ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2024, 9 (2): 359-375 doi: 10.28978/nesciences.1574453

Exploring Food Processing in Natural Science Education: Practical Applications and Pedagogical Techniques

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Abstract

Food processing is an essential link in the chain that connects agricultural production with consumer nutrition and safety. This paper attempts to discuss how effectively food processing can be integrated into the curriculum of natural sciences to further the understanding of students about scientific principles through practical applications. Discussion of relevance to food processing prepares the ground for biology, chemistry, and environmental science, focusing on such core processes as fermentation, pasteurization, and conservation. This paper outlines how reviewing successful strategies and case studies, concept concretization of science is realized through practical activities and interdisciplinary projects, and larger goals are achieved in education for sustainability, food safety, and healthier eating. Besides, it underscores the place of technology and

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innovation through digital tools and virtual simulation in making the lessons interactive for the students in a career-oriented manner. The article concludes with the following practical suggestions for educators and advocates of the partnership among schools, industry, and community toward an enriched education preparing students with vocational skills.

Keywords:

Food processing, natural science, practical applications, pedagogical techniques.

Article history:

Received: 11/06/2024, Revised: 07/08/2024, Accepted: 09/09/2024, Available online: 30/10/2024

Introduction to Food Processing in Natural Science Education

Learning by doing is an important pedagogical approach, which means that students learn better when they see and experience things themselves. This is especially true in natural science classes, like chemistry and biology, where students learn about the building blocks of our world, substances, and biological life (Llopiz-Guerra et al., 2024). Food has a special place in science classes because it connects students with what they eat, know, and experience in their lives. It can be a common subject for students to study more about the world around them.

Food processing is something everyone does in their everyday life, starting with breakfast. Processed food products are often the result of a series of purposeful actions on food raw materials. These purposes can include food preservation, combination of different food raw materials, and improvement of food quality and safety. The connections from food processing to applied natural science disciplines such as chemistry, biology, and microbiology provide good subject matter and learning objectives for practical laboratory work (Brandt et al., 2021). Different types of natural science education laboratory work have been analyzed, and their pedagogical value has been compared to each other (Doig et al., 2022). Edible gelatin capsules filled with prepared food emulsions were chosen as an experimental realization subject (Odilov et al., 2024; Felten & Lambert, 2020; Brown, 2021; Mehta et al., 2022).

The food processing topic and experiment were developed by science teachers for science teachers. The pedagogical considerations and learning (Lavanya et al., 2024) outcomes are presented from the perspective of grassroot level science teaching. Students' experiences related to the food processing topic and emulsions laboratory work are analyzed and shown to be positive on different levels. The laboratory work was found to be relevant as a pedagogical approach for natural science education. The food processing subject matter can be seen as a vehicle to promote learning (Srinivasa Rao et al., 2023) of natural science disciplines and the aim of natural science education (Vander et al., 2020; Juuti et al., 2021).

The Importance of Teaching Food Processing in Natural Science

Food processing, a topic often overlooked in natural science education, affirms its importance in both content knowledge and educational approaches. Broader framing of the food system, rather than solely static physical or chemical transformations, will prove fruitful. Life-cycle perspectives on food processing highlight potential impacts on food composition and preservation, coupled with discard, use, or clean water by-product processing (Guzzardo et al., 2021). Hands-on taste experiments reveal how processing influences properties such as color and mouthfeel, affecting market success. Framing food processing nodes in the context of novel products challenges preconceived notions, while socio-economic perspectives build awareness of global food chains and distribution in the local context. Food processing offers a rich exploration of natural phenomena and technologies, relevant to students' own lives.

Food processing is crucial for food safety, shelf life, and sensory quality. It is complex due to scientific and engineering challenges, while socio-economic factors raise questions of ownership, power, and distribution. During adolescence, food is crucial for identity, belonging, attitude formation, and health, making food processing vital in natural science education (Mathur et al., 2024) Contexts, challenges, and pedagogical approaches for exploring food processing in natural science are reviewed, including the importance of teaching food processing, its cultural and historical contexts, and how through illustrations the topic is expanded and made relevant, experiential, and engaging for students. The food system is framed more broadly to include distribution, use, and discard, alongside transformations of food (Karimov & Doniyorov, 2019).

Although ideas about food are often reduced to taste, processing has fundamental effects on food properties. For students, food processing is a rich topic relevant to their own lives. Food processing allows exploration of everyday phenomena in terms of natural science, with potential to appeal to different students' interests. Being energy or material intensive, food processing is open to much inquiry into its sustainability. Processing makes raw materials available for storage, use, clean water, something that otherwise cannot be done. It is appealing to question the preconceptions food processing captures. Framing food processing nodes/steps in the context of new products is engaging for students, as they explore some processed foods.

Nutritional Significance

Food is a basic human necessity, which in addition to satisfying hunger, provides nutrients essential for good health. Today, when ready-to-eat foods are on the rise, food processing such as cooking, fermentation, and drying are overlooked. This is unfortunate, as food processing has improved the quality and diversity of food for thousands of years. Food processing also has significant effects on the composition of the raw material and the health-related bioactivity of the foodstuff. Since food processing is very tangible, implements mandatory knowledge of biology, chemistry, and physics. Food processing tools can also be familiar in many homes and may serve as an incentive to discover the basic concepts of natural science. First attempts to teach food processing in natural science education in the high school level revealed several simple food processing experiments that can be provided as a laboratory course (Khaydarova et al., 2024).

Food processing has been of utmost importance since the emergence of cooking and processing methods that made food easier to digest and improved taste and absorption of nutrients. These processing methods are currently losing popularity, just as important and beneficial bioactive food ingredients are neglected. Ultimately, the individual who consumes the foodstuff has the final say about its attributes and effects. Without proper understanding food processing may be out of control, as it can also have detrimental effects (e.g., some vitamin loss, formation of acrylamide or methylglyoxal during frying, rosmarinic acid loss in dried rocket salads). All such concerns require an understanding of food processing (Odilov et al., 2024).

In recent years, basic concepts in biology and chemistry have waned in natural science education at the high school level. Despite the need for basic knowledge in biology and chemistry in every day life, often school chemistry concepts seem too abstract and removed from questions that arise in every day life. Currently, improvement of biological and chemical knowledge is emphasized in natural science education in the high school level. Food in connection with biology, chemistry, and physics is of very broad interest as every one eats. In Finland several studies have been conducted that reveal students’ limited understanding of biological and chemical questions underpinning food preparation (Sh et al., 2020).

Practical Applications of Food Processing in the Classroom

Emphasizing the importance and relevance of food processing in natural science education, there is a discussion of how food processing contributes to the understanding and relevance of fundamental natural science concepts, making topics such as biology, chemistry, and physics more tangible. In addition, these topics are presented in a way that relates them to everyday life, which in turn can help with understanding and retention. A number of practical applications are presented that allow teachers to easily integrate food processing into their teaching.

Food processing is often perceived as a complex concept that requires advanced knowledge in food science. As a result, students might not be able to create a clear image of food processing or relate it to their own lives. Food processing in natural science education lessons, on the other hand, can provide an easy introduction to food processing with demonstrations of easy experiments with food products. Free and open access laboratory settings equipped with devices such as microscopes, pH meters, and small scales can make food processing more approachable in a classroom setting (Bobojonova & Karimov, 2024).

Practical, hands-on activities are often a vital part of natural science education. In addition to making classes more interactive, hands-on activities can help to better understand how natural science phenomena work. Current initiatives for promoting food processing in natural science education often include hands-on activities with food products with focus on a specific lesson plan. The intention behind such initiatives is clearly to engage teachers by providing them with ready-to-use class activities. To help teachers implement food processing more easily into their current lessons, a number of everyday items have been compiled that can be used for various activities regarding food processing. A list of food processing-related activities focusing on biology, chemistry, and physics classes, with estimates of needed working time, classroom setting, and needed devices, is presented.

There are a number of everyday items that can be used to observe food processing phenomena. They are easily accessible and often found in schools, departments, or homes. Microscopes can easily be found in most school biology labs but are being used mainly for observing the anatomy of different organisms. Examining the appearance and structure of various food products such as bread, cheese or meat with a microscope, however, can provide an easy introduction to both food processing and microscopy in the classroom. Using a microscope allows the observation of how the structure of food products differs and how they affect the properties such as texture of the products. Crumb structure can also be quantitatively compared with image processing software, and results can be taken as a basis to discuss food processing techniques such as fermentation and proofing temperature in the classroom controlling for the input of variable parameters.

Food processing can also easily be integrated into chemistry lessons. Food processing experiments focusing on how the pH of food products affect texture, color or taste can be conducted, and results can be compared with similar commercial food processing processes. Observation of how food processing techniques can prevent microbial contaminations can be made with food products that are known to act as good culture media for either fungi or bacteria, such as bread and meat products. The results of the experiments can be taken to discuss either food safety or food preservation in general during either chemistry or biology lessons.

- ***Hands-On Activities and Experiments***

Food processing is an integral part of daily life, providing the means to make food readily available, edible, and safe for all. Furthermore, food processing also adds value to raw food materials by improving their flavor, taste, aroma, and appearance. As such, it is interesting to study food processing and develop thoughtful inquiries around the topic. In natural science education, food processing can be introduced in the classroom through simple hands-on activities and experiments (Mukhamajanovich et al., 2020).

Microbial Growth and Control Experiment

Bread, as a common food item, provides a reasonable food source for microorganisms for demonstration of food processing. The leftover bread gets molded when left for days. The activity described here is a simple science experiment that illustrates basic food processing and the control of microbial growth. It is done by demonstrating the growth of mold in pieces of bread with different treatments (Verma et al., 2020). The experiment setup should have four bread pieces, which are termed control with no treatment, boiled control with thermal treatment, cold control with chemical treatment, and hot control with chemical treatment. Food color, clove oil, and a mixture of food color and clove oil are used as chemical treatments to control mold growth, while hot water, 100°C (boiling), and cold water are used for the thermal treatment. Hoagie sandwich bread is the best option for this experiment. The bread pieces are placed in four different bags labeled appropriately, and the bags are placed in the same spot in a classroom. After observing the bread pieces for a week, it will be easily seen that the food color treatment and the control bread with no treatment both have lots of mold growth, whereas the hot control and the pieces with clove oil treatment both have no mold growth or very minimal growth.

Making Yogurt

Yogurt is popular fermented dairy food that can be easily made at home. As a traditional fermented food, it contains a variety of beneficial bacteria and provides health benefits when consumed in appropriate amounts. Yogurt can be made using any type of milk, with goat or cow's milk being commonly used. The activity described here involves making yogurt using almost no material, equipment, and economic resources. For this activity, pasteurized or boiled whole milk should be used, and powdered yogurt starter culture can be bought from a shops, markets, or stores. Plain yogurt with live culture may also be used, but it is more economical to make yogurt using powdered starter culture. The preparation requires boiled, hot milk of about 60°C and various materials like a medium-size bowl, small bowl, spoon, food-grade thermometer, and a cover. After preparing yogurt, anyone can enjoy the deliciously made homemade yogurt after refrigerating it after fermentation.

- ***Case Studies and Real-World Examples***

To further enhance the understanding of food processing within the context of natural science education, educators can present case studies of specific food products that highlight the food processing techniques involved in their production. Such case studies should ideally reference local products and well-known brands to facilitate students' engagement, and familiarity with the subject matter, and to highlight the local relevance of food processing. For example, an educator in Beijing, China might explain how tofu is produced from soybeans and then processed into sundried tofu, fuzzy tofu, or North-style braised tofu, as well as how yogurt is produced from milk, an approach that is particularly relevant to the Chinese market with its wide variety of yogurt products. In addition, the educator can showcase videos of how certain food products are processed, with an explanation of the corresponding processing technique, such as the video of making Mozzarella Cheese. Videos that run for 10-15 minutes are recommended, with effective options available on YouTube. Students can be assigned questions to answer after watching the video to stimulate their critical thinking regarding the food production and processing techniques featured in the video.

Utilizing a case study approach has several benefits. Case studies are an effective way to handle difficulty in teaching a large number of food processing techniques within a limited timeframe. Rather than covering a variety of food products and their production techniques superficially, students can be guided to study a few food products in detail regarding how the raw materials are grown and harvested, how the product is then processed, how the product is packaged and stored to prolong shelf life, and how distribution affects the freshness of the product. Such an in-depth discussion can cover several food processing techniques and the associated physical, chemical and biological principles. The case study approach is also consistent with the recommendation of the National Science Teachers Association. According to the National Science Teachers Association, “A case study is an in-depth exploration of a bounded system based on data collected from multiple sources.” A food product can be considered as a bounded system, as it is formed by a series of input transformation and output observations. Therefore, food products can make effective case studies (Yusubov et al., 2021).

An example of a case study on a specific food product, fresh gourd, is presented in this section. Using fresh gourd as an example, the conventional food product, fried gourd chips, and the processed food product, fresh gourd are described. The case study introduces how fresh gourds are grown and harvested, how they are packaged after processing, and how they are distributed to the market.

Pedagogical Techniques for Teaching Food Processing

Natural science education should encompass hands-on activities that broaden learners’ perspectives on their everyday surroundings. Food is a natural science-related concept that interests everyone. However, teaching food processing has not received much attention. Food processing is related to important natural science concepts, such as chemistry, biology, geology, physics, and technology. Through food processing, the practical applications of fundamental natural science concepts can be illustrated. It is important to note that in basic education in many countries, there is an opportunity for practical laboratory work in natural science subjects throughout the three-wide science subjects (i.e., biology, chemistry, and physics). This offers an opportunity to implement the teaching of food processing using available resources.

This study contributes to the development of experimental pedagogical techniques for teaching food processing in natural science education through the theoretical discussion, implementation, and evaluation of three types of pedagogical techniques. The three types of techniques are (1) inquiry-based learning, (2) multisensory teaching strategies, and (3) ‘world cafés’. Inquiry-based learning approaches include using experiments to illustrate fundamental natural science concepts applied in food processing. Inquiry-based approaches have been widely implemented and researched in school settings. Implementing inquiry-based teaching approaches is an effective pedagogical technique for teaching food processing in natural science education. It is crucial to realize that inquiry-based teaching approaches can be implemented at different inquiry levels and in more or less strict frameworks. It is instructor-dependent how inquiry-based food-processing experiments are implemented in a natural science classroom. Moreover, inquiry-based teaching approaches include a variety of experimental activities that can be adapted to local contexts and interests.

Natural sciences are taught often through lecture-based pedagogical styles. However, society increasingly demands that learners be taught in more multisensory ways, in which they can explore, discover, and construct ideas with better community and collaboration. There have been attempts to implement multisensory teaching strategies at natural science lessons and food sciences. Based on increased interest and growing social demands, the pedagogical complexity of implementing multisensory teaching strategies in natural science education is thoroughly addressed here. The main practical pedagogical implications are presented as an eight-point framework for implementation together with examples of the utilization of multisensory pedagogical strategies related to food processing.

Inquiry-Based Learning Approaches

A curriculum unit exploring food processing and food materials is developed and its implementation in three 9th grade classrooms is described. The unit was designed to facilitate students' understanding of food materials and a food processing concept based on select features of inquiry-oriented learning approaches. Three teachers attempted implementation of the unit under different conditions, and the results of student learning as well as classroom interaction were analyzed. Students' understanding of food processing improved across classrooms, but each classroom generated different learning interpretations of the concept based on teacher adaptation of the unit (Reiser et al., 2021). Classroom wide discussions of the concept were shown to stimulate near transfer of its understanding, but how such discourse was created and sustained differed among classrooms, leading to variation in student engagement. Elaborating on teachers' unexpected difficulties in prompting and maintaining unit discussions, several considerations for unit implementation in different classroom and educational contexts are explored.

Food is the primary item of life and has important connections to culture, personality, and health. The changing life style impacts both the food pattern and the food intentional consumption. At present, people still face hot food, frozen food, cold food, and bland food. Food processing is one of the basic concepts regarding food. It refers to all physical and/or chemical transformations undergone by food, starting from harvesting to its supplying in the market. There is a need to develop students' understanding of food materials and its processing. Science curriculum cannot be improved by mere changes in the content or pedagogy without considering the underlying epistemology or epistemological assumption. The idea of promoting students to take an initiative role in significant learning is an important pedagogical reform.

Inquiry-based learning approaches are intended to facilitate students' active initiation or alternation of a substantial aspect of learning. Transfers of the concept of inquiry to classroom learning can have different forms with a variety of terms, such as science/process skills, DI, model-based, and guided inquiry. Teachers play a central role in most design implementations of the approach since they need to adapt the proposed settings into classroom realities. The concern of how unit design is adapted by different teachers is oftentimes neglected and relatively little is known about variables that might cause differences in learning environments. In this view, three experienced teachers' attempts to implement a unit were examined, and teacher adaptation of learning activities was interpreted as enactment of the design. In conjunction, analyses of student responses, understanding of concepts, and classroom discourse were presented.

Assessment in Food Processing Education

The challenge of preparing a proper assessment in food processing education for both formal educational establishments and informal out-of-school settings, like ('food') science museums and science centres (uplifted to the term food processing education (FPE)), will be discussed in this chapter. Almost every Natural Science topic can be linked, directly or indirectly, to food. An understandably high interest in food topics is found among children, teenagers, and even adults. Food-related science topics also benefit from an unpredictable strong content linkage to health, environmental, and global issues.

FPE is considered a Natural Science topic choice among teachers in primary and tertiary formal educational establishments and among science centre communicators in informal education. Several possibilities for raising food processing as a Natural Science topic among teachers, communicators, and students are suggested. Various FPE practical applications designed by the author and implemented in different educational environments are presented, including innovative food processing experiments, multisensory food exhibits in science centre settings, and near-real virtual food processing experiments in personal kitchen settings for school-age children with accompanying these experiments labs and kits.

A summary of surveys assessing FPE practical applications is included, focusing on the approaches' educational effectiveness, usability for different educational environments, reproducibility, and transferability to other food processing experiments and food topics. A review of pedagogical techniques utilized in FPE practical applications is presented, with an emphasis on science centre settings. A summary of sentiments towards robust new food processing experiments and exhibits and scientists' involvement delightfulness in FPE widespread is included. Directions of future FPE research are suggested.

This chapter aims to inspire firm connections between food processing and a broader Natural Science topic so that all elementary food processing mechanisms can be better covered, and so that in-depth FPE would be fun and enjoyable, using a variety of interactive and engaging FPE experimental lab kits and exhibits. By doing so, a deeper understanding of the science behind food processing would be developed, and a more mindful, environmentally sound, and healthy food choice would arise.

Formative and Summative Assessment Methods

Assessment is an integral part of the teaching and learning process. It provides information on how well students have understood a topic and achieved the expected learning outcomes. Several different methods for assessing and evaluating knowledge, skills, and attitudes can be chosen according to the objectives of the teaching. The assessment used to evaluate the learning of students must assess the learning objectives.

Generally, the assessment methods are widely divided into two groups — Formative and Summative. Formative assessment refers to activities implemented during learning, which provide feedback on learning and so can improve it. The aim of formative assessment is to encourage learning, not to grade it. Many different formative assessment methods are available; some of them can be applied almost all the time in the classroom and some require more time. The highlights of the formative assessment methods applied at the Department of Natural Sciences of the Estonian University of Life Sciences are described. Formative assessment complements and weights the factual learning test.

Formative assessment methods include peer assessment and self-assessment of the small-group discussions held in the case method and group projects on food processing topics, monitoring the progress of the group or individual oral presentations on naturally fermented food production and assessment of the final discussion. Summative assessment methods include different pen-and-paper tests and assignments. The number of students in the Natural Science practical groups is about 10 students. The final grade from the Natural Science practical activities usually consists of 75-80% assessment from the factual learning test and 20-25% summative group assessment.

Summative assessment is implemented after learning is completed. The aim of summative assessment is to evaluate the level of knowledge, skills, and attitudes obtained by students, and based on that, to grade students. The assessment of Natural Science practical activities includes a factual learning test, usually a pen-and-paper test with questions based on theory lectures and practical tasks on food processing and sensorial food quality assessment. Usually, the teaching takes place before the tasks are assessed. The learning of students at the practical activities has not been assessed except for verification that each student has at least attended the teaching. The tasks are factual learning tests and assessment methods that can be used at the same time with the teaching of the subject.

Integrating Food Processing Across Natural Science Curricula

Natural science education encompasses a variety of disciplines with relevant topics. The design and material used for food processing experiments can be interesting for all of the following: general biology, nutrition science, plant biology, food engineering, food chemistry, food safety, microbial ecology, environmental science, and beyond. Recent pedagogical techniques that have been used in natural science and engineering classes include portable and modular laboratory equipment that facilitate hands-on work away from laboratory facilities. Here, this equipment is applied for food fermentation and decontamination experiments in natural science classes on five continents. The presented methodology is pedagogically versatile and modifiable, and it can be adopted by instructors on different academic levels all around the world.

In addition to curricular flexibility, there are also numerous topic connections with biological and chemical sciences in natural science education. Biology- relevant topics in food processing experiments include safe food handling, crop varieties, microbial fermentations, and healthy diets. Safety, sustainability, food composition, and food processing efficiencies can be analyzed from a chemistry perspective. Value chain analysis could encompass all these points and others even broader, e.g., economic and social factors, energy consumption, and political aspects.

Food processing topics can also be applied in motivation and project-based courses in natural science education. Motivated students are very welcome to design and conduct such experiments entirely by themselves, from conceptualization to data analysis, independently from the instructor. Experimental design and interpretation of results can deepen understanding of relevant concepts in biology, chemistry, environmental science, and engineering. Such projects ask for diverse skillsets, encouraging collaboration and having a great impact on the social dynamics of education. Overall, the presentation of the need and relevance of food processing experiments, and the demonstration of their diversity and versatility should stimulate discussion on increasing the amount of hands-on work in natural science education.

Biology and Chemistry Connections

Explorations of food processing lend themselves beautifully to all branches of natural science. However, food processing may not always seem like it fits with the subject of a particular class, especially when that class is focused on a single discipline such as life science or chemistry. Fortunately, the connections between food processing and the various disciplines of natural science are plentiful, and this section introduces a variety of activities that demonstrate many of those connections.

Biology is the most immediately obvious branch of natural science with which food processing can be connected. Fermentation—that is, the processing of foods with microorganisms—is all about biology, whether it employs bacteria or yeast. As yeast, Lactobacillus, or other microorganisms process sugars, they convert them to other products, such as lactic acid or ethanol. The generation of products occurs via specific metabolic pathways which can be demonstrated in school laboratories with culture growth compared to controls or with liquid chromatography if instrumentation is available. By-products themselves may be characterized with methods that vary in complexity from pH and odor measurements to GC-MSMS analysis. Experiments that investigate whether different fermenting organisms and different food substrates result in different by-products can promote inquiry and lead to interesting discussion about how biochemistry produces a variety of end-products as a function of the enzymes involved (e.g. alcoholic versus acidic fermentation) and how the substrate itself (such as whether it is high or low in sugar) influences product generation over growth (e.g. the "Great Taste" debate, which is discussed in another section).

Furthermore, connections between the microbiology of food and food processing using microorganisms do not have to be limited to fermentation. The study of food spoilage and its prevention via processing with heat or refrigeration is another example of an important topic at the biology-chemistry intersection. Experiments could measure food spoilage as a function of time versus temperature (e.g. how long does susu with a certain initial pH require to spoil if left out at room temperature as storage versus refrigeration?) to investigate hypotheses, such as which storage temperature would lead to the longest shelf life of the food. Processes designed to separate the sugars and acids naturally present in foods (using trapped porosity in aggregates of starch or gel pinning based on pH) and edible to humans thereafter could connect biochemistry with an environmental science component if the sugars are converted into biofuels using yeast or algae or the polysaccharides into biodegradable plastics by microorganisms. Biofuels made from food waste can address fuel and environmental issues all at once, tackling an oil shortage crisis while reducing the problem of food waste in landfills.

The chemistry of food processing is commonly taught as a single unit in a chemistry course and thus often seems like something that is very straightforward to include without prior thought. Chemistry is sometimes used with food as a lens and carried out at times during the food preparation or cooking process, although it often seems to be secondary in importance to biology, which is always the focus of a food science class. The more hard science-y properties of food usually explored in chemistry—such as the retention of color—as a function of time or pH during processing seem to often be non-issues because either non-desirable effects are only studied, general tactics to mitigate those effects can be focused on, or discussions about possible trading-off between effects concentrate on the biology (e.g. color-retaining blanching vs. microbial-growth-promoting storage). However, food processing has numerous pedagogically valuable connections with high school chemistry, from redox reactions in fermentation to the properties and interactions of water that can be quantitatively modelled.

The connections between food processing and chemistry frequently seem to boil down to a chosen processing example and a focus on chemistry alone, often with no discussion of biological aspects. However, the more it seems kin- fermented foods could be more immediately and obviously connected to both disciplines in an integrated (although still separate at times) way. Kin-food processing work just as well for food science classes as it does for chemistry and biology classes since they address subjects from both fields. At times, the detailed processing of a common food could be very quickly and easily tackled or described— and usually in a model system that would be very widely available or inexpensive.

Environmental Science Applications

Food processing can be introduced into high school Environmental Science education, encouraging students to investigate waste, pollution, energy use, and even the source of ingredients. The investigation may center on where food comes from. Fast food and convenience food purchasing patterns reflect the need to promote the importance of farming and food technology. Interest in food processing could also stem from cuisine varieties and exotic foods. Key questions arise: how food is grown, transported, stored, preserved, and the science behind it. Technology providing that science is increasingly influencing daily life, yet public understanding is often limited. A range of Environmental Science topics may be infused with food processing. Within an ecosystem model, students may investigate at local and a few upstream levels. Key questions arise: what waste and pollutants exist, are they affecting the ecosystem, are they being treated, and where do they go? Questions at the greater than local level could involve the effects of packaging and pollution in the processing chain.

Alternative pollutant investigations could include global pollution or food chain toxicity, focusing on toxic substances potentially entering crops. European-level questions could be investigated concerning policy and public responses. Hazardous Agricultural Wastes testing could be on a wider basis and include non-EU countries. Energy use issues could assess what energy sources each processing stage utilizes, how energy-intensive each stage is, how energy costs have increased, prospects for renewable technology, and impacts of producing bio-fuel crops on biodiversity. The potential impact of food processing innovations on crop choice, ecosystem, and a food producer's competitive edge could also be investigated. A broader view of the whole agriculture/food industry chain could be explored. Greater unpredictability in quantity and quality of raw materials, greater reliance on monoculture spray agriculture, or water table toxicity could stem from the demand for uniformity (Roehrig et al., 2021; Khudoyberdiyevich et al., 2019).

Geographical and political questions could arise. Is it ethical for northern countries to require Caribbean countries to adhere to EU regulations on chemical use? Is this hypocrisy considering EU's large domestic agricultural subsidies? Why isn't the far east included in Smyth's typology of major countryside changes? What implications does this have for global and European standard of living prospects? The European Union is globalizing its agriculture through free trade agreements and World Trade Organisation commitments.

Professional Development for Educators

The effective implementation of food processing-focused curricula in natural science education depends largely on professional development initiatives designed to equip educators with the requisite knowledge and skills. Various stresses can dampen the exchange of knowledge and inhibit effectively working with the panoply of phenomena described previously. The first basic stressor to be considered is the lack of content knowledge and pedagogical skills to deliver the novel science curriculum: food processing using local raw materials as examples. Teachers are pressured by the curriculum to teach subjects outside their initial training and skills and where available resources and facilities are wanting. Such internal stressors demand the introduction of initiatives designed to facilitate teacher development.

A secure environment for teaching and examination of innovative materials is vital. In a rural environment, where the exchange of knowledge may be limited or non existing, such an environment must rely on external encouragement for successful working and development. Networks may provide quick assurance that the endeavor is apprised and supported elsewhere. Focused in service opportunities, where external and experienced personnel visit the rural center for practical and theoretical innovative courses, may prove beneficial. As experienced staff leave rural communities, encouragement is required for the newly employed candidates to attend workshops to continue teaching work in the disciplines. The challenges posed to rural science teachers and on the sidelines of the background of existing exchange of knowledge must be approached wisely. Local or larger social professional lectures or monthly gatherings where informative talks are organized may build good morale and socialities and provide channels for the supply of knowledge and encouragement.

Recent changes in curriculum and educational practices have emphasized the importance of continuous professional development addressed, among other things, towards the development of science teaching. In recent years, professional development has also emerged as an important issue in educational reform projects at both national and school levels. Teachers' work has changed, and teaching has become increasingly seen as a professional activity that requires ongoing development of knowledge and skills. Professional development is broadly understood as activities intended to improve the growth of individuals' knowledge by enhancing their understanding of and skills relating to their work. Such activities aimed at the improvement of teachers, and hence of educational systems may take many forms including in service education.

Technological Tools for Enhancing Food Processing Education

With the progress of technology, teaching and learning food processing in schools gets easier and more interesting. Several technological tools and resources are available to help teachers with knowledge, skills, and practice. This chapter discusses two technological tools that can help teachers and learners effectively learn and teach food processing topics, especially in developing countries. These tools are simulation software and virtual laboratories. Developing countries like Zambia have limited access to specialized equipment for food processing education, which makes teaching food processing topics a challenge. Simulation software and virtual laboratories can help overcome this limitation and enhance food processing education.

Simulation software allows users to imitate or recreate real-life processes, operations, or scenarios before trying them in real life. This makes it easier to understand, learn, or troubleshoot such processes. In food processing education, simulation software can be used as teaching aids in learning institutions to teach complex theories and principles without dealing with the actual hands-on equipment. A variety of free and commercially available simulation software that would work well in teaching food processing topics exist, and information on such software is presented.

Virtual laboratories offer learners the opportunity to conduct food processing laboratory experiments as if they were in actual laboratories, without being physically present. Virtual laboratories enable enhanced or better participation in the learning process, and there are several free and commercially available virtual laboratories that can be integrated into the teaching and learning process. Information on free and commercially available virtual laboratories that deal specifically with food processing topics is presented.

Simulation Software

Adequate knowledge about food processing and preservation is often lacking among students in the food science field. Nevertheless, due to the great conceptual complexity of food processing, this topic is also hard to teach and comprehend. To help students visualize their knowledge and understanding about food processing, a simulation software called FoodProcessing has been developed. This software simulates food processing in a wide range of applications and forms and can be used for educational purposes in the natural sciences and technology courses. By using food processing as a concrete example, the personality of this software can be utilized: it helps students develop deeper understanding for food science and technology. This software also serves as a pedagogically valuable tool for teachers. Three ways of using the software in education are proposed. First, as a teacher demonstration tool, teachers can use it to introduce and illustrate physical processes in foods when teaching about the food processing equipment in various food processing or preservation techniques. Second, as a simulation tool, students can use it to study food processing effects (including concentration, temperature, moisture content, enzyme activity, etc.) on the textural and mechanical properties of foods and food structures. This would help students deepen their understanding on food structure and the food processing and preservation effects on food. Finally, as a homework assignment tool, a case study about food processing food strands for accurate simulation of 3 due to the uniform external pressure distribution on the body and no axial material velocity consideration that would induce a change of shape at the inlet. This case requires students to have knowledge concerning the mesh generation, boundary conditions, and physical modeling of food processing and preservation.

In recent years, the consistent increase of global energy expenditure and environmental pollution, along with the need of maintaining food safety and process efficiency of the food production industry, has posed default challenges to food engineering fields. A sophisticated computer model toolbox called 'Ansys Fluent' has been adopted and used for students to study the food heating, freeze/thawing, and drying process in food formulations in food engineering courses. With the tailor-made model, students can precisely analyze and simulate the complex food unit operation in multi-dimensions under various configurations. By using Ansys Fluent, students can visualize their knowledge and understanding related to food thermal processing and investigate the process from the perspective of real phenomena. Knowledge exploration, understanding and innovation on food engineering are also promoted. It is anticipated that simulation modeling tools like Ansys Fluent will be implemented as effective pedagogical techniques in food engineering courses to advance students' learning outcomes.

Virtual Laboratories

Universities around the world are increasingly using virtual laboratories in their lectures and practicals. Regardless of being on-site or online, these laboratories make it easier to obtain and share results; hence, they improve education. In literature, there are academic papers on the methodology and technical implementation of virtual laboratories, as well as their use with students. It seems that the vast majority of applications employ general-purpose laboratory simulation environments. However, there are hardly any academic publications or dissertations that describe the design and implementation of Laboratory as a Service (Lab-a-a-S) applications tailored specifically to ongoing research. This paper suggests Lab-a-a-S applications for two phenomena studied in natural science courses, namely food processing technology and polymer science. The associated instruments, switching device, laboratory pendulum, and reaction vessel, which are part of the Lab group, allow a better understanding of processes in nature and technology. This paper presents a general view of these applications intended for education, data analysis, and feedback purposes.

The use of computer-based simulations is extremely wide and ranges from pilot studies to modeling high-tech research reactors etc. Even prediction from next-year risk assessments can be computer-based. There have been many, written by hundreds of authors. Experimental computer based electronic systems for mergers, automotive, food technology, liquid electrodes, cometary impact prevention, household behavior, oceanography, etc. have been designed and implemented. Computer, laboratory, simulation and multi-disciplinary aided systems have emerged and spread exponentially wide over the decades. Nevertheless, health and ecology chambers, or Lab units as proposed here, have never been designed and implemented as PC student tools. Temperature oscillators, basin oscillators, swinging, or vibrating pendulums are interesting laboratory experiments even for undergraduate students. They allow cognition of energy forms, periodic phenomena, planetary motions, chaotic states, damping, damping time, driving frequency, phase shift, resonance, freedom degree, Lyapunov stability, and differential equations. Many real systems share the same principles with these educational observations, e.g., technological, safety, transportation, aerospace instruments, etc. Unfortunately, this understanding is usually abstract, and students may not appreciate it until obtaining a highly specialized job. At the same time, newly designed Lab-a-a-S devices and associated laboratory experiments could be used, vehicle mounted in particular. It would allow low-cost simple misusing understanding and prediction.

Ethical Considerations in Food Processing Education

The development of ethical considerations during the motivation stage of a FPE L2C design process is described. Emphasis is placed on questions concerning societal demands for transparent, safe, affordable, nutritious, and sustainable food produced by food science and technology students, in perspective of climate change, global population growth and urbanization. It is shown that transparent food processing and the safety of food processing substances are especially strong ethical drivers for FPE, and that they are reinforced by a sense of urgency.

During the challenge stage, a perspective on the ethical considerations addressed during the designing of an L2C educational trajectory is described. This perspective discusses the design choices thereof, rather than the content of student FPE proposals. The design choices touch on (i) the societal context of design challenges, (ii) challenges on ethical portrayal of food processing, (iii) broad scope of design challenges, (iv) ethical portrayal of food processing education, (v) implementation of design challenges in educational settings, (vi) addressing design challenges with stakeholder input, and (vii) ensuring diversity among stakeholder representatives.

Design choice (i) is illustrated with quotes from stakeholder as well as student perspectives. Stakeholder quotes are illustrated by striking student questions about food processing that draw further interest in student food processing design proposals. Illustrative student quotes touch on desires to address transparency and food safety in designs, as well as on positive experiences with creating food processing designs based upon societal demand instead of marketing requirements.

The societal context and initial ethical considerations of FPE L2C design process described provide a benchmark, which is to be used in substantial studies with food science and technology students. The substantial studies performed with biosystems engineering and industrial design engineering students serve to broaden the benchmark, which has provided more design experiences and illustration of developments in the intention to generate awareness of food processing in society.

Future Trends and Innovations in Food Processing Education

This chapter explores potential future trends and innovations in teaching food processing within natural science education. The discussions center on aspects such as emerging technologies, evolving pedagogical approaches, global perspectives, and innovative practical applications. Each facet presents unique challenges and opportunities for those involved in food processing education.

Emerging technologies, particularly artificial intelligence, are anticipated to radically alter food processing and education. Teachers are encouraged to consider the implications for their courses, anticipating both positive ramifications, like improved food quality and resource efficiency, and challenges involving job displacement and the propagation of misinformation. The chapter suggests focusing on educating students about the risks and ethical implications of automation rather than merely training them to use new technology, which could quickly become outdated.

Evolving pedagogical approaches, such as flipped classrooms, hands-on and project-based education, and forms of peer education, are viewed as particularly promising. They are thought to foster critical thinking and collaboration skills, lower barriers to entry, and facilitate student-centered, learner-initiated courses. Teachers are encouraged to experiment with these and other innovative pedagogical strategies while considering how to assess their impact.

Global perspectives on food processing education are shifting as new players emerge in the field. Brazil and China aim to become leaders in agricultural production, biotechnology, and nutritional research, while initiatives in Africa, India, and Vietnam seek to educate and leverage local talent. New collaborative frameworks, such as the Global Teaching Academy, emphasize teamwork, fresh perspectives, and proactive solutions in addressing pressing local debates and challenges tied to food conversion, preservation, and processing. Exploring these global endeavors can provide inventive ideas and approaches for food processing instructors, regardless of whether they aim to revise their courses or keep up with changing circumstances.

Innovative practical applications are expected to pose the greatest challenges and opportunities in food processing education. With the escalating activities of the emerging BRICS nations and the European Union, tensions are expected to rise around food availability and quality, food security concerns, climate change, and land ownership disputes. Teachers are encouraged to consider how their education programs can address these pressing and often contentious situations, both locally and globally. The imperative is to defend the role of science in food processing and foster transparent, scientific dialogue on these matters. Innovative tea and coffee tasting and ethical food processing exercises are proposed as possible starting points.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

References

Bobojonova, D., & Karimov, N. (2024). Traditions and History of Librarianship in Central Asia. *Indian Journal of Information Sources and Services*, 14(2), 70–77. https://doi.org/10.51983/ijiss-2024.14.2.11

Brandt, J. O., Barth, M., Merritt, E., & Hale, A. (2021). A matter of connection: The 4 Cs of learning in pre-service teacher education for sustainability. *Journal of Cleaner Production*, *279*, 123749. https://doi.org/10.1016/j.jclepro.2020.123749.

Brown, B. A. (2021). *Science in the city: Culturally relevant STEM education*. Harvard Education Press.

Doig, S.G.A., Ramírez, J.N.G., Ugaz, O.C., Hernández, R.M., Ortiz, J.B.F., Flores, L.A.G., & Larrea, Y.M.B. (2022). Educational Scenarios Using Technology: Challenges and Proposals During the Pandemic. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, 13(4), 182-195.

Felten, P., & Lambert, L. M. (2020). *Relationship-rich education: How human connections drive success in college*. Jhu Press.

Guzzardo, M. T., Khosla, N., Adams, A. L., Bussmann, J. D., Engelman, A., Ingraham, N., & Taylor, S. (2021). "The ones that care make all the difference": Perspectives on student-faculty relationships. *Innovative Higher Education*, *46*, 41-58.

Juuti, K., Lavonen, J., Salonen, V., Salmela-Aro, K., Schneider, B., & Krajcik, J. (2021). A teacher–researcher partnership for professional learning: Co-designing project-based learning units to increase student engagement in science classes. *Journal of Science Teacher Education*, 32(6), 625-641

Karimov, N., & Doniyorov, A. (2019). Conflicting views regarding the hadiths. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 8(3075), 2090-2094.

Khaydarova, S., & Khujamova, S. (2024). The Vital Role of Libraries in Enriching Tourism Experiences. *Indian Journal of Information Sources and Services*, 14(2), 11–16.

Khudoyberdiyevich, D. A., & Ugli, O. B. A. (2019). Ethnographic researches on irrigated agriculture and collective land cultivation of the Uzbek people (In the example of 20-30s of XX th century). *International Journal of Innovative Technology and Exploring Engineering*, 9(1), 3645-3649.

Lavanya, P., Subba, R. I. V., Selvakumar, V., & Shreesh, V. D. (2024). An intelligent health surveillance system: Predictive modeling of cardiovascular parameters through machine learning algorithms using LoRa communication and Internet of Medical Things (IoMT). *Journal of Internet Services and Information Security*, 14(1), 165-179.

Llopiz-Guerra, K., Daline, U.R., Ronald, M.H., Valia, L.V.M., Jadira, D.R.J.N., & Karla, R.S. (2024). Importance of Environmental Education in the Context of Natural Sustainability. *Natural and Engineering Sciences*, 9(1), 57-71.

Mathur, G., Nathani, N., Chauhan, A. S., Kushwah, S. V., & Quttainah, M. A. (2024). Students' Satisfaction and Learning: Assessment of Teaching-Learning Process in Knowledge Organization. *Indian Journal of Information Sources and Services*, 14(1), 1–8.

Mehta, K., Alter, T. R., Semali, L. M., & Maretzki, A. (2022). AcademIK connections: Bringing indigenous knowledge and perspectives into the classroom. *Journal of Community Engagement and Scholarship*, 6(2), 83-91.

Mukhamajanovich, S. S., Gayratovna, S. S., & Ravshanovich, G. M. (2020). The use of the mountain karst in the tourism sphere in the cort and recreation zone of Chimgan-Charvak. *Journal of Critical Reviews*, 7(3), 475-481.

Odilov, B. A., Madraimov, A., Yusupov, O. Y., Karimov, N. R., Alimova, R., Yakhshieva, Z. Z., & Akhunov, S. A. (2024). Utilizing Deep Learning and the Internet of Things to Monitor the Health of Aquatic Ecosystems to Conserve Biodiversity. *Natural and Engineering Sciences*, 9(1), 72-83. https://doi.org/10.28978/nesciences.1491795

Reiser, B. J., Novak, M., McGill, T. A., & Penuel, W. R. (2021). Storyline units: An instructional model to support coherence from the students' perspective. *Journal of Science Teacher Education*, 32(7), 805-829.

Roehrig, G. H., Dare, E. A., Ring-Whalen, E., & Wieselmann, J. R. (2021). Understanding coherence and integration in integrated STEM curriculum. *International Journal of STEM Education*, 8, 1-21.

Sh, S., Gudalov, M., & Sh, S. (2020). Geolologic situation in the Aydar-Arnasay colony and its atropny. *Journal of Critical Reviews*, 7(3), 451-454.

Srinivasa Rao, M., Praveen Kumar, S., & Srinivasa Rao, K. (2023). Classification of Medical Plants Based on Hybridization of Machine Learning Algorithms. *Indian Journal of Information Sources and Services*, 13(2), 14–21.

Vander Ark, T., Liebtag, E., & McClennen, N. (2020). *The power of place: Authentic learning through place-based education*. ASCD.

Verma, G., Campbell, T., Melville, W., & Park, B. Y. (2020). Science teacher education in the times of the COVID-19 pandemic. *Journal of Science Teacher Education*, 31(5), 483-490.

Yusubov, J. K., Yusubov, J. K., Khidaevich, J. B., Khadjiev, U. S., & Nematov, O. N. (2021). The importance of modern technologies in the teaching of philosophy. *Technology*, 2(1), 35-45.