today and how it is used is briefly stated through the concept of living things.	living things

Table 49 (cont'd)

The List of Codes Deduced from Life Science Biology Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
	b. Cellular structure, nutrition, respiration, excretion, movement, reaction to stimuli, metabolism, homeostasis, adaptation, organization, reproduction, growth and development features of living things are emphasized.	features of living things
	Explain the organic and inorganic compounds that make up the structure of living things.	structure of living things
	a. The importance of water, minerals, acids, bases and salts for living beings is stated.	minerals, acids, bases
	c. The structure, function and importance of carbohydrates, lipids, proteins, nucleic acids, enzymes are stated.	carbohydrates, enzymes
	ç. It is emphasized that DNA is found in all living species and contains the same nucleotides.	living species, DNA
	d. The importance of ATP and hormones for living things is questioned without including chemical formulas.	ATP, living things
	f. Students are provided to conduct experiments to detect the presence of carbohydrates, lipids and proteins in foods.	carbohydrates
	g. It is provided to conduct experiments related to factors affecting enzyme activity.	enzyme activity, affecting factors
	Establish the relationship of lipids, carbohydrates, protein, vitamins, water and minerals with healthy nutrition.	carbohydrates, healthy nutrition
	a. Insulin resistance, diabetes and obesity are addressed in the context of healthy eating.	diabetes, obesity, healthy eating
	b. Students are provided to prepare a weekly healthy diet program for their age group.	healthy diet

Deduced Codes from MoNE Science Curriculum

The 10 units out of 28 of MoNE science curriculum is analyzed for deducing codes from learning outcomes that are related with food fermentation practical work (Appendix B). As an example of the analysis made in this section, Table 50 shows the keywords deduced from one learning outcome of *World of living things* unit and it is explanations that are found related with food fermentation practical work.

Table 50

The List of Codes Deduced from World of Living Things Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
World of living things	Gives examples to living things and classifies them according to their similarities and differences.	living things, classifying
	a. Living things are classified as plants, animals, fungi and microscopic organisms.	living things, classification, fungi, microscopic organisms
	c. Examples of microorganisms (bacteria, amoeba, euglena and paramecium) and mushrooms are given, but structural details are not mentioned.	microorganisms, bacteria
	ç. Observes the presence of microorganisms with the help of a microscope.	microorganisms, microscope
	d. Students are warned not to eat poisonous mushrooms.	mushrooms, safety precautions, hygiene

Development of Themes from Codes

The codes collecting by deducing related outcomes were grouped according to their features. These identified features created themes that provide teachers with an overview for where they can incorporate food fermentation practical work. The codes associated with more than one theme were categorized according to the theme they are most suitable for. If some codes have an equally strong relationship with more than one theme, they were grouped in multiple themes at the same time. In this section, the codes grouped under the relevant categories and the themes created from these emerging categories are presented separately for the biology and science curricula.

Themes for Biology Curricula

IBDP biology curricula, IGCSE biology curricula and MoNE biology curricula were analyzed to constitute themes for biology teachers. After grouping codes, five themes were developed and named. The codes that composed the themes are listed under each theme table below. The theme *Living things* was derived from the following codes (Table 51).

Table 51

Listed Codes of the "Living Things" Theme for Biology Curricula

asexual reproduction	eukaryotes	mitosis
binary fission	functions of life	natural classification
binomial nomenclature	fungi	organisms
binomial system	fungus	origin of eukaryotic cells
budding	generation of cells	osmolarity
cell	genus	Pasteur's experiments
cell division	growth	pre-existing cells
cell theory	hierarchical category	Prokaryote
characteristics of living organisms	identification of species	prokaryotes
classifying / classification	kingdom / kingdoms	replacement of cells
common features of living things	living organisms / living species	reproduce / reproduction
development	membrane transport	structure of cells / cell structure
domain	microorganisms	structure of living things
endosymbiotic theory	microscope	yeasts

All of these codes were about maintaining life which is the key point of food fermentation practical work (Table 51). Food fermentation process is carried out by bacteria, fungi, mold or mixed cultures that reflect the vitality of these practical studies. It has been found that the practical work of food fermentation can be integrated into subjects relevant to living things in general.

In Table 52, the theme *Biochemistry* was derived from the following codes.

Table 52

Listed Codes of the "Biochemistry" Theme for Biology Curricula

acid	daily life examples	macromolecules
activity of enzymes / enzyme activity	denaturation	metabolic pathways
aerobic respiration	denatured enzymes	metabolism
anabolism	DNA	mineral
anaerobic /anaerobic respiration	electron carriers	monomers
ATP	electron transfer	nutrient molecules
base	end-product inhibition	oxidation

Table 52 (cont'd)

Listed Codes of the "Biochemistry" Theme for Biology Curricula

carbohydrates	energy	pH
carbon compounds	energy efficiency	phosphorylation
carbon dioxide	enzyme-catalyzed reactions	pyruvate
carbon dioxide concentration	enzymes	pyruvic acid
catabolism	ethanol	rate of activity of enzymes
cellular respiration	ethyl alcohol	reaction chain
cellular respiration processes	glucose	reduction
chemical energy	glycolysis	respiration
chemical reactions	hydrolysis	solutions of different concentrations
concentration difference	lactic acid	substrate concentration
condensation reactions	light intensity	surface area
controlled experiment	limiting factor / limiting factors / affecting factors	temperature

As seen in Table 52, all codes were about biochemistry which is reflected the features of the theme. Fermentation is a metabolic process that followed the successive reactions known as anaerobic respiration. Food fermentation practical work can be used subjects related with biochemistry in general.

Table 53 shows the list of codes forming the theme of *Biotechnology*.

Table 53

Listed Codes of the "Biotechnology" Theme for Biology Curricula

anaerobic respiration	contribution of living things	lactose-free milk
antibiotic penicillin	culture	metabolically diverse
antimicrobial agents	deep-tank batch fermentation	metabolites
archaeans	disease-causing organism	microorganisms
Aspergillus niger	DNA profiles	number of genes
bacteria	DNA profiling	optimal conditions
baking / bread-making	economy	organic matter
base sequence	ethanol	Pasteur's experiments
batch	fermentation	pathogen
biofilms	fermenter / fermenters	pathway engineering
biofuels	flavouring	penicillin / Penicillium
biogas	fungus	plasmid
biological process	gene	preservative
bioremediation	genetic engineering	probes

Table 53 (cont'd)

Listed Codes of the "Biotechnology" Theme for Biology Curricula

biotechnology	genome size	reproduction rate
chromosome	growth of the microorganisms	small-scale fermenter
circular DNA	growth rate	waste products
citric acid	industry	yeast / yeasts

Biotechnology is one of the important fields where practical work of food fermentation can be integrated. It also reflects the industrial use and benefits of microorganisms. Food fermentation practical work can be used subjects related with biotechnology in general (Table 53).

Below, Table 54 presents the codes that compose the *Ecology* theme.

Table 54

Listed Codes of the "Ecology" Theme for Biology Curricula

abiotic	glass	organic nutrients
autotrophic	growth curve / growth curves	organisms
autotrophs	habitat	population dynamics
biology	heterotrophic	population growth
biotic	heterotrophs	populations
carbon cycle	impacts of humans on ecosystems	prevention of environmental pollution
community	influencing factors	producer
consumer / consumers	ingestion	rate of population growth
decomposer / decomposers	inorganic nutrients	recycle
decomposition	interaction /interactions	reuse
detritivores	interdisciplinary relations	saprotrophs
ecosystem	keystone species	spatial habitat
energy flow	limiting factor / limiting factors / affecting factors	species
environment	matter cycles	sufficient food
external digestion	method of nutrition / mode of nutrition	sustainable / sustainability
feeding	niche	sustainable development
fertile offspring	nutrient cycling	symbiotic relationships
food chain / food web / food pyramid	nutritional relationships	variation

All living things interact with each other and their environment. The microorganisms that perform fermentation also interact with each other and their environment. Therefore, food fermentation practical work can be used subjects related with ecology in general (Table 54).

In Table 55, the theme *Health* was derived from the following codes.

Table 55

Listed Codes of the "Health" Theme for Biology Curricula

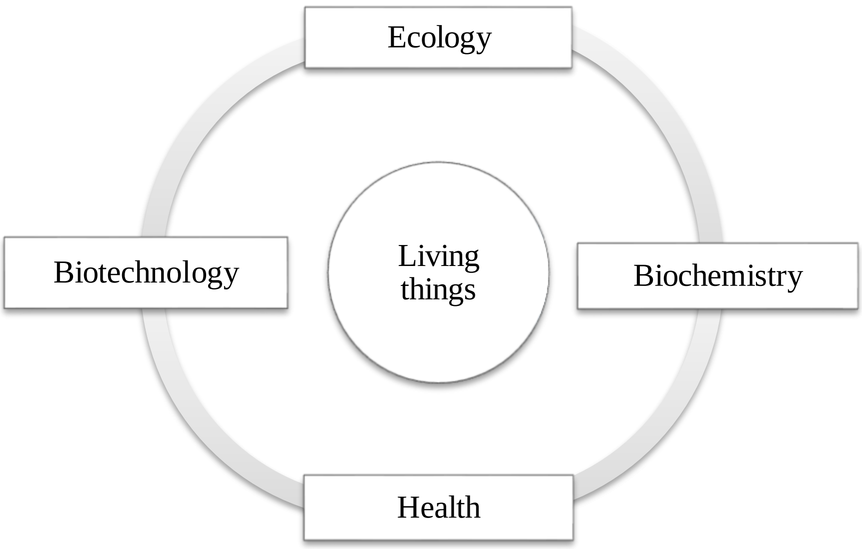
balanced diet	healthy eating	obesity
diabetes	human health	overweight
digestive system disorders	intestinal flora	symbiotic relationship
digestive system health	mutualism	type II diabetes

Fermented foods are directly associated with healthy eating. The fact that fermented foods are rich in probiotics and contain trace amounts of sugar makes them preferable for many health issues. Food fermentation practical work can be used subjects related with health in general (Table 55).

In substance, food fermentation practical work can be incorporated underneath five themes in biology curricula. *Living things* is the global theme for application of food fermentation practical work in biology classes. Practical work of food fermentation can be used in every lesson related with living things in general. The other four organizing themes are *Biotechnology*, *Ecology*, *Biochemistry*, and *Health* that are interlinked with the *Living things* theme (Figure 4).

Figure 4

Themes Developed from Content Analysis of Biology Curricula



Themes for Science Curriculum

MoNE science curriculum was analyzed to constitute themes for science teachers. After grouping codes, five themes were developed and named. The codes that composed the themes are listed under each theme table. Below, Table 56 presents the codes that compose the *Living things* theme.

Table 56

Listed Codes of the "Living Things" Theme for Science Curriculum

aerobic respiration	common features of living things	living things
anaerobic respiration	development	microorganisms /microscopic organisms
asexual reproduction	development process	microscope
ATP	differences of living things	mitosis
bacteria	factors affecting growth and development	mushrooms
caring for living things	fungi	respiration / cellular respiration
cell	growth	senses
cell division	growth and development	smell
classifying / classification		

In science curriculum, the content is more limited about living things, but covers all the knowledge that underpins life. Microorganisms involved in food fermentation establish the connection of these studies with vitality and the codes under Table 56 manifests the basics of living things. Therefore, food fermentation practical work can be incorporated into subjects relevant to living things in general (Table 56).

The theme *Chemistry* was derived from the following initial codes in Table 57.

Table 57

Listed Codes of the "Chemistry" Theme for Science Curriculum

acidity	chemical change	pH
acid / acids	heterogeneous mixture	physical change
alkalinity	homogeneous mixture	pressure
base / bases	mixtures	solution

Fermentation is the process that produces chemical changes, and it is easy and safe to show these changes with food fermentation studies in science classes. It has been found that the practical work of food fermentation can be incorporated in some chemistry subjects associated with the codes shown in Table 57.

Table 58 shows the list of codes forming the theme of *Experimental design*.

Table 58

Listed Codes of the "Experimental Design" Theme for Science Curriculum

applications of pressure in daily life and technology	dependent variable	observation
affecting factors	design of experiments	process
biotechnological studies	experiment	project
controlled variable	independent variable	safety precautions
daily life examples	microscope	

There are many variables in food fermentation practical work. Different experimental processes can be designed according to the needs of the science curriculum. These studies are a good opportunity of combining daily life examples with the curriculum. Therefore, the practical work of food fermentation can be incorporated into many of the subjects that require experimental design in science curriculum (Table 58).

In Table 59, the theme *Health* was derived from the following codes.

Table 59

Listed Codes of the "Health" Theme for Science Curriculum

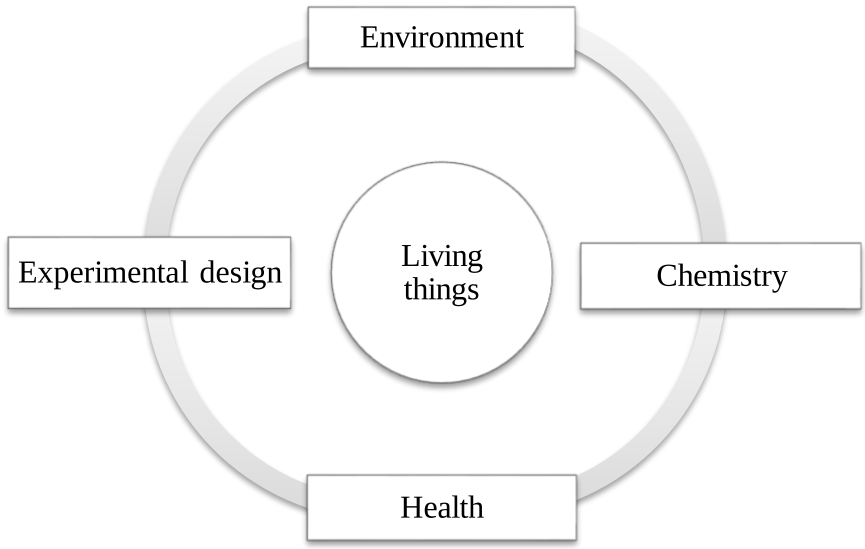
diabetes	obesity	safety precautions
hygiene	health of body systems	

Most habits should be adopted at an early age, and students should learn how to maintain their health. The content of the science curriculum is found limited about raise awareness about health. While covering health subjects in science curriculum, food fermentation practical work can be used (Table 59).

As a result of the content analysis, food fermentation practical work can be incorporated underneath five themes in science curricula. *Living things* is the global theme for application of food fermentation practical work in science classes. Practical work of food fermentation can be used in every lesson related with living things in general. The other four organizing themes are *Experimental design*, *Environment*, *Chemistry*, and *Health* that are interlinked with the *Living things* theme (Figure 5).

Figure 5

Themes Developed from Content Analysis of Science Curriculum



Analysis of How to Use Food Fermentation Practical Work

Lastly, the researcher categorized learning outcomes according to how food fermentation practical can be used specifically for each one. Teachers can use this manual to grasp how to increase the use of food fermentation practical work in many subjects and to adapt it to a spiral curriculum. Usage of food fermentation practical work is scaled into five categories (Table 3). Code 1 means that practical work of food fermentation can be given as an example. Code 2 means the requirements of the learning outcome can be taught by comparing food fermentation practical work and the subject. For example, the subject of photosynthesis is not directly associated with the food fermentation practical work, but the limiting factors on the rate of photosynthesis can be taught by comparing with the liming factors on the rate of food fermentation and it is categorized as Code 2. Also, the food fermentation process can be divided into parts and used partly to meet the requirements of the subjects more effectively. If the teacher wants to apply part of the process such using ready cultures rather generating culture or directly using the end-product rather starting from beginning, it was categorized as Code 3. Starting from generating culture and finishing practical work with the end-product reflect the whole process and is named Code 4. If the fermentation practical studies meet the requirements of the learning outcome but there is no curriculum link to add, the learning outcome can be arranged to apply these studies. It is coded as *addition* to incorporate these studies in the relevant learning outcomes and classified as Code 5. At this point, teachers can add food fermentation practical work as an extra studies and curriculum developers can integrate this into new curricula. All the learning outcomes in which practical work of food fermentation can be incorporated are listed under each curriculum and how they can be implemented are codded from one to five in the same row.

Usage of Food Fermentation Practical Work for IBDP Biology Curriculum

The food fermentation practical work was found to relate to 10 units of the IBDP biology curriculum, and an analysis of how to use it for each learning outcome is presented below. Table 60 shows the usage of food fermentation practical work for 11 learning outcomes of *Cell biology* unit.

Table 60

Usage of Food Fermentation Practical Work for Cell Biology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Cell biology	According to the cell theory, living organisms are composed of cells.	1
	Organisms consisting of only one cell carry out all functions of life in that cell.	1
	Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. (Practical 1)	3
	Prokaryotes have a simple cell structure without compartmentalization.	1
	Eukaryotes have a compartmentalized cell structure.	1

Table 60 (cont'd)

Usage of Food Fermentation Practical Work for Cell Biology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
	Prokaryotes divide by binary fission.	1
	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)	3
	Cells can only be formed by division of pre-existing cells.	1, 3
	The origin of eukaryotic cells can be explained by the endosymbiotic theory.	1
	Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.	1, 3
	Mitosis is division of the nucleus into two genetically identical daughter nuclei.	1

Fermentation process includes different microorganism cultures such as bacteria, yeast, mold or mixed. These microorganisms can be used as examples (Code 1) to cover most of the learning outcomes of the unit. Also, while making pickles like sauerkraut (German sour cabbage, lacto-fermented vegetable), we salt in sliced cabbage and massage it until the juice is released which is an example of osmolarity in tissues for the Practical 2 (Table 60). This only contains beginning (preparation phase) of the fermentation process (Code 3). The rest of the process (pickling) can be maintained to cover some of the learning outcomes of the *Molecular biology* unit.

Table 61 shows the usage of food fermentation practical work for 14 learning outcomes of the *Molecular biology* unit.

Table 61

Usage of Food Fermentation Practical Work for Molecular Biology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Molecular biology	Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism.	1
	Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions.	1
	Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.	1, 3
	Temperature, pH and substrate concentration affect the rate of activity of enzymes.	1, 3
	Enzymes can be denatured.	1, 3
	Methods of production of lactose-free milk and its advantages.	1
	Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes.	1, 3
	Experimental investigation of a factor affecting enzyme activity. (Practical 3)	1, 2, 3, 5
	Cell respiration is the controlled release of energy from organic compounds to produce ATP.	1
	ATP from cell respiration is immediately available as a source of energy in the cell.	1
	Anaerobic cell respiration gives a small yield of ATP from glucose.	1, 4
	Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.	3, 4
	Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.	2
	Design of experiments to investigate the effect of limiting factors on photosynthesis.	2, 5

Fermentation is a metabolic process that consists of enzyme-catalyzed reactions. All food fermentation practical studies can be used in this unit with different applications. In fact, food fermentation is a very suitable experiment for Practical 3 to investigate factors affecting enzyme activity (Table 61). Moreover, limiting factors of photosynthesis and fermentation can be compared (Code 2) to cover the enzyme action in detail and to comprehend different metabolic processes (Table 61).

Table 62 shows the usage of food fermentation practical work for seven learning outcomes of the *Genetics* unit.

Table 62

Usage of Food Fermentation Practical Work for Genetics Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Genetics	Comparison of the number of genes in humans with other species.	1, 2
	Use of a database to determine differences in the base sequence of a gene in two species.	1, 2
	Prokaryotes have one chromosome consisting of a circular DNA molecule.	1
	Some prokaryotes also have plasmids but eukaryotes do not.	1, 2
	Comparison of genome size in T2 phage, Escherichia coli, Drosophila melanogaster, Homo sapiens and Paris japonica.	1, 2, 5
	DNA profiling involves comparison of DNA.	1, 2
	Analysis of examples of DNA profiles.	1, 2, 5

In *Genetics* unit, we can benefit from different microorganisms inside the cultures as both prokaryotes and eukaryotes. Today, many researchers are carried out on fermented food cultures. For example, lactic acid bacteria in sauerkraut fermentations were analyzed by DNA fingerprinting (Plengvidhya et al., 2007). The data obtained from such studies can be used as examples (Code 1) and for comparison (Code 2) in the lessons (Table 62).

Table 63 shows the usage of food fermentation practical work for 12 learning outcomes of the *Ecology* unit.

Table 63

Usage of Food Fermentation Practical Work for Ecology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Ecology	Species are groups of organisms that can potentially interbreed to produce fertile offspring.	1
	Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).	1
	Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.	1
	A community is formed by populations of different species living together and interacting with each other.	1
	A community forms an ecosystem by its interactions with the abiotic environment.	1
	The supply of inorganic nutrients is maintained by nutrient cycling.	1
	Ecosystems have the potential to be sustainable over long periods of time.	1
	Classifying species as autotrophs, consumers, detritivores or saprotrophs from a knowledge of their mode of nutrition.	1
	Chemical energy in carbon compounds flows through food chains by means of feeding.	1
	Energy released from carbon compounds by respiration is used in living organisms and converted to heat.	1
	Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.	1, 3
	Construct a diagram of the carbon cycle.	1

The relationship between different microorganisms in mixed cultures and their relationships with their abiotic environment can be used as an example (Code 1) for this unit (Table 63). Microorganisms in food fermentation are heterotrophic that use carbon compounds (flour, table sugar, etc.) to produce energy through anaerobic respiration. Natural carbonated beverages are formed by the conversion of carbon products such as glucose to carbon dioxide diffused into water. To demonstrate this transformation, fermented beverages can be prepared using ready-made cultures (Code 3) such as ginger bug (culture of microorganisms to make ginger ale) and carbon dioxide release can be observed (Table 63).

Table 64 shows the usage of food fermentation practical work for three learning outcomes of the *Evolution and biodiversity* unit.

Table 64

Usage of Food Fermentation Practical Work for Evolution and Biodiversity Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Evolution and biodiversity	When species are discovered they are given scientific names using the binomial system.	1
	All organisms are classified into three domains.	1
	Natural classifications help in identification of species and allow the prediction of characteristics shared by species within a group.	1

The microorganisms used in food fermentation cultures belong to the Eubacteria and Eukaryota domains. Food fermentation bacterial and fungal species are examples of different kingdoms and binomial naming system (Code 1). To illustrate, *Saccharomyces cerevisiae*, a well-known member of sourdough microbiome, can be used to cover the listed learning outcomes of the unit (Table 64).

Table 65 shows the usage of food fermentation practical work for two learning outcomes of the *Human physiology* unit.

Table 65

Usage of Food Fermentation Practical Work for Human Physiology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and skills	How to Use
Human physiology	Causes and treatment of Type I and Type II diabetes.	1, 5
	Testing of leptin on patients with clinical obesity and reasons for the failure to control the disease.	1

The appropriateness of fermented food consumption to the diet of a person with type II diabetes and its contribution to obesity treatment can be given and discussed as examples (Code 1) while covering two practical learning outcomes of this unit (Table 65).

Table 66 shows the usage of food fermentation practical work for six learning outcomes of the *Metabolism, cell respiration and photosynthesis* unit.

Table 66

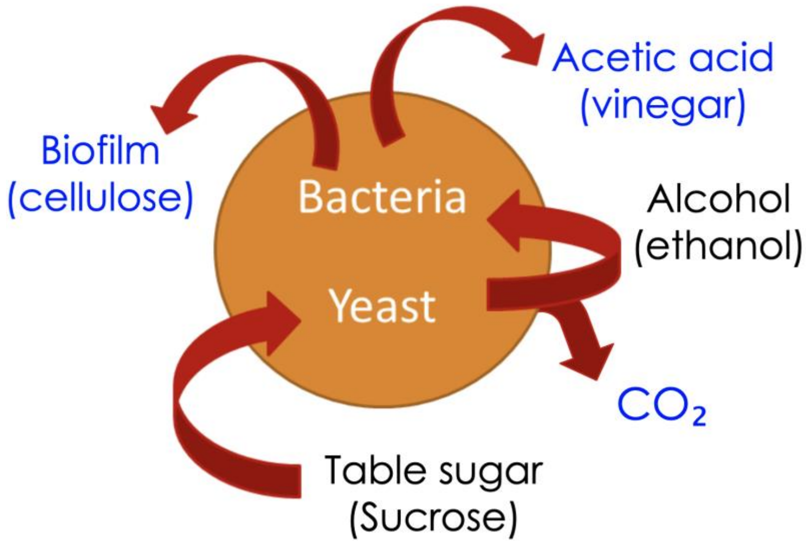
Usage of Food Fermentation Practical Work for Metabolism, Cell Respiration and Photosynthesis Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Metabolism, cell respiration and photosynthesis	Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.	1
	Metabolic pathways can be controlled by end-product inhibition.	1, 3
	Cell respiration involves the oxidation and reduction of electron carriers.	1
	Phosphorylation of molecules makes them less stable.	1
	In glycolysis, glucose is converted to pyruvate in the cytoplasm.	1
	Glycolysis gives a small net gain of ATP without the use of oxygen.	1

All food fermentation processes are metabolic pathways. This process can be illustrated by drawing diagrams to make practical work more understandable. The metabolic pathway of Kombucha culture is shown by multiple chains and cycles in Figure 6.

Figure 6

Metabolic Pathway for Kombucha Microbiome (SCOBY)



Note. This model was produced by the researcher in 2020. The metabolic pathway shows the fermentation process of Kombucha tea made by a symbiotic culture of bacteria and yeast. Sucrose is used by yeast to produce carbon dioxide (CO_2) and alcohol. The alcohol produced is then used by bacteria for acetic acid and biofilm formation (May et al., 2019).

Table 67 shows the usage of food fermentation practical work for nineteen learning outcomes of the *Biotechnology and bioinformatics* unit.

Table 67

Usage of Food Fermentation Practical Work for Biotechnology and Bioinformatics Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Biotechnology and bioinformatics	Microorganisms are metabolically diverse.	1
	Microorganisms are used in industry because they are small and have a fast growth rate.	1, 3, 4
	Pathway engineering optimizes genetic and regulatory processes within microorganisms.	1, 3
	Pathway engineering is used industrially to produce metabolites of interest.	1, 3

Table 67 (cont'd)

Usage of Food Fermentation Practical Work for Biotechnology and Bioinformatics Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
	Fermenters allow large-scale production of metabolites by microorganisms.	1, 4
	Fermentation is carried out by batch or continuous culture.	1, 4, 5
	Microorganisms in fermenters become limited by their own waste products.	1, 3, 4
	Probes are used to monitor conditions within fermenters.	1, 3, 4
	Deep-tank batch fermentation in the mass production of penicillin.	1, 2, 3, 5
	Production of citric acid in a continuous fermenter by Aspergillus niger and its use as a preservative and flavouring.	1, 2, 3
	Biogas is produced by bacteria and archaeans from organic matter in fermenters.	1, 2, 3
	Production of biogas in a small-scale fermenter.	1, 2, 3
	Microorganisms are used in bioremediation.	1, 2
	Cooperative aggregates of microorganisms can form biofilms.	1, 2, 3
	Biofilms possess emergent properties.	1, 2, 3, 5
	Microorganisms growing in a biofilm are highly resistant to antimicrobial agents.	1, 2, 3, 5
	Microorganisms in biofilms cooperate through quorum sensing.	1, 2, 3, 5

The unit of *Biotechnology and bioinformatics* has the most matched content with the food fermentation practical work (Table 67). All food fermentation investigations can be done as a whole process or partially (Code 3 and Code 4) to cover the listed outcomes of the unit or can be used as examples and comparisons (Code 1 and Code 2). For example, SCOBY (symbiotic culture of bacteria and yeasts) of Kombucha tea is an example of a biofilm, shown in Figure 7. The thickness of Kombucha biofilm can be investigated by using different media such as different tea types as an application idea or the studies that have been carried out can be shown as examples or compared (Kayisoglu & Coskun, 2021; Shade, 2021).

Figure 7

The Appearance of Kombucha Biofilm at the Top of the Fermented Tea

Note. From *Mature Kombucha* [Photograph], by M. Garten, 2007, English Wikipedia (https://en.wikipedia.org/wiki/Kombucha#/media/File:Kombucha_Mature.jpg). CC BY-SA 3.0.

Table 68 shows the usage of food fermentation practical work for five learning outcomes of the *Ecology and conservation* unit.

Table 68

Usage of Food Fermentation Practical Work for Ecology and Conservation Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Ecology and conservation	Community structure can be strongly affected by keystone species.	1, 2, 3
	Each species plays a unique role within a community because of the unique combination of its spatial habitat and interactions with other species.	1, 2, 3
	Interactions between species in a community can be classified according to their effect.	1, 2, 3
	Two species cannot survive indefinitely in the same habitat if their niches are identical.	2
	Local examples to illustrate the range of ways in which species can interact within a community.	1, 3
	Modelling the growth curve using a simple organism such as yeast or species of Lemna.	1, 3

Most of the food fermentation cultures (microflora) consist of different species that are sharing the same habitat. For instance; lactic acid bacteria, mold (*Penicillium roqueforti)* and yeasts are working together to make blue cheese (Martín & Coton, 2017). The interactions between these species and their quantities in cultures are very crucial and determine the success of the fermentation process and the flavors of fermented foods. Food fermentation practical work can be used as an example or making comparisons among different cultures (Code 1 and Code 2) to cover the learning outcomes of the unit (Table 68). Also, these practical studies can be applied partially by using ready cultures (Code 3) to make investigation about interactions between species and modelling a growth curve of microorganism inside the cultures.

Table 69 shows the usage of food fermentation practical work for one learning outcome of the *Human physiology* unit.

Table 69

Usage of Food Fermentation Practical Work for Human Physiology Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	How to Use
Human physiology	Overweight individuals are more likely to suffer hypertension and type II diabetes.	1, 5

The researchers show that fermented foods show anti-diabetic properties and use to contribute the treatment strategies for high blood sugar (Sivamaruthi et al., 2018). The health benefits of fermented foods can be given as an example (Code 1) while covering the related learning outcome of the *Human physiology* unit (Table 69).

In summary, the practical study of food fermentation can be used as an example (Code 1) for all listed units of the IBDP biology curriculum. 6 out of 10 units are suitable for partial application (Code 3) in classrooms. On the other hand, *Molecular biology* and *Biotechnology and bioinformatics* units are compatible with all codes (Codes 1, 2, 3 and 4). Also, some units (4 out of 10) are suitable for making comparisons (Code 2) between topic and food fermentation practical work to enhance learning.

Usage of Food Fermentation Practical Work for IGCSE Biology Curriculum

The food fermentation practical work was found to relate to 13 units of the IGCSE biology curriculum, and an analysis of how to use it for each learning outcome is presented below. Table 70 shows the usage of food fermentation practical work for 5 learning outcomes of *Characteristics and classification of living organisms* unit.

Table 70

Usage of Food Fermentation Practical Work for Characteristics and Classification of Living Organisms Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Characteristics and classification of living organisms	Describe the characteristics of living organisms by defining the terms	1
	State that organisms can be classified into groups by the features that they share	1
	Define species as a group of organisms that can reproduce to produce fertile offspring	1
	Define and describe the binomial system of naming species as an internationally agreed system in which the scientific name of an organism is made up of two parts showing the genus and species	1
	List the main features used to place all organisms into one of the five kingdoms: Animal, Plant, Fungus, Prokaryote, Protoctista	1

Since food fermentation cultures (microbiome) are living organisms and consists of different species belonging to different kingdoms, can be used as an example (Code 1) to cover the listed learning outcomes of the unit (Table 70).

Table 71 shows the usage of food fermentation practical work for one learning outcome of the *Movement in and out of cells* unit.

Table 71

Usage of Food Fermentation Practical Work for Movement in and out of Cells Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Movement in and out of cells	Investigate and describe the effects on plant tissues of immersing them in solutions of different concentrations	1, 3, 5

All pickled vegetables can be given as an example (Code 1) to cover the listed learning outcome of the unit (Table 71). For example, it is started to make Sauerkraut (sour cabbage) by adding salt on the chopped cabbage leaves and rubbing leaves with salt until the liquids pull out of the cabbage via osmosis and cover up it. This liquid prevents the reproduction of unwanted microorganisms such as *E. coli* during the fermentation process (Xiong et al., 2016). Salt concentration has effect on having a healthy culture and the quality of the final product. The practical study of sauerkraut can be implemented in the classrooms (Code 3) to investigate how much liquid pull out from cabbage leaves via osmosis by changing salt concentrations. There are different studies that investigated effects of different salt concentrations on Sauerkraut quality and microbiome. Yang et al. (2020) stated that "The best quality of sauerkraut was obtained from fermented under 2.5% salt concentration" (p. 1458). This practical work can also be connected to the learning outcomes of other units such as Enzymes by doing further investigations on prepared sauerkrauts in different salt concentrations.

Table 72 shows the usage of food fermentation practical work for two learning outcomes of the *Enzymes* unit.

Table 72

Usage of Food Fermentation Practical Work for Enzymes Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Enzymes	Investigate and describe the effect of changes in temperature and pH on enzyme activity	1, 2, 3, 5
	Explain the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation	1, 2, 3

All food fermentation practical studies are enzyme catalyzed reactions and can be investigated (Code 3) to describe effect of changes in temperature and pH on enzyme activity. As mentioned above different salt concentrations can be used to see the effect of pH on the enzyme activity in sauerkraut. It is possible to compare results of driven studies (Code 2) or give as an example while covering the learning outcomes of the unit (Table 72).

Table 73 shows the usage of food fermentation practical work for one learning outcome of the *Plant nutrition* unit.

Table 73

Usage of Food Fermentation Practical Work for Plant Nutrition Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Plant nutrition	Define the term limiting factor as something present in the environment in such short supply that it restricts life processes	1, 2

There are plenty of limiting factors that affects food fermentation process such as temperature, pH, and glucose amount. It is used to cover the listed learning outcome of the unit (Table 73) by giving as an example or making comparison (Code 1 and 2).

Table 74 shows the usage of food fermentation practical work for two learning outcomes of the *Human nutrition* unit.

Table 74

Usage of Food Fermentation Practical Work for Human Nutrition Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Human nutrition	State what is meant by the term balanced diet for humans	1
	Describe the effects of malnutrition in relation to starvation, constipation, coronary heart disease, obesity and scurvy	1

The benefits of fermented foods are known, and a lot of research is conducted to learn about the effects on human health. It is stated that its content is rich in probiotics, and it is enhanced with biologically active peptides, minerals and vitamins that are produced by microorganisms beneficial to human health (Marco et al., 2017; Şanlier et al., 2017). The articles about health of fermented foods can be given as an example (Code 1) and discussed to cover listed learning outcomes of the unit (Table 74).

Table 75 shows the usage of food fermentation practical work for one learning outcome of the *Diseases and immunity* unit.

Table 75

Usage of Food Fermentation Practical Work for Diseases and Immunity Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Diseases and immunity	Define pathogen as a disease-causing organism	1, 2

To prevent misconception about all microorganisms are disease causing, the food fermentation cultures can be given as an example (Code 1) and compared with pathogens (Code 2). Contrary to what is believed, it is known that the majority of microorganisms are useful and helpful to human health. However, this belief reinforced with Covid-19 pandemic and will cause more obstacles while covering these topics (Simard, 2021). The practical study of food fermentation is a good source to avoid confusion about microorganisms.

Table 76 shows the usage of food fermentation practical work for four learning outcomes of the *Respiration* unit.

Table 76

Usage of Food Fermentation Practical Work for Respiration Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Respiration	State that respiration involves the action of enzymes in cells	1
	Define anaerobic respiration as the chemical reactions in cells that break down nutrient molecules to release energy without using oxygen	1, 2, 5
	State that anaerobic respiration releases much less energy per glucose molecule than aerobic respiration	1, 2
	State the balanced chemical equation for anaerobic respiration in the microorganism yeast as C6H12O6 → 2C2H5OH + 2CO2	1

Fermentation is an anaerobic respiration performed by microorganism for breaking down glucose. Thus, food fermentation practical work can be given as an example (Code 1) or used to make comparison to cover listed learning outcomes of the unit (Table 76).

Table 77 shows the usage of food fermentation practical work for one learning outcome of the *Reproduction* unit.

Table 77

Usage of Food Fermentation Practical Work for Reproduction Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Reproduction	Identify examples of asexual reproduction from information provided	1

Food fermentation cultures are rich in biodiversity, so microbiomes provide examples of different types of asexual reproduction to cover the listed learning outcome of the unit (Table 77). For instance, bacterium can be used for binary fission, yeast cell for budding and molds for spore formation.

Table 78 shows the usage of food fermentation practical work for one learning outcome of the *Inheritance* unit.

Table 78

Usage of Food Fermentation Practical Work for Inheritance Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Inheritance	State the role of mitosis in growth, repair of damaged tissues, replacement of cells and asexual reproduction	1

While covering the listed learning outcome of the unit (Table 78), yeasts can be used as an example for the role of mitosis in asexual reproduction (Code 1).

Table 79 shows the usage of food fermentation practical work for one learning outcome of the *Variation and selection* unit.

Table 79

Usage of Food Fermentation Practical Work for Variation and Selection Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Variation and selection	Define variation as differences between individuals of the same species	1

As microbial cultures of food fermentation include different species, the variations in bacteria, yeasts and molds can be used as examples (Code 1) to cover the listed learning outcome of the unit (Table 79).

Table 80 shows the usage of food fermentation practical work for nine learning outcomes of the *Organisms and their environment* unit.

Table 80

Usage of Food Fermentation Practical Work for Organisms and Their Environment Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Organisms and their environment	State that energy is transferred between organisms in a food chain by ingestion	1
	Define consumer as an organism that gets its energy by feeding on other organisms	1
	Define decomposer as an organism that gets its energy from dead or waste organic material	1
	Describe the carbon cycle, limited to photosynthesis, respiration, feeding, decomposition, fossilisation and combustion	1
	Define population as a group of organisms of one species, living in the same area, at the same time	1
	Identify and state the factors affecting the rate of population growth for a population of an organism, limited to food supply, predation and disease	1, 2
	Define community as all of the populations of different species in an ecosystem	1
	Define ecosystem as a unit containing the community of organisms and their environment, interacting together, e.g. a decomposing log, or a lake	1
	Explain the factors that lead to each phase in the sigmoid curve of population growth, making reference, where appropriate, to the role of limiting factors	1, 2, 3

Food fermentation mixed cultures (microbiomes) are good examples (Code 1) of a community living together in an ecosystem, such as in a jar or on the food. It can also be used to make comparisons in terms of limiting factors for the population, and the role of limiting factors on population growth can be investigated by using ready-made fermentation cultures (Code 3).

Table 81 shows the usage of food fermentation practical work for six learning outcomes of the *Biotechnology and genetic engineering* unit.

Table 81

Usage of Food Fermentation Practical Work for Biotechnology and Genetic Engineering Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Biotechnology and genetic engineering	State that bacteria are useful in biotechnology and genetic engineering due to their rapid reproduction rate and their ability to make complex molecules	1, 2, 3
	Discuss why bacteria are useful in biotechnology and genetic engineering, limited to:	1, 2
	Describe the role of anaerobic respiration in yeast during production of ethanol for biofuels	1, 2, 3
	Describe the role of anaerobic respiration in yeast during bread-making	1, 4
	Describe the role of the fungus Penicillium in the production of the antibiotic penicillin	1, 2
	Explain how fermenters are used in the production of penicillin	1, 2, 3

As the unit of *Biotechnology and genetic engineering* is directly connected with fermentation, practical work of food fermentation can be used in many ways. It is an explicit example (Code 1) for all learning outcomes, can be partially or fully applied as an investigation (Code 3 and 4) and compared using different articles or examples (Code 2).

Table 82 shows the usage of food fermentation practical work for three learning outcomes of the *Human influences on ecosystems* unit.

Table 82

Usage of Food Fermentation Practical Work for Human Influences on Ecosystems Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
Human influences on ecosystems	Discuss the social, environmental and economic implications of providing sufficient food for an increasing human global population	1
	State that products can be reused or recycled, limited to paper, glass, plastic and metal	1

Table 82 (cont'd)

Usage of Food Fermentation Practical Work for Human Influences on Ecosystems Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	How to Use
	Define the term sustainable development as development providing for the needs of an increasing human population without harming the environment	1

This study discusses and explores many different aspects of the food fermentation practical work. One of the most important contributions of food fermentation is that it is a sustainable method. Fermentation cultures are cultures that can be reused indefinitely and shared as they multiply if kept in optimal conditions. On the other hand, it contributes to the preservation of food for a long time and the development of its content in terms of nutritional value. It can be used as an example (Code 1) to cover listed learning outcomes of the unit (Table 82).

Consequently, the practical work of food fermentation can be used as an example (Code 1) for all of the listed learning outcomes of the IGCSE biology curriculum and for many to make comparisons (Code 2). *Movement in and out of cells*, *Enzymes*, *Organisms and their environment*, and *Biotechnology and genetic engineering* units are suitable for partially implementing the practical study of food fermentation (Code 3). Furthermore, food fermentation practical work can be fully applied (Code 4) from culturing to final product in *Biotechnology and genetic engineering* unit.

Usage of Food Fermentation Practical Work for MoNE Biology Curriculum

The food fermentation practical work was found to relate to 9 units of the MoNE biology curriculum, and an analysis of how to use it for each learning outcome is presented below. Table 83 shows the usage of food fermentation practical work for three learning outcomes and their explanations of *Life science biology* unit.

Table 83

Usage of Food Fermentation Practical Work for Life Science Biology Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Life science biology	Examine the common features of living things.	1
	a. The meaning of biology today and how it is used is briefly stated through the concept of living things.	1
	b. Cellular structure, nutrition, respiration, excretion, movement, reaction to stimuli, metabolism, homeostasis, adaptation, organization, reproduction, growth and development features of living things are emphasized.	1
	Explain the organic and inorganic compounds that make up the structure of living things.	1
	a. The importance of water, minerals, acids, bases and salts for living beings is stated.	1
	c. The structure, function and importance of carbohydrates, lipids, proteins, nucleic acids, enzymes are stated.	1
	ç. It is emphasized that DNA is found in all living species and contains the same nucleotides.	1
	d. The importance of ATP and hormones for living things is questioned without including chemical formulas.	1
	f. Students are provided to conduct experiments to detect the presence of carbohydrates, lipids and proteins in foods.	1, 3
	g. It is provided to conduct experiments related to factors affecting enzyme activity.	1, 3, 5
	Establish the relationship of lipids, carbohydrates, protein, vitamins, water and minerals with healthy nutrition.	1
	a. Insulin resistance, diabetes and obesity are addressed in the context of healthy eating.	1, 5
	b. Students are provided to prepare a weekly healthy diet program for their age group.	1

Food fermentation is started by microbial cultures, which are prerequisite in the process. Since the basis of food fermentation is the anaerobic respiration of living organisms, it can be used as an example (Code 1) for all learning outcomes related to vitality. Furthermore, practical work of food fermentation is suitable for investigating the substances contained in fermented foods using ready-made fermented foods, and for enzyme activity experiments using ready-made cultures (Code 3).

Table 84 shows the usage of food fermentation practical work for two learning outcomes and their explanations of the *Cell* unit.

Table 84

Usage of Food Fermentation Practical Work for Cell Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Cell	Explain cell structures and functions.	1
	a. Parts of prokaryotic cells are shown.	1, 3
	b. The structure of eukaryotic cells and the parts that make up this structure are shown.	1, 3
	ç. Cell samples are examined with a microscope.	1, 3
	Conduct a controlled experiment on the move across of particles through the cell membrane.	1, 3
	a. The scientific method steps before the experiment on the move across of particles through the cell membrane are explained with an example.	1, 2
	c. A controlled experiment is performed on one of the factors (surface area, concentration difference, temperature) affecting the move across of particles through the cell membrane.	1, 3

As mentioned above, food fermentation cultures are good examples (Code 1) of living things, containing both prokaryotic and eukaryotic cells. Bacteria can be investigated under a microscope to learn more about prokaryotic cells. Yeasts and molds belonging to the Fungi kingdom can be examined with a microscope as an example of eukaryotic cells. To generating cultures from the beginning and exploring their structure and particle movement through cell membrane under a microscope is the first part of the food fermentation process (Code 3) that is sufficient to cover the listed learning outcomes and their explanations for this unit (Table 84).

Table 85 shows the usage of food fermentation practical work for three learning outcomes and their explanations of the *World of living things* unit.

Table 85

Usage of Food Fermentation Practical Work for World of Living Things Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
World of living things	Explain the importance of classification in understanding the diversity of living things.	1
	Explain the categories used in the classification of living things and the hierarchy between these categories with examples.	1, 2
	c. Considering the hierarchical categories, binomial nomenclature examples are given about living species to be selected from the environment.	1, 2
	ç. Students are provided to create a video or a product from photos taken / acquired about the world of living things.	1, 3, 5
	Explains the kingdoms used in the classification of living things and the general characteristics of these kingdoms.	1
	a. Examples are given by explaining the general characteristics of bacteria, arcs, protists, plants, fungi, animals. Classification of other kingdoms is not included except the animal kingdom.	1
	Explain the contribution of living things to biological processes, economy and technology with examples.	1, 5

The microbial cultures of food fermentation are used as an example (Code 1) or making comparisons (Code 2) for classifying living things under different hierarchical categories. The generated cultures in the previous Cell unit can be used (Code 3) to take a photo of the living things to provide evidence to world of living things. Moreover, the contributions of cultures of food fermentation in food industry to biological processes, economy and technology can be discussed deeply.

Table 86 shows the usage of food fermentation practical work for two learning outcomes and their explanations of the *Cell divisions* unit.

Table 86

Usage of Food Fermentation Practical Work for Cell Divisions Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Cell divisions	Explain the necessity of cell division in living things.	1
	a. Cell division is explained by associating it with reproduction, growth and development in living things.	1
	Explain asexual reproduction with examples.	1
	a. Binary fission, budding, spore production, regeneration, parthenogenesis and vegetative reproduction samples are given in the context of asexual reproduction. In spore reproduction, only examples are given, fertilization is not mentioned.	1

As discussed under the IGCSE biology curriculum (Table 74), food fermentation cultures are rich in biodiversity, thus providing examples of different asexual reproduction context. For example, bacteria can be used for binary fission, yeast cell for budding and molds for spore formation (Code 1) to cover the listed learning outcomes of the unit (Table 86).

Table 87 shows the usage of food fermentation practical work for six learning outcomes and their explanations of the *Ecosystem ecology and current environmental problems* unit.

Table 87

Usage of Food Fermentation Practical Work for Ecosystem Ecology and Current Environmental Problems Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Ecosystem ecology and current environmental problems	Explains the relationship between biotic and abiotic components of the ecosystem.	1
	a. The relationship between population, community and ecosystem is explained by examples.	1
	b. Possible consequences in the system of any changes that may occur in the ecosystem are emphasized.	1, 2, 3
	c. Students are provided to prepare a presentation introducing an ecosystem of their choice.	1, 2, 3, 5

Table 87 (cont'd)

Usage of Food Fermentation Practical Work for Ecosystem Ecology and Current Environmental Problems Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
	Explains the mode of nutrition in living things with examples.	1, 2
	Analyzes the flow of matter and energy in the ecosystem.	1, 2
	a. The role of producers, consumers and decomposers in the flow of matter and energy is examined.	1, 2
	b. Matter and energy flow in ecosystems is exemplified by associating it with the food chain, the food web and the food pyramid.	1, 2
	ç. Students are provided to construct a food web showing the nutritional relationships between living things.	1, 2, 5
	Interrelates the cycles of matter and the sustainability of life.	1
	a. Nitrogen, carbon and water cycles are reminded.	1
	Offers solutions for the prevention of environmental pollution in the local and global context.	1
	b. It is provided to discuss human activities that harm the environment locally and globally.	1
	c. Examples are given about how biology is associated with other disciplines in preventing environmental pollution.	1
	Explains the importance of sustainability of natural resources.	1

Population, community and ecosystem relationships can be explained in detail using food fermentation practical work as an example (Code 1) and a specific type food fermentation process can be chosen to introduce an ecosystem (Code 3). Also in this unit, comparison of different food fermentation ecosystems with each other or with other ecosystems can be used to grasp the many learning outcomes (Code 2). Flow of matter and energy in the ecosystems can be explained by drawing diagrams to show relationships between community (see Figure 6). In this study, it has been emphasized many times that the practical work of food fermentation is a sustainable method as cultures are reused and prevents food from spoiling for a long time. Considering these aspects, it can be used as an example (Code 1) when covering learning outcomes related to sustainability and cycles of matter.

Table 88 shows the usage of food fermentation practical work for two learning outcomes of the *Human physiology* unit.

Table 88

Usage of Food Fermentation Practical Work for Human Physiology Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Human physiology	Explains digestive system disorders.	1
	Students make inferences about what needs to be done to protect the health of the digestive system.	1, 5

In this study, the benefits of fermented foods were emphasized and discussed at the point of integration into the curriculum. Fermented foods are known to be rich in probiotics, and studies have indicated that they support digestive system health, such as preventing and treating inflammatory bowel disease (IBD) (Saez-Lara et al., 2015). The benefits of fermented foods on digested system can be given as an example or discussed (Code 1) to cover the listed learning outcomes of the unit (Table 88).

Table 89 shows the usage of food fermentation practical work for one learning outcome and its explanations of the *Community and population ecology* unit.

Table 89

Usage of Food Fermentation Practical Work for Community and Population Ecology Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Community and population ecology	Explain symbiotic relationships between species in the community with examples.	1, 5
	a. Parasitism and mutualism are associated with human health (lice, fleas, ticks, tapeworms, intestinal flora).	1, 2
	Analyzes the factors affecting population dynamics.	1, 2, 3
	b. Different growth curves (S and J) are drawn for population growth.	1, 2, 3

Mixed cultures of food fermentation, such as the culture of Kombucha tea, SCOBY (symbiotic culture of bacteria and yeasts), are good examples (Code 1) to grasp the symbiotic relationships in the community. The practical work of food fermentation can be applied to analyze population dynamics by generating new cultures or using ready-made cultures (Code 3). On the other hand, the relationship between human and human gut probiotics can be given as an example (Code 1), or the relationship between different communities can be used for comparison (Code 2).

Table 90 shows the usage of food fermentation practical work for one learning outcome of the *From gene to protein* unit.

Table 90

Usage of Food Fermentation Practical Work for From Gene to Protein Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
From gene to protein	Evaluates the effects of genetic engineering and biotechnology applications on human life.	1, 5

Genetic engineering and biotechnology applications are used directly in the food fermentation industry and can be given as an example (Code 1) for this unit. For example, starter cultures (microorganisms) are genetically improved by using engineering techniques and desired microorganisms are selected with biotechnological methods applied for production efficiency (Harlander, 1992).

Table 91 shows the usage of food fermentation practical work for two learning outcomes and their explanations of the *Energy transformations in living things* unit.

Table 91

Usage of Food Fermentation Practical Work for Energy Transformations in Living Things Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Energy transformations in living things	Explains the necessity of energy for the continuation of life.	1
	a. The structure of the ATP molecule is explained.	1
	b. Phosphorylation types are briefly mentioned.	1
	Explains cellular respiration.	1
	c. It is emphasized in all living things that glucose is broken down into pyruvic acid by a chain of reactions. Intermediate steps and intermediate products up to pyruvic acid are not mentioned.	1
	ç. Ethyl alcohol and lactic acid fermentation is explained and examples from daily life are given.	1, 2, 3, 4
	d. In anaerobic respiration, it is stated that the electron is transferred to a molecule (sulfate, sulfur, nitrate, carbon dioxide, iron) other than oxygen.	1
	e. The reasons of higher energy efficiency than fermentation in aerobic respiration are emphasized.	1, 2
	f. Cellular respiration processes are explained using visual elements, graphic organizers, e-learning object and applications.	1, 2, 3, 5

Anaerobic respiration of microorganisms can be covered by applying food fermentation practical work either partially by using ready-made culture (Code 3) or whole process by starting from generating cultures (Code 4). Energy transformations in microorganisms can be explained by giving food fermentation practical work as an example (Code 1) or by comparison with aerobic respiration (Code 2).

To sum up, the practical work of food fermentation can be used as an example (Code 1) for all listed learning outcomes of MoNE biology curriculum units and as a comparison (Code 2) for many. In addition, 6 out of 9 units are suitable for partially implementing (Code 3) food fermentation practical work. The unit of *Energy transformations in living things* has been determined as the only unit in which practical work of food fermentation can be applied to the whole process from culture to the final product (Code 4).

Usage of Food Fermentation Practical Work for MoNE Science Curriculum

The food fermentation practical work was found to relate to 10 units of the MoNE science curriculum, and an analysis of how to use it for each learning outcome is presented below. Table 92 shows the usage of food fermentation practical work for one learning outcome and its explanations of *World of living things* unit.

Table 92

Usage of Food Fermentation Practical Work for World of Living Things Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
World of living things	Gives examples to living things and classifies them according to their similarities and differences.	1, 2
	a. Living things are classified as plants, animals, fungi and microscopic organisms.	1, 2
	c. Examples of microorganisms (bacteria, amoeba, euglena and paramecium) and mushrooms are given, but structural details are not mentioned.	1, 2, 5
	ç. Observes the presence of microorganisms with the help of a microscope.	1, 3, 5
	d. Students are warned not to eat poisonous mushrooms.	1, 2

Food fermentation cultures are good examples of microscopic organisms (Code 1) and can be used to explain that the fungi kingdom is not just mushrooms. Samples from cultures can be examined under a microscope (Code 3) and comparisons can be made between different cultures (Code 2).

Table 93 shows the usage of food fermentation practical work for one learning outcome of the *Human and environment* unit.

Table 93

Usage of Food Fermentation Practical Work for Human and Environment Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Human and environment	Students provide suggestions for the solution of an environmental problem in their immediate environment or in our country.	1

One of the important parts of the application of food fermentation practical work is that the materials needed for this practical are very simple and reusable equipment such as glass jars, wood spoons, cloth covers. In addition, microbial cultures can be reused and shared with others indefinitely if kept in optimal conditions.

Moreover, the products of practical work are edible and need not be wasted. Another advantage is that fermented foods have a long shelf life, so they can be offered as a solution to food waste in areas where it is needed. Considering all these aspects of the practical work of food fermentation, it can be given as an example (Code 1) to cover the listed learning outcome of the unit (Table 93).

Table 94 shows the usage of food fermentation practical work for two learning outcomes of the *Human body systems and its health* unit.

Table 94

Usage of Food Fermentation Practical Work for Human Body Systems and Its Health Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Human body systems and its health	Students demonstrate the relationship between sense of smell and taste with an experiment they designed.	1, 3, 5
	Discusses what needs to be done for the health of human body systems based on research data.	1, 5

Food fermentation gives foods a pungent odor and distinct taste, and this odor and flavor depend on fermentation time, culture characteristics, environmental conditions, etc. may vary accordingly. By manipulating the variables, an experiment can be designed (Code 3), and the effects of these changes can be investigated by smelling and tasting the fermented foods produced. Also, the health benefits of fermented foods can be given as an example (Code 1) and discussed in classes.

Table 95 shows the usage of food fermentation practical work for two learning outcomes of the *Cell and divisions* unit.

Table 95

Usage of Food Fermentation Practical Work for Cell and Divisions Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Cell and divisions	Compares animal and plant cells in terms of their basic parts and functions.	1, 2
	Explains the importance of mitosis for living things.	1

While comparing the parts and functions of animal and plant cells, microorganisms in food fermentation cultures can be given as an example (Code 1) or included in the comparison (Code 2) to enhance students' learning. Yeast cells can be given as an example to explain mitosis and its importance (Code 1).

Table 96 shows the usage of food fermentation practical work for four learning outcomes of the *Pure substances and mixtures* unit.

Table 96

Usage of Food Fermentation Practical Work for Pure Substances and Mixtures Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Pure substances and mixtures	Students give examples by classifying mixtures as homogeneous and heterogeneous.	1
	Distinguishes substances that can be recycled and not recycled in domestic waste.	1
	Designs projects for the recycling of domestic solid and liquid wastes.	1
	Students develop projects to convey its reusable items to those in need.	1

Fermented beverages can be used as an example (Code 1) to cover homogeneous and heterogeneous mixtures. For example, sugar and tea are mixed before the starter culture (SCOBY) of Kombucha tea is added. After the starter culture has been added, the distribution of microorganisms and transformation of sugar molecules in different parts of a jar can vary. These starter and final teas are good examples for homogeneous and heterogenous mixtures.

On the other hand, the equipment required for the fermentation process can be obtained from domestic wastes such empty glass jars or leftover fresh vegetables. The leftover brewed teas can be used to make Kombucha tea, and this is an excellent example of recycled domestic wastes (Code 1).

Table 97 shows the usage of food fermentation practical work for four learning outcomes and their explanations of the *Reproduction, growth and development in living things* unit.

Table 97

Usage of Food Fermentation Practical Work for Reproduction, Growth and Development in Living Things Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Reproduction, growth and development in living things	Compares reproduction types in plants and animals.	1, 2
	Explains the growth and development processes in plants and animals by giving examples.	1, 2, 3
	a. An experiment involving dependent, independent and controlled variables is provided regarding the factors affecting seed germination.	1, 2, 3, 5
	Explains the main factors affecting growth and development in plants and animals.	1, 2, 3
	Students take care of a plant or animal and reports its development process.	1, 2, 3, 4, 5

Plant and animal reproduction, growth and development are examples well known and experienced by all students. As an alternative and unfamiliar option, food fermentation starter cultures can be generated (Code 3) and taken care of these microbial cultures (Code 4) to cover listed learning outcomes of the unit (Table 97).

In addition, comparisons can be made with plant and animal reproduction, growth and development processes (Code 2). Factors affecting the food fermentation process, such as temperature and the amount of sugar added each day, can be examined to explain the reproduction, growth and development process of microbial cultures.

Table 98 shows the usage of food fermentation practical work for one learning outcome of the *DNA and genetic code* unit.

Table 98

Usage of Food Fermentation Practical Work for DNA and Genetic Code Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
DNA and genetic code	Discusses the beneficial and harmful aspects of these practices with the dilemmas created within the scope of biotechnological applications.	1, 2, 5

The starter cultures of food fermentation are selected and genetically developed using biotechnology applications (Harlander, 1992) to meet the food needs of the growing world population and increase efficient production in the food industry. These genetic modifications and biotechnology applications can be given as an example (Code 1) or used to make comparisons (Code 2).

Table 99 shows the usage of food fermentation practical work for one learning outcome of the *Pressure* unit.

Table 99

Usage of Food Fermentation Practical Work for Pressure Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Pressure	Students give examples of applications of pressure properties of solids, liquids and gases in daily life and technology.	1, 2, 3, 5

Carbon dioxide gas that occurs naturally during the fermentation process causes fermented beverages to become fizzy (carbonated) drinks. The process of food fermentation can be applied partially by using ready-made cultures (Code 3). For instance, ginger bug (culture of ginger ale) can be used to make fizzy drinks in pressurized bottles (see Figure 8) and can be shown students as a daily life example of pressure applications (Code 1).

Figure 8

The Appearance of Naturally Fizzy Ginger Ale in the Pressurized Bottles

Note. From "*How to make fizzy, probiotic-rich ginger ale,"* by H. Dessinger, 2021, Mommypotamus (https://mommypotamus.com/homemade-ginger-ale-recipe/).

Table 100 shows the usage of food fermentation practical work for five learning outcomes of the *Matter and industry* unit.

Table 100

Usage of Food Fermentation Practical Work for Matter and Industry Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Matter and industry	Explains the differences between physical and chemical changes by observing various events.	1, 2, 3
	Refers to the general properties of acids and bases.	1, 2, 3
	Gives examples of acids and bases from daily life.	1, 2
	Make inferences about the acidity and alkalinity of the substances by using pH values.	1, 2, 3
	It is ensured that they make inferences by doing experiments on the subject.	1, 2, 3, 5

Practical studies of food fermentation are good examples of comparing physical and chemical changes by making observations or even smelling and tasting. The increased acidic conditions during the fermentation process can be used as a daily life example (Code 1) or compared to other examples (Code 2). Also, practical study of food fermentation can be applied using ready-made cultures (Code 3) and inference can be made by taking pH measurements between different fermented products or at different time intervals of a particular product.

Table 101 shows the usage of food fermentation practical work for six learning outcomes and their explanations of the *Energy transformations and environmental science* unit.

Table 101

Usage of Food Fermentation Practical Work for Energy Transformations and Environmental Science Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	How to Use
Energy transformations and environmental science	Gives examples to producers, consumers and decomposers in the food chain.	1, 2
	Indicates the importance of respiration in living things.	1
	c. Aerobic and anaerobic respiration are given without entering stages, but the amount of energy released is not specified numerically.	1, 2
	ç. Specifies the name of ATP without entering the structure.	1
	Explains cycles of matter by showing them on the diagram.	1
	Interrogates the importance of matter cycles for life.	1
	Designs projects for economical use of resources.	1
	Explains the importance of separating solid wastes for recycling.	1

The practical study of food fermentation can be used as an example (Code 1) to describe food chains. In this process, the plants used for fermentation are in the role of producers, and the sugar content of these plants is used by the microbial cultures of fermentation, that is, by decomposers, and fermented foods are consumed by humans. This food chain example can also be used in comparison with other food chains to reinforce students' learning (Code 2). It also constitutes a direct example

(Code 1) to explain anaerobic respiration and its importance in living things. The discussed benefits of food fermentation practical work under Table 101 can be used to explain the economical use of resources and reusable solid wastes.

To conclude, food fermentation practical work can be used as an example (Code 1) for almost all of the listed learning outcomes of the MoNE science curriculum and for many to make comparisons (Code 2). The *World of living things*, *Human body systems and its health*, *Reproduction, growth and development in living things*, *Pressure*, and *Matter and industry* units are found proper to partially apply practical work of food fermentation in classes (Code 3). Finally, the unit of *Reproduction, growth and development in living things* unit is the only suitable unit for the application of the whole process from generating cultures to the final product (Code 4).

Curricula Integration Study of Participant Teachers

The second research question of the study was answered by analyzing curricula integration study of the participant teachers. The curricula integration study of participant teachers also used to triangulate the researcher's content analysis. The participant teachers of the workshop separated into groups according to the curricula that they are following in their schools. The IBDP, IGCSE, MoNE biology and MoNE science curricula were analyzed and the learning outcomes that are found related with food fermentation practical work and for extracurricular studies were listed by the participants. Moreover, high school teachers and middle school teachers separately analyzed the possible interdisciplinary and extracurricular activities suitable for practical work on food fermentation. The researcher then consolidated all the listed units under each relevant curriculum and school phase activity to present the data in the tables in the following sections.

High School Teachers' Curricula Study

The five high school biology teachers who participated in the study worked together on the IBDP biology, IGCSE biology, and MoNE biology curricula. They reviewed each curriculum separately. They selected and listed the topics and learning outcomes they found relevant by discussing. The listed learning outcomes are grouped by the researcher under each unit and shown in the tables below.

Table 102 shows the listed units of the IBDP biology curriculum related to food fermentation practical work deduced by participant teachers.

Table 102

The Related Units of IBDP Biology Curriculum with Food Fermentation Practical Work

Topic 1: Cell biology
Topic 2: Molecular biology
Topic 5: Evolution and biodiversity
Topic 8: Metabolism, cell respiration and photosynthesis
Option B: Biotechnology and bioinformatics
Option C: Ecology and conservation
Option D: Human physiology

As seen in Table 102, seven units, four of the topics and three of the options, were found to be related to the practical study of food fermentation by the participating teachers.

Table 103 shows the listed units of the IGCSE biology curriculum related to food fermentation practical work deduced by participant teachers.

Table 103

The Related Units of IGCSE Biology Curriculum with Food Fermentation Practical Work

1 Characteristics and classification of living organisms
3 Movement in and out of cells
5 Enzymes
7 Human nutrition
12 Respiration
16 Reproduction
17 Inheritance
19 Organisms and their environment
20 Biotechnology and genetic engineering

Nine units of the IGCSE biology curriculum were associated with the practical study of food fermentation by participating teachers (Table 103).

Table 104 shows the listed units of the MoNE biology curriculum related to food fermentation practical work deduced by participant teachers.

Table 104

The Related Units of MoNE Biology Curriculum with Food Fermentation Practical Work

9.1. Life science biology
9.2. Cell
9.3. World of living things
10.1 Cell divisions
11.1. Human physiology
11.2. Community and population ecology
12.1. From gene to protein
12.2 Energy transformations in living things

Eight units of the IGCSE biology curriculum were found related with the food fermentation practical work by participating teachers (Table 104).

Interdisciplinary and Extracurricular Activities from Biology Teachers

After completing the curricula analysis, the biology teachers discussed about interdisciplinary and extracurricular activities that can be suitable for food fermentation practical studies. Table 105 shows the listed subject areas and topics to which practical studies of food fermentation can be applied.

Table 105

Interdisciplinary Ideas of High School Teachers for Practical Work on Food Fermentation

Group 4 Project	
Mathematic	Correlation
Chemistry	Molarity counting
Language	Names in different languages
Physics	Gas pressure
Biology	DNA sequencing
Economy	Contribution to the home economy
History	Application methods from past to present and differences between regions

The Group 4 project is an interdisciplinary project of the IBDP programme, defined by the IB organization as:

> The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the processes involved in, rather than the products of, such an activity. (IBO, 2014a, p. 161)

Seven different subject areas were identified by the participating teachers and the topics on which the practical study of food fermentation can be applied for each subject are listed in Table 105.

Middle School Teachers' Curricula Study

The seven middle school science teachers who participated in the study worked on the MoNE science curriculum in two separate groups of 3 and 4 teachers. They separately listed the subjects and learning outcomes of the MoNE science curriculum that they found related to the practical study of food fermentation. The learning outcomes listed separately by the two groups were combined by the researcher and shown in the tables below.

Table 106 shows the listed units of the MoNE science curriculum related to food fermentation practical work deduced by participant teachers.

Table 106

The Related Units of MoNE Science Curriculum with Food Fermentation Practical Work

F.5.2. World of living things
F.6.6. Human body systems and its health
F.7.2. Cell and divisions
F.7.6. Reproduction, growth, and development in living things
F.8.2. DNA and genetic code
F.8.4. Matter and industry
F.8.6. Energy transformations and environmental science

As seen in Table 106, seven units of the MoNE science curriculum were found to be related to the practical study of food fermentation by the participating teachers.

Interdisciplinary and Extracurricular Activities from Science Teachers

After completing the curriculum analysis, science teachers discussed in their groups about interdisciplinary and extracurricular activities and listed ideas that might be relevant to practical work of food fermentation.

Table 107 shows the scientific skills that practical studies of food fermentation are thought to contribute to a science applications course.

Table 107

Interdisciplinary Ideas of Middle School Teachers for Practical Work on Food Fermentation

Science Applications Course	
Scientific skills	Graphic literacy
	Observation skills
	Reporting
	Data analysis

In Turkish national education system, science applications course is an elective middle school subject that applied in many public schools. According to MoNE Science applications course curriculum (2018c), science applications course is a curriculum that aims students to understand the nature of science and gain scientific process skills and life skills. It has been determined by participating science teachers that four different scientific skills listed in Table 107 can be improved more by conducting applied studies on food fermentation in science applications courses.

Conclusion

The number of units containing the learning outcomes in which food fermentation practical work can be incorporated was determined by adding up according to the curriculum analysis of the participating teachers. Table 108 compares the number and percentage of units that can be integrable for each curriculum based on the analysis of the curriculum study.

Table 108

Teachers' Curriculum Study Analysis

Analyzed Curricula	Number of Units	Number of Units can be Incorporated	%
IBDP Biology	15	7	47
IGCSE Biology	21	9	43
MoNE Biology	12	8	67
MoNE Science	28	7	25

As seen in Table 108, the teachers analyzed that food fermentation practical work could be integrated into 47% of the IBDP biology curriculum units and 43% of the IGCSE biology curriculum units. Besides, practical work of food fermentation can be incorporated more than two thirds of the units in MoNE biology curriculum (67%) which is higher than the other two biology curricula according to the teachers' curriculum analysis. The lowest incorporation percentage could be seen in the MoNE science curriculum with 25%, in all curricula. Overall, the proportion of integrable units that all biology curricula average is 52%, which is nearly double than the science curriculum percentage (25%).

Teachers' Perceptions on Food Fermentation Practical Work

The second research question was answered by analyzing semi-structured interviews of participant teachers. The semi-structured interview tool was used for gathering data (Appendix A). In the first part of the interview, the teachers answered 11 demographic questions and background information obtained from the participants is given in Table 2. In the second part of the interview 17 questions were asked to the participants and all interviews were recorded and transcribed. Participant teachers were numbered from one to twelve according to their interview order. The main findings of the semi-structured interviews are presented in three sections as follows.

First six questions were asked to grasp the effects of resources on teachers' perceptions to practical work implementation. Then, seven questions were asked to determine teachers' perceptions towards teaching the subject of fermentation. The last four questions were asked to understand the teachers' interest in food fermentation studies that can be applied outside of the classroom.

The Effects of Resources on Teachers' Perceptions to Implement Practical Work

All questions were analyzed according to teachers' responses to detect the effects of resources on teachers' perceptions to implement practical work in their classes.

Resources were evaluated under four subtopics which are available equipment for food fermentation practical work, promoting practical work by the school administration, allowed time in curriculum for practical work, organizing in-service training on practical work and availability of ready-made materials.

Available Equipment for Food Fermentation Practical Work

The majority of the teachers (n=9) stated that their schools' equipment are adequate for food fermentation practical studies. T1 stated:

> There are tools and equipment required for this practical work in my school. When needed, it can be purchased, and a budget can be allocated. Most of the materials we needed are already easily accessible from the market, I do not think that it will create a problem at the point of supply.

Also, a science teacher referred the *Design-Skill Workshops* which are constructing in the primary and secondary state schools with the project of Ministry of Education. In this context, T3 mentioned that "We are in the process of opening a kitchen workshop in our school, maybe we will have more favorable conditions for these studies”.

In line with the 2023 Education Vision, Design-Skill Workshops were evaluated with a focus on 21st century skills, higher education, science, art, culture, sports and life skills. Within the scope of this project, 11 workshop models were projected and one of them is the Life skills workshop. Food fermentation practical studies can be integrated among the activities that can be done in Life skills workshop. On the other side, three teachers who are working in the same school specified that their school does not have suitable laboratory to use. T6 explained “We do not have an available laboratory, for example, we do not have sinks. So, I do not find it hygienically appropriate. Otherwise, I think all kinds of materials can be provided”.

These teachers (T6, T10, and T12) enunciated that they would not do any practical work because of lack of laboratory. Nevertheless, all teachers said that materials needed for food fermentation practical work, can be easily accessible. The teachers who have the appropriate conditions in terms of resources, were more willing to apply food fermentation practical work in their classes.

Promoting Practical Work by the School Administration

All teachers stated that the school administration's encouragement and emphasis to practical work would affect them positively. Also, many of them said that this would increase the practical work implementation in their classes. T6 said that “It will motivate, some of our current problem stems from it already. At the moment, our laboratory is not given much importance to the school administration, I think this situation reduces us a little in terms of laboratory”.

Some of the curricula based on practical work so it is reflected to the school administrations' attitudes. For example, T2 stated that "The IBMYP B criterion says, design experiment, for this reason the school admins lean towards about it". School administrations' support affects teachers positively and increase their practical work implementation frequency in general according to the results.

On the other hand, eight teachers out of twelve mentioned that their physical conditions in their workplace such as daily working hours intensity and adequacy of the course intervals, are suitable for them to apply food fermentation practical studies. The general approach of the teachers who have suitable conditions was that we can create time, and do it if we want. T6 stated "A situation that changes every year is actually our lesson intensity. Time can be created depending on the number of lesson hours and the number of hours of teachers". Also, T5 mentioned that:

> Since we are a very crowded school, we may have some difficulties in this regard, because we are very crowded. We are not suitable as a place; we have a limited amount of space in the laboratory. But whenever we want, we can do it anywhere, just that can push us a little bit.

Four teachers stated their physical conditions in their workplace are not suitable to apply food fermentation practical studies. The reasons were overloaded weekly schedule with 36 hours (T7), crowded class sizes and students who not accustomed to practical work (T10), and scholar academic approach of the school is an obstacle to practical work because practical work takes time (T11). Also, T2 mentioned that "We do not have much time for lab preparation or post-lab cleaning, once a lesson is over, the next lesson starts in the same place. So, this is what will challenge us the most".

The results show that physical conditions have an impact on teachers' perceptions about the application of practical work in their classrooms. The physical conditions of the teachers can be improved by school admins attitude towards the need for and importance of practical work.

Allowed Time in Curriculum for Practical Work

Most teachers' comments (n=7) on the adequacy of the time allotted for practical work in the curriculum they followed were negative. Three biology teachers out of five did not find the allocated time adequate for practical work. One of them, T7 stated that:

> It is very insufficient lesson time for MoNE biology curriculum because we have 2 lessons per week in 9th and 10th grades. We have 4 hours of lessons per week in 11th and 12th grades and we have very intensive curriculum. The time allocated to the MoNE biology curriculum is too insufficient to implement practical work, which means that if I am doing an experiment, I will follow this schedule from behind. More reasonable hours for the IBDP curriculum, but an extra 2 hours of lesson a week could have been better.

Two biology teachers following the international curricula find the allocated time for biology curriculum adequate to carry out practical work. T1 stated:

> It is quite sufficient within the IGCSE and IB curricula because it is completely left to us. In other words, even if it is told us the time, we can do a lot of manipulation in our program. At the point of allocated time, our curriculum gives a great opportunity to implement practical work.

Four science teachers out of seven think that the time allocated for science lessons is not sufficient for implementing practical work. One of them, T6 stated that:

> Our time is absolutely not enough, so after we have covered our MoNE science curriculum, there is no time for us to do any laboratory work. In fact, I always say that I wish we had an extra time such as 2 hours for laboratory lessons.

On the other hand, practical work is an essential component of IBMYP science curriculum. However, sometimes lack of resources affects the implementation of practical studies, even if the time allocated is appropriate. In this context, T2 stated:

> We have four criteria in IBMYP science curriculum, two of them are the B and C criteria, which guides us to the laboratory. We have to do B and C criteria at least 2 times a year. The distribution of this happens with the common decision of the teachers who attend those classes, so there may be conflicts. In other words, we are experiencing laboratory limitation rather than time restrictions.

The results show that international curricula (IGCSE, IBDP and IBMYP) have sufficient time for practical work and even the implementation of practical work is an essential part of these curricula. However, the time allocated for the MoNE science and biology curriculum was not found sufficient for the implementation of practical studies by teachers.

In-service Training on Practical Work and Availability of Ready-made Materials

The perceptions of all teachers are positive in providing vocational training to increase their effectiveness in practical work. For example, T3 stated the difficulties of science faculty graduate teachers rather than education faculty in applying practical work on three branches of science (physics, chemistry, and biology) as follows:

> Extra trainings should be given because there are teachers who graduate from the faculty of science. For example, I am a graduate of chemistry, and I took physics lab course during my studentship. So, it was with my own effort to train myself in the field of biology, more precisely, with the extra training I joined. On the other hand, I ran after my colleague -biology teacher, I learned to use a microscope from him.

Additionally, T11 noted the difficulties in accessing information about the application and the importance of training:

> Very nice effects, I recently participated a STEAM training from a very good teacher. I have been researching the STEAM for about a year and a half, I have read a few books, but I did not find reasonable application of it. Also, there is no video about it on YouTube or any other source, which is our biggest problem. I had great problems and difficulties with the rubrics. So, I wanted to learn this job deeply and do it properly. Finally, after the STEAM workshop, I hardly reached real knowledge and implementation.

T7 stated the importance of vocational training in finding new ideas for international curriculum projects:

> It affects positively because every conference or every workshop means an idea. We can use this in both IB and IGCSE to directly find internal assessment ideas. Sometimes, students have difficulties to find an idea for their projects, I have to support them where the student is stuck. If there are conferences, seminars, workshops that feed the teacher with such things; this would be a great chance for the teacher.

The results show that organizing vocational training on practical work will fulfil the needs of teachers about implementing practical studies in their classes, help teachers to generate new ideas for projects and involve students to the lessons with up-to-date activities.

On the other hand, all teachers stated that they would be positively affected by the presence of ready-made materials for practical work. T6 mentioned that “It speeds up the work, you progress more programmatically and reduces the chance of making mistakes. I think that having directives all the time is a force that pushes us to work”. Also, T2 stated:

> Having ready-made materials facilitates the process. Many years ago, when the curriculum changed in 2007, teacher guides were published, and we were very happy. In the initial phase, giving ready materials as a warming process can really make the application easier. It may be easier to put this into action if there is a ready worksheet. But of course, this should be limited, because this time productivity and creativity will begin to die when working with ready-made materials.

The ready-made materials and guidelines are supportive resources for teachers and the results show that it has a positive effect on teachers’ perceptions in terms of increasing practical work in classes. The framework which will be developed as a result of this research, is aimed to assist teachers as an implementation guide while the integration of practical work of food fermentation into the curriculum.

After all, resources have an impact on teachers’ perception about the implementation of practical work, which can be summarized as the appropriate laboratory setting, the time allocated in the curriculum, the approach of schools to practical work, the appropriate timetable for the preparation of practical work, the class sizes, vocational training for many purposes and the availability of ready-made materials especially as a starter.

Teachers' Perceptions towards Teaching the Subject of Fermentation

In this section of semi-structured interviews, teachers' perceptions about the contribution of food fermentation practical work to learning were examined and the results were interpreted. The perceptions of teachers were evaluated under five subtopics which are contribution of practical work to learning and teaching fermentation topic through practical work, contribution of practical studies associated with daily life to learning, challenges of learning fermentation topic, misconceptions about fermentation topic, and other contributions of food fermentation practical work to students.

Contribution of Practical Work to Learning and Teaching Fermentation Topic

All teachers shared positive thoughts and experiences about the contribution of practical work on understanding the topics. For example, T2 emphasized Albert Einstein's "Education is what remains after one has forgotten everything he learned in school" quote and T3 reminded Confucius's "I hear, I know. I see, I remember. I do, I understand" quote for express the importance of practical work on learning. Also, T4 said that 90% of learning occurs through with what we do. On the other hand, three teachers who are positively prone to practical work mentioned about some challenges on application of practical work in their classes. T5 stated lack of resources thus:

> We would like to have suitable conditions, large laboratories, take our classes to the lab and let everything be done there more efficiently. Because, science is really better understood by doing experiment, but it does not work when

> the conditions are not suitable. Indeed, learning by seeing and living is more permanent in the minds of children.

The practical work should be adjusted according to the needs and interests of the generations. T7 stated this issue as follows “Especially in this generation, they want to take practice-oriented lessons and you have to renew the practical studies constantly. Something very interesting for me can be very ordinary for them. Applications directly creates learning, as make learning more permanent”.

Moreover, T11 stated the difficulties in the implementation of practical work due to the lack of time as follows:

> I definitely think it is very effective, when the child conducts an experiment about that topic, when he holds a material, he listens to the lesson more actively and willingly comes to the lesson. Also, the biology lesson is very prone to the laboratory, especially our biggest fight with children is that why we do not go to the laboratory too much. Because, we cannot finish the topic on time, so we do not go to the lab. Otherwise, it is a very, very active way of learning. I wish we could go to laboratory every week.

The results show that practical work has a great contribution to learning with makes learning more permanent, increase the level of understanding the subject and enthusiasm of the students to the lesson. Even if teachers and students want to apply practical work in their classes, sometimes the conditions are an obstacle to the implementation of practical work that teachers mentioned as the most effective way of learning.

On the other hand, all teachers said that students' knowledge about fermentation was more permanent if they learned the topic through practical work. They mentioned that practical work will help the student to commit this abstract subject in their memory and that these experiences will be permanent for a lifetime. T1 noted that these practical studies are cost-efficient and easy to apply so this opportunity should be used by all teachers. Also, T6 said that practical work of food fermentation is very valuable as it has a sociological dimension and affects students' lifestyles in terms of healthy life. Eventually, teachers' thoughts and experiences confirmed that teaching fermentation topic by applying practical work is more effective teaching strategy.

Contribution of Practical Studies Associated with Daily Life to Learning

All teachers commented positively on the contribution of practical work related with daily life to learning in many ways. They stated daily life related studies prepare students for life, strengthen the knowledge by repetition at daily life and make the knowledge more permanent. Moreover, T1 mentioned:

> The students leave aside the understanding of we did to this for perfunctory. The practical studies related with daily life are excited the students, increase their love for biology, and affects their interest in the course…it can give an opportunity to discover the profession they are interested in…

As a consequence, students' attitudes towards learning can be changed using daily life related practical work, and they understand why they learned this information and how they can use it in real life. Students' curiosity and interest in practical work associated with daily life support them academically and socially in their lives. Food fermentation practical studies are one of the good examples of daily life that can be applied in classes very easily and effectively by establishing strong and varied connections with daily life.

Challenges of Learning Fermentation Topic

Seven teachers mentioned fermentation topic has some challenges in terms of students' learning. Three teachers out of seven were biology teachers and four of them were science teachers. On the other hand, five teachers stated that they did not find the fermentation topic difficult for students to learn. Two teachers out of five were biology teachers and three of them were science teachers. In general half of the teachers stated the biggest difficulty is that the subject is abstract. T9 mentioned that "The most difficult part is that students cannot visualize these things in their eyes, because events occur at the molecular level".

As noted by teachers, anaerobic respiration is an abstract subject and hard to imagine the process for students. In the following section discussed the many misconceptions about this abstract topic that cause further difficulties in the teaching and learning process. Food fermentation practical work supports learning by visualizing the process with various indicators such as CO_2 output, pH change and culture growth (microorganisms).

Furthermore, most of the teachers stated that the students remember the subject more easily when they give examples from daily life. Apart from this, the students have challenges to remember the end products of fermentation. In addition, some teachers noted that fermentation remained among the difficult topics and encountered with the student barrier. T6 mentioned "First, we teach photosynthesis, then we move on to aerobic respiration, and finally, when it comes to fermentation, I feel that the students are broken there, and the subject is not very permanent".

According to the teachers' responses, the students face with some difficulties in remembering the fermentation topic when the topic was only taught by lecturing. The students' level of recall the topic can be improved by using food fermentation studies and doing experiment may increase the students' enthusiasm to fermentation after difficult topics.

Misconceptions about Fermentation Topic

The main and common misconception emphasized by most of the teachers is the classification of bacteria and yeast. In general, students have problem about classifying the microorganisms as prokaryotes and eukaryotes. Also, a science teacher, T2 stated:

> Since even the mushroom in their heads remains in the category of plants, it can be very challenging to pull them out of there. Is mushroom a vegetable or a fruit? Very few students answered that mushrooms are neither vegetables nor plants. Because even in life, we see mushrooms in the market next to vegetables and fruits. Therefore, at the point of learning, some concepts in classifying living things are problematic. On the other hand, their microscopic living things knowledge is very limited, microorganisms are generally harmful according to them. When I say that there is a beneficial microorganism in our body, the student says that do the bacteria cause disease.

Some teachers stated students mixed lactic acid fermentation and ethanol fermentation. Also, they mentioned that students have difficulties to determine which fermentation process (lactic acid or ethanol) is performed by which microorganisms (bacteria or yeast). A science teacher (T8) expressed those students think water is the end product of fermentation because of water is the end product of aerobic respiration. A biology teacher (T11) stated students confused about the yield of ATP in fermentation which only occurs during glycolysis, and they forget carbon dioxide production. On the other side, T1 mentioned the misuse of the word equivalent to fermentation known as “mayalanma” in Turkish. Because, the word “mayalanma” means fermentation with yeast but it is used for all fermentation types such as during yogurt making. All misconceptions about fermentation topic can be eliminated by using food fermentation practical work in classes.

Other Contributions of Food Fermentation Practical Work to Students

Food fermentation practical work not only contributes scientifically to students but also their personal development. Most teachers emphasized the contribution of these studies to health and consciousness of healthy nutrition. They also stated that practical work of food fermentation increases the socialization, communion, and communication skills of the students. The students share this knowledge and their fermentation cultures (microorganisms) with their friends, families and perhaps in the future with their colleagues. Therefore, they can interact with many people through these studies. On the other hand, when working on food fermentation, the development of students’ manipulative skills and increased self-confidence are among the most mentioned contributions. Moreover, the teachers stated that these studies develop the sense of responsibility of the students who tend to the microorganisms. Some teachers pointed out the importance of producing a product and emphasized the pleasure of students would get from their own production. Lastly, some other contributions of food fermentation studies specified by several teachers are as follows; it contributes to creativity, informs students about an area of profession, and creates awareness about the domestic economy.

After all, teachers’ perceptions about the contribution of food fermentation practical work to learning are very positive. All teachers stated that they prefer to teach fermentation topic with practical work. They also mentioned these studies contribute to the challenges of fermentation topic, misconceptions about fermentation topic, and the students' level of recall the topic.

Teachers' Perceptions towards Food Fermentation Studies as an Extracurricular Activity

In the last section of the semi-structured interview, teachers' perceptions towards application of food fermentation practical work as an extracurricular activity was investigated and reported. The thoughts of teachers about the extra-curricular application of food fermentation practical work were evaluated under four subtopics which are suitability of food fermentation practical work to extracurricular activities, suitability of food fermentation practical work to interdisciplinary projects, teachers' intention to fermentation club, and teachers' interest to food fermentation as a hobby.

Suitability of Food Fermentation Practical Work to Extracurricular Activities

All teachers said that the practical work of food fermentation is very suitable for extracurricular activities. They put forward different application areas which they can integrate these studies in their own schools such as science festival, TÜBİTAK science fair, school bazaar, end of school activities, fermented product sales for charity events, projects, term paper projects, internal assessment projects for IBDP students, international cuisine club, science club. T2 stated:

> I think it might even be a great club activity such as a healthy life club or fermented products club. At the middle school level, we have a tremendous range of work in club activities and there is no time limit.

All processes of food fermentation practical work (from culture to the end product) can be an activity that can be fully implemented in different extracurricular activities without time limits of curricula.

Suitability of Food Fermentation Practical Work to Interdisciplinary Projects

The practical work of food fermentation can be applied in joint projects of different subject areas and the suitability of these studies for interdisciplinary projects has been approved by teachers. They stated that interdisciplinary projects could be done with subject areas such as physics, chemistry, mathematics, history, social studies, philosophy, geography, technology design, religious studies, and languages. T3 shared some implementation experiences and ideas as follows:

> … At the beginning of the year social studies teachers prepared yogurt and pickles with 5th graders as part of the Traditions unit. For example, if I made a sourdough bread in science lesson that day and I was unable to cook it because of time is end, visual art teachers can continue with bread models or bread shaping in the next lesson. Because we do not establish a connection among subjects, students cannot link what they see in a lesson to another lesson, which is a problem.

Food fermentation studies have a wide range to allow teachers to do interdisciplinary projects with different branches. It can be used to associate different fields with each other.

Teachers' Intention to Fermentation Club

Most of the teachers stated that they would like to set up or join a food fermentation club. One of them said that they can integrate these activities underneath science club. Some shared their concerns about the approval of administer to club work and lack of club hours. But if their conditions are appropriate, all teachers were willing to do so.

Teachers' Interest to Food Fermentation as a Hobby

The teachers showed great interest in food fermentation practical work, and many began to adapt it to their lives. Some have said that they have already shared their knowledge and cultures with their social environment and will continue food fermentation. The two of them said they wanted to start but could not because of timelessness, because these activities need continuity. One teacher said that she is not capable of such activities and does not have much interest in it.

In general, teachers have positive perceptions towards the application of food fermentation practical studies apart from the curriculum. They supported the implementation of these studies for extracurricular activities, interdisciplinary projects, and club activities. Some have integrated food fermentation into their lives as a hobby for it is health contribution and other reasons.

Conclusion

This chapter presented the results of the curricula content analysis, curriculum study of the teachers in the workshop and the interviews with the workshop participant teachers. It can be concluded that the data gathered in this study able to answer the two research questions and their sub-questions. The findings of the study analyzed in this section enable comparisons and discussions in the following chapter 5.

CHAPTER 5: DISCUSSION

Introduction

This chapter discusses the findings of the study accompanied by a literature review. It includes overview of the study, discussion of major findings, implications for practice, and implications for further research sections.

Overview of the Study

This study aimed to develop an integration framework to promote the application of food fermentation practical work in classes. For this purpose, a food fermentation workshop was organized for the teachers participating in this study. The participants of the study are twelve female teachers. The workshop included the following three parts: theoretical knowledge about food fermentation practical work, application of three different ways of food fermentation, and curriculum integration study conducted by participating teachers.

The first research question, how food fermentation practical work can be incorporated into IBDP, IGCSE, MoNE biology, and MoNE science curricula, included data from the researcher's curricula content analysis and participant teachers' curricula integration study in the workshop. Teachers' curriculum study was used to triangulate the researcher's curricula content analysis. IBDP, IGCSE, MoNE biology, and MoNE science curricula were analyzed to find out in which learning outcomes of the units the practical work of food fermentation could be incorporated. The codes were deduced from the related learning outcomes to create the themes for developing an integration framework. Moreover, the researcher offered how the practical work of food fermentation could be used for related learning outcomes of the units as a component of the developed framework.

The second research question, how do teachers perceive application of food fermentation practical work in classes, included data from interviews with participating teachers to find out which resources encourage and prepare teachers to apply food fermentation practical work, teacher's opinions on practical work in teaching fermentation topics, and the integration of food fermentation practical work into science curricula and interdisciplinary projects. Teachers' perceptions of the application of food fermentation provided insight and evidence for integration to promote food fermentation studies.

These two main components of the study, *incorporation of food fermentation practical work into curricula* and *teachers' perception on application of food fermentation practical work in classes,* are discussed for integration to promote application of food fermentation practical work in classes.

Discussion of Major Findings

In this section, the major findings of the study discussed in the light of the literature to answer each research question. The headings and the sub-headings correspond to the research questions, respectively.

Incorporation of Food Fermentation Practical Work into Curricula

This study used two different strategies to identify opportunities to integrate food fermentation concepts and practices into subject area curriculum. The first was a content analysis of the curriculum conducted by the researcher and the second was curriculum integration study conducted by teachers at the end of the workshop. Both strategies involved scanning the learning outcomes of the curricula and listing suitable units for the implementation of food fermentation practical work. Table 46 and Table 108 show the percentages in which units of each curriculum the practical work of food fermentation can be integrated, analyzed by the researcher and participants, respectively.

The percentages of integrable units of all curricula in the researcher's curriculum integration analysis were approximately 15% higher than in the teachers' curriculum study analysis. These findings are consistent with each other and shows positive correlation for each curriculum. The researcher's expertise on topic and the fact that the time devoted to content analysis is much higher than the time allocated to the curriculum study at the end of the workshop explains the difference between the integration rates. In addition, the teachers did not have the chance to apply these studies or do research about the topic before the curriculum study in the workshop. Considering all of these variables, the fact that the curriculum integration rates are consistent with each other and show a difference of only 15% indicates the reliability of the analysis results. The study revealed that the MoNE biology curriculum, with an integration rate of 75%, is more suitable for the implementation of practical work of food fermentation. This is followed by the IBDP biology curriculum with 67%, and the IGCSE biology curriculum with 62%. Lastly, it has been determined that food fermentation practical studies can be integrated into 36% of the MoNE science curriculum. The reason for the lower integration rate here is due to the limited scope and content of middle school curriculum. These integration rates reflect only written curriculum analysis; it is discussed to what extent the implemented program overlaps with these rates below the second sub-heading.

Along with the content analysis of IBDP, IGCSE and MoNE biology curricula, themes were created for biology teachers to integrate food fermentation practical work into possible units. These themes are *Living things,* the global theme, and the four organizing themes, *Biotechnology, Ecology, Biochemistry,* and *Health*.

Therewithal, as a result of the content analysis of the MoNE science curriculum, the themes for the integration of food fermentation practical work into the curriculum were determined for science teachers. The global theme is *Living things,* as in biology, and the four organizing themes are *Environment, Chemistry, Health* and *Experimental design*.

The results of the content analysis of biology and science curricula revealed that food fermentation practical studies can be used in any topic related to *Living things* which is also common and global theme for both educational levels. Food fermentation microbial cultures contain many specimens of different kingdoms and provide all the characteristics of living things. In this framework, they make great examples for all issues related to vitality and can be easily integrated into topics.

The findings suggest that *Health* is another related common organizing theme for both educational levels. It is opened to linking with studies of food fermentation due to its diverse effects on health.

Since food fermentation is a chemical process, many involve chemical changes and *Chemistry* in general another organizing theme for science curriculum. In biology, it can be categorized under *Biochemistry* theme so as its detailed and rich content.

Same as *Biotechnology* is found the other organizing theme for biology with connections to industrial production, pathway and genetic engineering but it is determined as *Experimental design* for science with the limited content of the curriculum. Food fermentation practical work are versatile studies that allow students to easily manipulate various variables and design experiments with products that are safe to touch, smell, and eat. The findings suggest that practical work of food fermentation can be incorporated into any topics related with biochemistry in biology curricula and experimental design topics in science curriculum.

The other and last organizing theme was found *Ecology* for the biology curricula and *Environment* for the science curriculum, given the interactions of microbial cultures of food fermentation with their environment. It has been found that topics related with ecology in biology and environment in science are open to the integration of applied studies of food fermentation.

Finally, the researcher determined how to use the applied study of food fermentation for the related learning outcomes of each unit by using the coding system 1 to 5. This provided a ready-made instruction manual to encourage teachers to easily integrate the practical work of food fermentation into the curriculum. Also, the how to use manual provides ideas for curriculum and program developers to further integrate the practical work of food fermentation with minor modifications.

Teachers' Perception on Application of Food Fermentation Practical Work in Classes

In this study, teachers' perception about food fermentation practical work, gathered through semi-structured interviews after the workshop, provided clarification of different factors to promote the implementation of these practical studies. Their perceptions are divided into three factors based on the research questions.

Resources to Encourage and Prepare Teachers to Apply Food Fermentation Practical Work

The first factor is *effect of resources* to encourage and prepare teachers for the application of food fermentation practical work in their classrooms. One of the important aspects of food fermentation practical work is that materials needed for these studies can be easily affordable and accessible which was also supported by all participating teachers. According to Lyles and Oli (2020), fermentation practical studies are applicable in many levels of education due to its adaptability, easy implementation, minimum and accessible equipment requirement. This allows teachers and students to apply these studies more in the classrooms and even at home during distance learning. However, although these studies do not require expensive and difficult-to-obtain materials, laboratory or home conditions with water and sink are required to ensure hygienic conditions and cleanliness. The teachers (T6, T10, and T12) who do not have an available laboratory for their use in their schools stated that they would not apply practical work of food fermentation due to the unsuitable hygienic conditions although all the other materials needed were suitable. In the light of this information, it is found that the teachers who have appropriate conditions and resources are more willing to implement practical work of food fermentation in their classrooms.

The effect of school administration's support for practical work on teachers' willingness and frequency of practice was investigated. The study revealed that when experiments are a compulsory component of the curriculum, school administrations also give more support to practical work to fulfill the program and curriculum obligations. As stated above the teachers (T6, T10, and T12) who do not have an available laboratory were following MoNE science curriculum the does not require any compulsory practical work to complete the program even it is in the written curriculum. On the other hand, T2 who is following IBMYP science curriculum mentioned that as the designing experiment (Criteria B) is the compulsory component of the IBMYP curriculum to complete the program successfully, school admins support the practical work quite a lot for the success of the following curriculum.

Moreover, participating teachers (T2, T7, T10, and T12) stated that their physical conditions at their school are not proper to apply food fermentation practical work because of overloaded weekly schedules, crowded class sizes, scholar academic approach of schools and not having preparation and cleaning time before and after lab classes for teachers. In another study, Ghartey-Ampiah et al. (2004) found that the reason why teachers do not allowed students to design their own experiments is the limited time allocated for the curriculum followed, the overloaded content of the curriculum, crowded class sizes, lack of equipment, and the absence of these type of questions in the national science practical examination. It shows that if practical work is required as a condition to complete an education program, school administrators will be more effective in providing teachers with proper physical conditions such as appropriate laboratories, schedules and encouraging practical work. This would help and promote the application of food fermentation in classes.

According to content analysis of the study, even MoNE biology curriculum has the highest integration rate with 75%, teachers mentioned that the curriculum is overloaded and time allocation for the subject to do practical is not possible. Despite the lower integration rates of IBDP and IGCSE biology curricula with 67% and 62% respectively, teachers emphasized that their programs are open to manipulation and the international curricula provide time for practical study. The IBMYP science curriculum were not analyzed in the content analysis because of it is a framework-based curriculum and does not include any learning outcomes. Most of the schools in Turkey who are following the IBMYP curriculum are considering the learning outcomes of the national curriculum (MoNE science curriculum), which is integration rate for the food fermentation practical studies is found 36%. But, the reflection from four science teachers who are following MoNE science curriculum is that the provided time for MoNE science curriculum does not give an opportunity them to do any practical work. On the other side, the teacher who is following the IBMYP curriculum by considering the same learning outcomes stated that they have no limitations in terms of time as the practical work is an essential component of IBMYP curriculum and the time allocated for the curriculum is appropriate. Also, T6, the MoNE science teacher and T7, MoNE biology teacher, expressed they wish to have an extra 2 hours of lessons a week in order to provide the opportunity for application of practical work in their classes. This shows that the analysis of the written curriculum is not matched with the physical conditions provided to teachers in real life and can be improved by the curriculum developers and education leaders of national curricula. Making practical work as a compulsory component of the MoNE curricula by including practical work questions in national exams may be the solution. These changes allow and help promotion of food fermentation practical work in classes.

All participants responded positively about the importance and effectiveness of in-service trainings and ready-made materials in promoting practical work. Food fermentation workshop organized at the beginning of the study aims to give ideas and improve teachers' practical skills on implementation of food fermentation studies. Moreover, the framework that is developed in this study provides teachers a guide how to implement food fermentation practical work in their lessons and the following curriculum. According to Shim et al. (2014), teachers have the greatest influence on students' science learning, training programs should be provided to increase teachers' positive attitudes and facilitate practical work for student engagement.

Teachers' Opinions about Use of Practical Work while Teaching Fermentation Topics

The second factor investigated in this study is that teachers' opinions for the application of food fermentation practical work in their classrooms while teaching fermentation topics. Teachers' perceptions about covering science topics with practical work and especially for fermentation topic were positive. All of them emphasized that it is the most effective way of learning and makes the learning more permanent. In another study, teachers' opinions about practical work is found important and essential for understanding biology concepts and they stated biology cannot be taught effectively without practical work (Danmole, 2012).

Another important aspect of food fermentation practical work is that it is a daily life example. The consumption of fermented foods is greater than expected and is increasing day by day. According to a research, the value of the global fermented food and ingredients market is estimated to grow from 24 billion U.S. dollars in 2018 to over 35.5 billion U.S. dollars by 2023 (Wunsch, 2020). Some very well-known examples of fermented foods and beverages are cheese, yogurt, pickles, kefir, wine, beer, soy sauce, sourdough bread, etc. Those and many other examples can be used to connect fermentation topic with daily life and industry. All the teachers stated that the practical studies related to daily life increase the curiosity and interest of students, prepare students for life, give opportunity to apply in daily life to enhance learning and these experiences makes the knowledge more permanent. Also, other researchers claimed that students engage with school science if it is connected with daily life (Osborne & Collins, 2001).

Half of the participants expressed that the biggest challenge in learning fermentation is, it is an abstract topic. Etobro and Fabinu (2017) found that abstractness, complexity, misconceptions, lack of instructional materials and practical classes, poor attitude of teachers to teaching, and students poor study habits are the reasons why students perceive the biology topics as difficult. Other than this, Çimer (2012) also found that the first reason why some biology topics are stated as difficult by students is concepts that including Latin words and the abstractness of the topics based on memorization. These can be easily visualized by the implementation of food fermentation practical studies. Yip (2000) suggested that the practical work of winemaking, which is an alcohol fermentation, would increase students' motivation and understanding of the biochemical process involved. In addition, most of the teachers underlined that the students' level of recall of fermentation topic can be increased by implementing practical work on food fermentation. Moreover, students suggested that using appropriate materials and instructional strategies such as hands-on and minds-on activities and integrating daily life into biology concepts could be the solution to coping with the learning difficulties they encountered (Etobro & Fabinu, 2017).

Another challenge about fermentation topic is misconceptions and the first misconception highlighted by teachers is the classification of microorganisms. Also, T2 said that students generally think that microorganisms are harmful and disease-causing. The literature also suggests that this belief reinforced with Covid-19 pandemic and will cause more obstacles while covering these topics (Simard, 2021). In contrary to this, Aydın (2015) found that students are positive and knowledgeable about microorganism. Due to the results of the study, 69% of the students mentioned microorganism can be both harmful and beneficial, but still there 31% of the participants who stated different ideas (Aydın, 2015). Practical work of food fermentation is very beneficial studies that can be used to overcome all these misconceptions and the extra challenges brought by Covid-19.

Apart from the academic contributions of the practical study of food fermentation, it also has many contributions to the personal development of students. The first and one of the most important benefit of fermented foods are their contributions to human health. There are many studies on health benefits of probiotic foods especially on type 2 diabetes and obesity (Ejtahed, 2012; Kim et al., 2011; Kwon et al., 2010; Parvez et al., 2006; Piemonte, 2019). In addition, preparing foods for fermentation improves students' manipulative skills; these preparations include kneading sourdough bread, chopping vegetables or measuring other ingredients. In the literature, Ghartey-Ampiah et al. (2004) and Sani (2014) found that teachers' purpose of implementing practical work in their classes is to develop students' understanding of theoretical knowledge and laboratory skills such as manipulative skills. On the other hand, sharing microbial cultures, recipes and fermentation knowledge with friends and other people develop communication, communion and socialization skills of students. One of the other contributions of these studies indicated by teachers is that taking care of microbial cultures increase sense of responsibility of students. Moreover, producing their own product may give them pleasure and self-confidence. Toplis (2011) determined that the importance of practical work in science lessons according to the students are listed as follows; interest and activity for students' participation, trust and autonomy, different types of teaching media, and visualizing the scientific concepts to help comprehension, memorization, and recall. When the findings of the Toplis's study (2011) are compared with the perceptions of teachers in this study, it can be said that the characteristics of the practical work of food fermentation can meet the expectations of the students from the practical work. Lastly, these studies enhance creativity and give ideas about the domestic economy. The conclusions can be drawn that the practical study of food fermentation should be promoted because of its numerous contributions to students' personal development besides its academic contributions.

Incorporation of Food Fermentation Practical Work into Extracurricular Activities

The third factor investigated in this study is that teachers' perceptions towards application of food fermentation practical work as an extracurricular activity. All the teachers mentioned that food fermentation practical study is suitable for extracurricular activities to do as a whole process from culturing to end-product, without the time limit of the curriculum. Some of the extracurricular activities which teachers expressed are science festivals and fairs, end of school activities, fermented product sales for charity events, school bazaar, term paper projects, different club activities, TÜBİTAK science fair and IBDP internal assessment projects. Besides, participating teachers stated that these studies can be applied as interdisciplinary projects with subject areas such as social studies, geography, technology design, religious studies, modern languages, history, mathematics, and other fields of science. T3 underlined these interdisciplinary projects can help students to establish connection among subject which is important for learning. According to Jones (2009), although interdisciplinary approach has some disadvantages such as required time and teamwork; it allows the development of many skills such as critical thinking, communication, creativity, pedagogy, and essential academia for student's future learning.

Moreover, teachers' intention to form or join a fermentation club and an interest in food fermentation as a hobby are some of the ways in which they can increase their motivation, improve their practical skills, and increase their knowledge of the subject under investigation. Such extracurricular activities contribute to the promotion of practical studies of food fermentation.

Implications for Practice

The findings from this study have implications for science teachers, curriculum developers, administrators, and other stakeholders. This study offers an integration framework especially for teachers and all stakeholders to promote its application in classes. The integration framework (see Table 109) includes ideas for integration by providing themes for biology and science curricula, outlining how to use manual for teachers, and covering teachers' perceptions.

The themes developed by content analysis of the curricula are listed separately for high school biology and middle school science curricula. Science teachers can integrate the study of food fermentation into topics relevant to the themes for each level of education. Moreover, the manual outline in the framework gives ideas to teachers and curriculum developers that shows how these studies can be integrated for high school biology and middle school science curricula. Further and detailed information on the use of food fermentation practical work in learning outcomes of each curriculum is presented in Chapter 4 (see Analysis of How to Use Food Fermentation Practical Work, p. 89). Lastly, teachers' perceptions on integration of these studies are another component of the framework that provides broad perspective for integration. Teachers' perceptions are divided into three parts as: resources, teaching fermentation topic with practical work, and extracurricular activities.

To promote the implications of food fermentation; the effects of available equipment, administration support, allowed time in the curriculum, availability of in-service trainings and ready-made materials are evaluated under resources. The teachers, who have suitable conditions in terms of resources, are more willing to implement practical work of food fermentation in their classes. In order to increase and support teachers' willingness to implement these studies, recommendations for relevant stakeholders are presented in the framework developed (Table 109). For example, the contributions of school administrators and program developers are found important and needed for better integration of these studies.

Also, some findings of the study suggest ideas to IB, IGCSE, MoNE and other curriculum developers to integrate food fermentation practical work as a restricted practical or extending learning expectations by considering this type of practical studies. More importantly, some problems have been identified regarding the real-life implementation of the MoNE written curricula. Science and biology teachers, who follow the MoNE curricula, underlined that the allocated time for each curriculum is not enough to apply any practical work and extra time should be provided for these implications. To encourage practical work, especially the practical work of food fermentation for this study, appropriate physical and environmental conditions should be provided by curriculum and program developers to fulfill the curriculum's requirements. Requiring some practical work mandatory and making them an integral part of the program may solve this problem.

Considering the other aspects of these studies, it is important to encourage and apply them in terms of establishing a relationship with real life, eliminating misconceptions, developing many skills such as manipulative skills, and contributing to health. Additionally, the findings of the study show that food fermentation practical studies are really good practice in order to avoid the misconceptions about microorganisms mentioned by the participating teachers and supported by the literature. Also, the negative effects of Covid-19 about microorganisms can be eliminated by promoting the practical work of food fermentation to show not all organisms cause disease, most of them beneficial for human health and the environment. On the other hand, the classification of viruses and organisms can be more easily clarified by the help of these studies.

Food fermentation practical work is also suitable for distance education. Only materials that are always used in homes and cost-effective for all segments of society are required. Moreover, the materials used in these studies are safe to touch, smell and taste. Teachers can also use this opportunity to enhance learning in pandemic conditions and to develop students' scientific inquiry skills.

Lastly, practical studies of food fermentation have also been found applicable to extracurricular activities. Interdisciplinary projects are found proper for implication of these studies. It is contributions to connecting topics in different subject areas and many other mentioned benefits on human lives are the main reasons for the promotion of these studies. In addition, teachers can engage with these studies by establishing fermentation club in their schools or may adopt as a hobby in their lives. By this mean, they can gain more experience and have their own microbial cultures, which makes integration of these studies easier in their classes.

Below, Table 109 shows the developed integration framework of the study to promote its integration in science curriculum and extracurricular activities.

Table 109

Developed Integration Framework of Food Fermentation Practical Work

Components of the Framework	Biology (High School)	Science (Middle School)
Themes developed for integration	• Living things • Biotechnology • Biochemistry • Ecology • Health	• Living things • Experimental design • Chemistry • Environment • Health
How to use manual for teachers to integrate	• Proper for application of food fermentation for most of the units as a whole process (Code 4) or partially (Code 3) • Curriculum developers can include these studies more into curriculum (Code 5) to connect several units	• Mostly can be used as examples (Code 1) and to make comparisons (Code 2) • Curriculum developers can include these studies more into curriculum (Code 5) to improve students' skills, health, and scientific knowledge
Suggestions according to teachers' perceptions on integration	• Provide suitable conditions to increase application of these studies	
Resources	• Provide cost effective and easily affordable equipment • Ensure a laboratory has proper hygienic conditions • Provide administrators support • Allow enough time for practical work • Offer in-service trainings and ready-made materials needed for support	
Teaching Fermentation topic with practical work	• Use practical work for better learning of the topic • Use daily life connections of these studies for more permanent knowledge and increase students' interest • Overcome challenges of learning by visualizing this abstract topic • Avoid misconceptions by applying these studies • Use for improving students' health and many skills	
Extracurricular activities	• Use for Group 4 project, Internal assessment, and Extended essay for IBDP biology curriculum • Proper for interdisciplinary projects • Engage by establishing fermentation club and as a hobby	• Proper for science festival, TÜBİTAK science fair, school bazaar, end of school and club activities, projects • Proper for interdisciplinary projects • Engage by establishing fermentation club and as a hobby

Implications for Further Research

The findings from this study suggest several further research implications. The first and most useful implication is to application of food fermentation practical studies in classes as an action research. It is analyzed and discussed with subject teachers and a framework is developed for possible implications in this study. It should be investigated the effectiveness of this practical studies by considering different aspects of the learning process in real classroom environment. The inputs and the outputs of the practical work might be analyzed.

In addition, there are limited resources in the literature to promote these studies so more research might be done to support promotion of food fermentation. As found in this study, practical work of food fermentation is proper to implement for many topics with high integration rates, this allows to do further research on spiral curriculum. More curricula might be analyzed and compared to provide larger scale framework for teachers.

The effects of Covid-19 on teaching and learning fermentation topics and misconceptions about microorganisms might be investigated. Furthermore, contribution of food fermentation practical studies to handle with these problems would provide more data to learn effectiveness of these studies. The effects of promoting food fermentation in the health's of students and teachers may yield interesting results. The skills that students can gain through the application of food fermentation might also be an area to study.

Lastly, perceptions of other stakeholders such as school administers, other subject teachers, students, parents, and curriculum developers on the application of food fermentation practical work would have provided a broader perspective to the study.

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APPENDIX A

Interview Questions

Part 1: Questions Regarding Demographic Information

1. Your gender?

2. Age/date of birth?

3. City where you teach?

4. What is your educational background?
    - Undergraduate
    - MA degree
    - PhD degree

5. Department you graduated from?

6. Institution you work for?
    - Public school
    - Private school

7. What educational programs do you follow?
    - International Baccalaureate Diploma Program (IBDP)
        - Biology Standard level
        - Biology Higher level
    - International Baccalaureate Middle Years Program (IBMYP)
    - International General Secondary Education Certificate (IGCSE) Curriculum
    - Ministry of National Education (MoNE) Curriculum

8. How many years of teaching experience do you have in the curriculum group you represent?

9. How many years of your total teaching experience (in all curricula)?

10. What are the social media accounts that you can access when the fermentation club is established?

11. Your food fermentation cultural background and experiences?

Part II: Questions About the Food Fermentation Practical Study

1. In the workshop you attended; you have observed the materials required for food fermentation practical studies. How would you evaluate the adequacy of the tools and equipment at your school in terms of food fermentation practical work?

2. How do you evaluate the suitability of the physical conditions in your working environment (daily working hours intensity, adequacy of the course intervals, etc.) in order to allow for food fermentation practical studies?

3. How are you affected by the school administration's encouragement and emphasis on practical work?

4. How would you evaluate the adequacy of the time allocated to do practical work in the curriculum that you follow?

5. How does the presence of ready-made materials (laboratory worksheet, etc.) related to the laboratory work affect you?

6. What are your thoughts and experiences about the effect of laboratory studies on understanding of topics?

7. How does participation in trainings such as meetings, workshops, conferences from experts in their fields, affect your effectiveness in practical work?

8. What are the challenges of fermentation topic in terms of students' learning?

9. What are the misconceptions you come across while teaching fermentation topic?

10. What are your experiences about students' level of remembering the subject after teaching fermentation topic?

11. What are your thoughts and experiences about teaching fermentation topic through practical work?

12. Does it make a difference to do practical work that can be adapted to students' daily lives?

13. What do you think when you compare the effectiveness of food fermentation laboratory studies with other fermentation experiments?

14. In what ways do you think food fermentation practical work can contribute to students?

15. What do you think about the integration of food fermentation practical work into different topics other than respiration?

16. What do you think about the suitability of food fermentation practical work for extracurricular activities and studies?

17. What do you think about the suitability of food fermentation practical work for interdisciplinary studies?

18. Did the food fermentation workshop have an impact on your attitude to implement food fermentation practical work in your classes?

19. Would you like to set up or join a food fermentation club at your school?

20. Do you want to start on food fermentation as a hobby?

21. What are your opinions that you think will contribute to the study, you want to add or share?

APPENDIX B

Tables

Deduced Codes from IBDP Biology Curriculum

The List of Codes Deduced from *Cell Biology* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Cell biology	According to the cell theory, living organisms are composed of cells.	cell, cell theory
	Organisms consisting of only one cell carry out all functions of life in that cell.	organisms, functions of life
	Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. (Practical 1)	structure of cells
	Prokaryotes have a simple cell structure without compartmentalization.	prokaryotes, cell structure
	Eukaryotes have a compartmentalized cell structure.	eukaryotes, cell structure
	Prokaryotes divide by binary fission.	prokaryotes, binary fission
	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions. (Practical 2)	osmolarity
	Cells can only be formed by division of pre-existing cells.	pre-existing cells
	The origin of eukaryotic cells can be explained by the endosymbiotic theory.	origin of eukaryotic cells, endosymbiotic theory
	Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.	Pasteur's experiments, generation of cells
	Mitosis is division of the nucleus into two genetically identical daughter nuclei.	mitosis, cell division

The List of Codes Deduced from *Molecular Biology* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Molecular biology	Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism.	metabolism, enzyme-catalysed reactions, cell, organism
	Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions.	anabolism, condensation reactions, macromolecules, monomers
	Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.	catabolism, hydrolysis, macromolecules, monomers
	Temperature, pH and substrate concentration affect the rate of activity of enzymes.	temperature, pH, substrate concentration, rate of activity of enzymes
	Enzymes can be denatured.	denatured enzymes
	Methods of production of lactose-free milk and its advantages.	lactose-free milk, microorganisms

	Design of experiments to test the effect of temperature, pH and substrate concentration on the activity of enzymes.	activity of enzymes, temperature, pH, substrate concentration
	Experimental investigation of a factor affecting enzyme activity. (Practical 3)	enzyme activity, affecting factors
	Cell respiration is the controlled release of energy from organic compounds to produce ATP.	cell respiration, energy, ATP
	ATP from cell respiration is immediately available as a source of energy in the cell.	ATP, cell respiration, energy, cell
	Anaerobic cell respiration gives a small yield of ATP from glucose.	anaerobic, cell respiration, ATP, glucose
	Use of anaerobic cell respiration in yeasts to produce ethanol and carbon dioxide in baking.	anaerobic, cell respiration, yeasts, ethanol, carbon dioxide, baking
	Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.	temperature, light intensity and carbon dioxide concentration, limiting factors
	Design of experiments to investigate the effect of limiting factors on photosynthesis.	limiting factors

The List of Codes Deduced from *Genetics* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Genetics	Comparison of the number of genes in humans with other species.	number of genes, species
	Use of a database to determine differences in the base sequence of a gene in two species.	base sequence, gene
	Prokaryotes have one chromosome consisting of a circular DNA molecule.	prokaryotes, chromosome, circular DNA
	Some prokaryotes also have plasmids but eukaryotes do not.	prokaryotes, plasmid, eukaryotes
	Comparison of genome size in T2 phage, Escherichia coli, Drosophila melanogaster, Homo sapiens and Paris japonica.	genome size
	DNA profiling involves comparison of DNA.	DNA profiling
	Analysis of examples of DNA profiles.	DNA profiles

The List of Codes Deduced from *Ecology* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Ecology	Species are groups of organisms that can potentially interbreed to produce fertile offspring.	species, organisms, fertile offspring
	Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).	species, autotrophic, heterotrophic, method of nutrition
	Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.	heterotrophs, saprotrophs, organic nutrients, external digestion
	A community is formed by populations of different species living together and interacting with each other.	community, populations, species, interaction

	A community forms an ecosystem by its interactions with the abiotic environment.	community, ecosystem, interaction, abiotic environment
	The supply of inorganic nutrients is maintained by nutrient cycling.	inorganic nutrients, nutrient cycling
	Ecosystems have the potential to be sustainable over long periods of time.	ecosystems, sustainable
	Classifying species as autotrophs, consumers, detritivores or saprotrophs from a knowledge of their mode of nutrition.	Classifying, species, autotrophs, consumers, detritivores, saprotrophs, mode of nutrition
	Chemical energy in carbon compounds flows through food chains by means of feeding.	chemical energy, carbon compounds, food chains
	Energy released from carbon compounds by respiration is used in living organisms and converted to heat.	carbon compounds, respiration, living organisms
	Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.	carbon dioxide, respiration, organisms
	Construct a diagram of the carbon cycle.	carbon cycle

The List of Codes Deduced from *Evolution and Biodiversity* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Evolution and biodiversity	When species are discovered they are given scientific names using the binomial system.	species, binomial system
	All organisms are classified into three domains.	organisms, classification, domain
	Natural classifications help in identification of species and allow the prediction of characteristics shared by species within a group.	natural classification, identification of species,

The List of Codes Deduced from *Human physiology* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Human physiology	Causes and treatment of Type I and Type II diabetes.	type II diabetes
	Testing of leptin on patients with clinical obesity and reasons for the failure to control the disease.	obesity

The List of Codes Deduced from *Metabolism, Cell Respiration and Photosynthesis* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
Metabolism, cell respiration and photosynthesis	Metabolic pathways consist of chains and cycles of enzyme-catalysed reactions.	metabolic pathways, enzyme-catalysed reactions

	Metabolic pathways can be controlled by end-product inhibition.	metabolic pathways, end-product inhibition
	Cell respiration involves the oxidation and reduction of electron carriers.	cell respiration, oxidation, reduction, electron carriers
	Phosphorylation of molecules makes them less stable.	phosphorylation
	In glycolysis, glucose is converted to pyruvate in the cytoplasm.	glycolysis, glucose, pyruvate
	Glycolysis gives a small net gain of ATP without the use of oxygen.	glycolysis, ATP

The List of Codes Deduced from *Biotechnology and Bioinformatics* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
B: Biotechnology and bioinformatics	Microorganisms are metabolically diverse.	microorganisms, metabolically diverse
	Microorganisms are used in industry because they are small and have a fast growth rate.	microorganisms, industry, growth rate
	Pathway engineering optimizes genetic and regulatory processes within microorganisms.	pathway engineering, microorganisms
	Pathway engineering is used industrially to produce metabolites of interest.	pathway engineering, industry, metabolites
	Fermenters allow large-scale production of metabolites by microorganisms.	fermenters, microorganisms, metabolites
	Fermentation is carried out by batch or continuous culture.	fermentation, batch, culture
	Microorganisms in fermenters become limited by their own waste products.	microorganisms, fermenters, waste products
	Probes are used to monitor conditions within fermenters.	probes, fermenters
	Conditions are maintained at optimal levels for the growth of the microorganisms being cultured.	optimal conditions, growth of the microorganisms, culture
	Deep-tank batch fermentation in the mass production of penicillin.	Deep-tank batch fermentation, penicillin
	Production of citric acid in a continuous fermenter by Aspergillus niger and its use as a preservative and flavouring.	citric acid, fermenter, Aspergillus niger, preservative, flavouring
	Biogas is produced by bacteria and archaeans from organic matter in fermenters.	biogas, bacteria, archaeans, organic matter, fermenters
	Production of biogas in a small-scale fermenter.	biogas, small-scale fermenter
	Microorganisms are used in bioremediation.	microorganisms, bioremediation
	Cooperative aggregates of microorganisms can form biofilms.	microorganisms, biofilms
	Biofilms possess emergent properties.	biofilms
	Microorganisms growing in a biofilm are highly resistant to antimicrobial agents.	microorganisms, biofilms, antimicrobial agents
	Microorganisms in biofilms cooperate through quorum sensing.	microorganisms, biofilms

The List of Codes Deduced from *Ecology and Conservation* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
C: Ecology and conservation	Community structure can be strongly affected by keystone species.	community, keystone species
	Each species plays a unique role within a community because of the unique combination of its spatial habitat and interactions with other species.	species, community, spatial habitat, interactions
	Interactions between species in a community can be classified according to their effect.	interactions, species, community, classification
	Two species cannot survive indefinitely in the same habitat if their niches are identical.	species, habitat, niche
	Local examples to illustrate the range of ways in which species can interact within a community.	species, community, interactions
	Modelling the growth curve using a simple organism such as yeast or species of Lemna.	growth curve, organism, yeast

The List of Codes Deduced from *Human Physiology* Unit in IBDP Biology Curriculum

Unit	Understandings and Application and Skills	Keywords (Codes)
D: Human physiology	Overweight individuals are more likely to suffer hypertension and type II diabetes.	overweight, type II diabetes

Deduced Codes from IGCSE Biology Curriculum

The List of Codes Deduced from *Movement in and out of Cells* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Movement in and out of cells	Investigate and describe the effects on plant tissues of immersing them in solutions of different concentrations	solutions of different concentrations

The List of Codes Deduced from *Enzymes* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Enzymes	Investigate and describe the effect of changes in temperature and pH on enzyme activity	temperature, pH, enzyme activity
	Explain the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation	pH, enzyme activity, denaturation

The List of Codes Deduced from *Plant Nutrition* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Plant nutrition	Define the term limiting factor as something present in the environment in such short supply that it restricts life processes	limiting factor

The List of Codes Deduced from *Human Nutrition* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Human nutrition	State what is meant by the term balanced diet for humans	balanced diet
	Describe the effects of malnutrition in relation to starvation, constipation, coronary heart disease, obesity and scurvy	obesity

The List of Codes Deduced from *Diseases and Immunity* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Diseases and immunity	Define pathogen as a disease-causing organism	pathoge, disease-causing organism

The List of Codes Deduced from *Respiration* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Respiration	State that respiration involves the action of enzymes in cells	respiration, action of enzymes, cells
	Define anaerobic respiration as the chemical reactions in cells that break down nutrient molecules to release energy without using oxygen	anaerobic respiration, chemical reactions, cells, nutrient molecules, energy
	State that anaerobic respiration releases much less energy per glucose molecule than aerobic respiration	anaerobic respiration, energy, glucose, aerobic respiration
	State the balanced chemical equation for anaerobic respiration in the microorganism yeast as $C6H12O6 \rightarrow 2C2H5OH + 2CO2$	anaerobic respiration, microorganism, yeast

The List of Codes Deduced from *Reproduction* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Reproduction	Identify examples of asexual reproduction from information provided	asexual reproduction

The List of Codes Deduced from *Inheritance* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Inheritance	State the role of mitosis in growth, repair of damaged tissues, replacement of cells and asexual reproduction	mitosis, growth, replacement of cells, asexual reproduction

The List of Codes Deduced from *Variation and Selection* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Variation and selection	Define variation as differences between individuals of the same species	variation, species

The List of Codes Deduced from *Organisms and Their Environment* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Organisms and their environment	State that energy is transferred between organisms in a food chain by ingestion	energy, food chain, ingestion
	Define consumer as an organism that gets its energy by feeding on other organisms	consumer, organism
	Define decomposer as an organism that gets its energy from dead or waste organic material	decomposer, organism
	Describe the carbon cycle, limited to photosynthesis, respiration, feeding, decomposition, fossilisation and combustion	carbon cycle, respiration, feeding, decomposition
	Define population as a group of organisms of one species, living in the same area, at the same time	population, organisms, species
	Identify and state the factors affecting the rate of population growth for a population of an organism, limited to food supply, predation and disease	affecting factors, rate of population growth, organism
	Define community as all of the populations of different species in an ecosystem	community, populations, species, ecosystem
	Define ecosystem as a unit containing the community of organisms and their environment, interacting together, e.g. a decomposing log, or a lake	ecosystem, community, organisms, environment
	Explain the factors that lead to each phase in the sigmoid curve of population growth, making reference, where appropriate, to the role of limiting factors	population growth, limiting factors

The List of Codes Deduced from *Biotechnology and Genetic Engineering* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Biotechnology and genetic engineering	State that bacteria are useful in biotechnology and genetic engineering due to their rapid reproduction rate and their ability to make complex molecules	bacteria, biotechnology, genetic engineering, reproduction rate, complex molecules
	Discuss why bacteria are useful in biotechnology and genetic engineering, limited to:	bacteria, biotechnology, genetic engineering
	Describe the role of anaerobic respiration in yeast during production of ethanol for biofuels	anaerobic respiration, yeast, ethanol, biofuels
	Describe the role of anaerobic respiration in yeast during bread-making	anaerobic respiration, yeast, bread-making
	Describe the role of the fungus Penicillium in the production of the antibiotic penicillin	fungus, Penicillium, antibiotic penicillin
	Explain how fermenters are used in the production of penicillin	fermenters, penicillin

The List of Codes Deduced from *Human Influences on Ecosystems* Unit in IGCSE Biology Curriculum

Unit	Core and Supplement	Keywords (Codes)
Human influences on ecosystems	Discuss the social, environmental and economic implications of providing sufficient food for an increasing human global population	sufficient food

	State that products can be reused or recycled, limited to paper, glass, plastic and metal	reuse, recycle, glass
	Define the term sustainable development as development providing for the needs of an increasing human population without harming the environment	sustainable development, environment

Deduced Codes from MoNE Biology Curriculum

The List of Codes Deduced from *Life Science Biology* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Life science biology	Examine the common features of living things.	common features of living things
	a. The meaning of biology today and how it is used is briefly stated through the concept of living things.	living things
	b. Cellular structure, nutrition, respiration, excretion, movement, reaction to stimuli, metabolism, homeostasis, adaptation, organization, reproduction, growth and development features of living things are emphasized.	features of living things
	Explain the organic and inorganic compounds that make up the structure of living things.	structure of living things
	a. The importance of water, minerals, acids, bases and salts for living beings is stated.	minerals, acids, bases
	c. The structure, function and importance of carbohydrates, lipids, proteins, nucleic acids, enzymes are stated.	carbohydrates, enzymes
	ç. It is emphasized that DNA is found in all living species and contains the same nucleotides.	living species, DNA
	d. The importance of ATP and hormones for living things is questioned without including chemical formulas.	ATP, living things
	f. Students are provided to conduct experiments to detect the presence of carbohydrates, lipids and proteins in foods.	carbohydrates
	g. It is provided to conduct experiments related to factors affecting enzyme activity.	enzyme activity, affecting factors
	Establish the relationship of lipids, carbohydrates, protein, vitamins, water and minerals with healthy nutrition.	carbohydrates, healthy nutrition
	a. Insulin resistance, diabetes and obesity are addressed in the context of healthy eating.	diabetes, obesity, healthy eating
	b. Students are provided to prepare a weekly healthy diet program for their age group.	healthy diet

The List of Codes Deduced from *Cell* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Cell	Explain cell structures and functions.	cell structures
	a. Parts of prokaryotic cells are shown.	prokaryotes, cells
	b. The structure of eukaryotic cells and the parts that make up this structure are shown.	eukaryotes, cells
	ç. Cell samples are examined with a microscope.	cell, microscope

	Conduct a controlled experiment on the move across of particles through the cell membrane.	membrane transport, controlled experiment
	a. The scientific method steps before the experiment on the move across of particles through the cell membrane are explained with an example.	membrane transport
	c. A controlled experiment is performed on one of the factors (surface area, concentration difference, temperature) affecting the move across of particles through the cell membrane.	membrane transport, surface area, concentration difference, temperature, controlled experiment

The List of Codes Deduced from *World of Living Things* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
World of living things	Explain the importance of classification in understanding the diversity of living things.	classification, living things
	Explain the categories used in the classification of living things and the hierarchy between these categories with examples.	classification, living things
	c. Considering the hierarchical categories, binomial nomenclature examples are given about living species to be selected from the environment.	hierarchical categories, species, binomial nomenclature
	ç. Students are provided to create a video or a product from photos taken / acquired about the world of living things.	living things
	Explains the kingdoms used in the classification of living things and the general characteristics of these kingdoms.	classification, kingdoms
	a. Examples are given by explaining the general characteristics of bacteria, arcs, protists, plants, fungi, animals. Classification of other kingdoms is not included except the animal kingdom.	bacteria, fungi
	Explain the contribution of living things to biological processes, economy and technology with examples.	contribution of living things, economy, biological process

The List of Codes Deduced from *Cell Divisions* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Cell divisions	Explain the necessity of cell division in living things.	cell division, living things
	a. Cell division is explained by associating it with reproduction, growth and development in living things.	cell division, living things, reproduction, growth, development
	Explain asexual reproduction with examples.	asexual reproduction
	a. Binary fission, budding, spore production, regeneration, parthenogenesis and vegetative reproduction samples are given in the context of asexual reproduction. In spore reproduction, only examples are given, fertilization is not mentioned.	asexual reproduction, binary fission, budding

The List of Codes Deduced from *Ecosystem Ecology and Current Environmental Problems* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Ecosystem ecology and current environmental problems	Explains the relationship between biotic and abiotic components of the ecosystem.	ecosystem, biotic, abiotic
	a. The relationship between population, community and ecosystem is explained by examples.	population, community, ecosystem
	b. Possible consequences in the system of any changes that may occur in the ecosystem are emphasized.	ecosystem
	c. Students are provided to prepare a presentation introducing an ecosystem of their choice.	ecosystem
	Explains the mode of nutrition in living things with examples.	living things, mode of nutrition
	Analyzes the flow of matter and energy in the ecosystem.	ecosystem, energy flow
	a. The role of producers, consumers and decomposers in the flow of matter and energy is examined.	producers, consumers, decomposers
	b. Matter and energy flow in ecosystems is exemplified by associating it with the food chain, the food web and the food pyramid.	matter flow, energy flow, food chain, food web, food pyramid
	ç. Students are provided to construct a food web showing the nutritional relationships between living things.	nutritional relationships, food web
	Interrelates the cycles of matter and the sustainability of life.	matter cycles, sustainability
	a. Nitrogen, carbon and water cycles are reminded.	carbon cycle
	Offers solutions for the prevention of environmental pollution in the local and global context.	prevention of environmental pollution
	b. It is provided to discuss human activities that harm the environment locally and globally.	impacts of humans on ecosystems
	c. Examples are given about how biology is associated with other disciplines in preventing environmental pollution.	prevention of environmental pollution, biology, interdisciplinary relations
	Explains the importance of sustainability of natural resources.	sustainability

The List of Codes Deduced from *Human Physiology* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Human physiology	Explains digestive system disorders.	digestive system disorders
	Students make inferences about what needs to be done to protect the health of the digestive system.	digestive system health

The List of Codes Deduced from *Community and Population Ecology* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Community and population ecology	Explain symbiotic relationships between species in the community with examples.	community, species, symbiotic relationships
	a. Parasitism and mutualism are associated with human health (lice, fleas, ticks, tapeworms, intestinal flora).	mutualism, human health, intestinal flora
	Analyzes the factors affecting population dynamics.	population dynamics, affecting factors
	b. Different growth curves (S and J) are drawn for population growth.	population growth, growth curves

The List of Codes Deduced from *From Gene to Protein* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
From gene to protein	Evaluates the effects of genetic engineering and biotechnology applications on human life.	genetic engineering, biotechnology applications

The List of Codes Deduced from *Energy Transformations in Living Things* Unit in MoNE Biology Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Energy transformations in living things	Explains the necessity of energy for the continuation of life.	energy
	a. The structure of the ATP molecule is explained.	ATP
	b. Phosphorylation types are briefly mentioned.	phosphorylation
	Explains cellular respiration.	cellular respiration
	c. It is emphasized in all living things that glucose is broken down into pyruvic acid by a chain of reactions. Intermediate steps and intermediate products up to pyruvic acid are not mentioned.	glucose, reaction chain, pyruvic acid
	ç. Ethyl alcohol and lactic acid fermentation is explained and examples from daily life are given.	ethyl alcohol, lactic acid, fermentation, daily life examples
	d. In anaerobic respiration, it is stated that the electron is transferred to a molecule (sulfate, sulfur, nitrate, carbon dioxide, iron) other than oxygen.	anaerobic respiration, electron transfer
	e. The reasons of higher energy efficiency than fermentation in aerobic respiration are emphasized.	aerobic respiration, fermentation, energy efficiency
	f. Cellular respiration processes are explained using visual elements, graphic organizers, e-learning object and applications.	cellular respiration processes

Deduced Codes from MoNE Science Curriculum

The List of Codes Deduced from *World of Living Things* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
World of living things	Gives examples to living things and classifies them according to their similarities and differences.	living things, classifying
	a. Living things are classified as plants, animals, fungi and microscopic organisms.	living things, classification, fungi, microscopic organisms
	c. Examples of microorganisms (bacteria, amoeba, euglena and paramecium) and mushrooms are given, but structural details are not mentioned.	microorganisms, bacteria
	ç. Observes the presence of microorganisms with the help of a microscope.	microorganisms, microscope
	d. Students are warned not to eat poisonous mushrooms.	mushrooms, safety precautions, hygiene

The List of Codes Deduced from *Human and Environment* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Human and environment	Students provide suggestions for the solution of an environmental problem in their immediate environment or in our country.	solution to the environmental problem

The List of Codes Deduced from *Human Body Systems and Its Health* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Human body systems and its health	Students demonstrate the relationship between sense of smell and taste with an experiment they designed.	smell, taste, senses, design of experiments
	Discusses what needs to be done for the health of human body systems based on research data.	diabetes, obesity, health of human body systems

The List of Codes Deduced from *Cell and Divisions* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Cell and divisions	Compares animal and plant cells in terms of their basic parts and functions.	cell
	Explains the importance of mitosis for living things.	cell division, mitosis

The List of Codes Deduced From *Pure Substances and Mixtures* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Pure substances and mixtures	Students give examples by classifying mixtures as homogeneous and heterogeneous.	homogeneous mixture, heterogeneous mixture, mixtures
	Distinguishes substances that can be recycled and not recycled in domestic waste.	domestic waste, recycle
	Designs projects for the recycling of domestic solid and liquid wastes.	domestic liquid waste, domestic solid waste, recycling, project
	Students develop projects to convey its reusable items to those in need.	reusable, project

The List of Codes Deduced from *Reproduction, Growth and Development in Living Things* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Reproduction, growth and development in living things	Compares reproduction types in plants and animals.	asexual reproduction
	Explains the growth and development processes in plants and animals by giving examples.	growth, development, processes
	a. An experiment involving dependent, independent and controlled variables is provided regarding the factors affecting seed germination.	affecting factors, dependent variable, independent variable, controlled variable
	Explains the main factors affecting growth and development in plants and animals.	factors affecting growth and development
	Students take care of a plant or animal and reports its development process.	caring for living things, development process

The List of Codes Deduced from *DNA and Genetic Code* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
DNA and genetic code	Discusses the beneficial and harmful aspects of these practices with the dilemmas created within the scope of biotechnological applications.	biotechnological applications, benefits and harms of biotechnology applications

The List of Codes Deduced from *Pressure* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Pressure	Students give examples of applications of pressure properties of solids, liquids and gases in daily life and technology.	pressure, applications of pressure in daily life and technology

The List of Codes Deduced from *Matter and Industry* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Matter and industry	Explains the differences between physical and chemical changes by observing various events.	physical change, chemical change, observation
	Refers to the general properties of acids and bases.	acids, bases
	Gives examples of acids and bases from daily life.	acids, bases, daily life examples
	Make inferences about the acidity and alkalinity of the substances by using PH values.	acidity, alkalinity, pH
	It is ensured that they make inferences by doing experiments on the subject.	acids, bases, pH, experiment

The List of Codes Deduced from *Energy Transformations and Environmental Science* Unit in MoNE Science Curriculum

Unit	Learning Outcomes and Explanations	Keywords (Codes)
Energy transformations and environmental science	Gives examples to producers, consumers and decomposers in the food chain.	food chain, producers, consumers, decomposers
	Indicates the importance of respiration in living things.	cellular respiration
	c. Aerobic and anaerobic respiration are given without entering stages, but the amount of energy released is not specified numerically.	aerobic respiration, anaerobic respiration
	ç. Specifies the name of ATP without entering the structure.	ATP
	Explains cycles of matter by showing them on the diagram.	cycles of matter
	Interrogates the importance of matter cycles for life.	matter cycles
	Designs projects for economical use of resources.	economical use of resources, sustainable life, project
	Explains the importance of separating solid wastes for recycling.	recycling