Physics Concepts in Traditional Bakpia Production: Exploring Local Culinary Processes as Contextual Learning Resources

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ABSTRACT

Traditional culinary practices often involve physics processes that can be interpreted through scientific principles, yet these phenomena are rarely explored as contextual learning resources in physics education. This study aims to identify and analyze physics concepts embedded in the traditional production of bakpia, a well-known local pastry from Yogyakarta, Indonesia. The research employed a qualitative descriptive approach through direct observation and documentation of the dough mixing and roasting stages in a local bakpia production setting. The observed processes were then analyzed using fundamental physics concepts, particularly in the domains of mechanics and heat transfer. The results indicate that the dough mixing stage reflects principles of rotational motion, pulley transmission, angular velocity, frictional interaction, and mechanical power, while the roasting stage demonstrates multiple heat transfer mechanisms, including conduction, convection, and radiation. These findings reveal that traditional bakpia production inherently embodies scientific principles that can be explained through physics concepts. The study highlights the potential of local culinary practices as meaningful contextual resources for physics learning, contributing to the development of culturally relevant and context-based science education.

Keywords: *Bakpia Production; Contextual Learning Resources; Local Culinary; Physics Concepts.*

ABSTRAK

Praktik kuliner tradisional sering kali melibatkan proses-proses fisika yang dapat dijelaskan melalui prinsip-prinsip ilmiah, namun fenomena tersebut masih jarang dieksplorasi sebagai sumber pembelajaran kontekstual dalam pendidikan fisika. Penelitian ini bertujuan untuk mengidentifikasi dan menganalisis konsep-konsep fisika yang terkandung dalam proses produksi tradisional bakpia, salah satu kue khas dari Yogyakarta, Indonesia. Penelitian ini menggunakan pendekatan deskriptif kualitatif melalui observasi langsung dan dokumentasi pada tahap pencampuran adonan dan proses pemanggangan di salah satu tempat produksi bakpia. Proses yang diamati kemudian dianalisis menggunakan konsep-konsep dasar fisika, khususnya pada bidang mekanika dan perpindahan kalor. Hasil penelitian menunjukkan bahwa tahap pencampuran adonan merepresentasikan prinsip-prinsip gerak rotasi, transmisi puli, kecepatan sudut, interaksi gaya gesek, dan daya mekanik, sedangkan tahap pemanggangan menunjukkan adanya beberapa mekanisme perpindahan kalor, yaitu konduksi, konveksi, dan radiasi. Temuan ini menunjukkan bahwa proses produksi bakpia secara tradisional secara inheren mengandung prinsip-prinsip ilmiah yang dapat dijelaskan melalui konsep-konsep fisika. Penelitian ini menyoroti potensi praktik kuliner lokal sebagai sumber pembelajaran kontekstual yang bermakna dalam pembelajaran fisika serta berkontribusi pada pengembangan pendidikan sains yang berbasis konteks dan relevan secara kultural.

Kata kunci: Produksi Bakpia; Sumber Pembelajaran Kontekstual; Kuliner Lokal; Konsep Fisika.

INTRODUCTION

Physics learning often presents challenges for students because many of its concepts are abstract and difficult to visualize in real-life situations (Asriadi AM et al., 2025; Georgiou et al., 2021; Rosenberg & Lawson, 2019; Uwambajimana et al., 2023). Concepts such as energy conversion, mechanical motion, and heat transfer are commonly introduced through theoretical explanations or simplified textbook examples (Wati et al., 2025), which may limit students' ability to connect these ideas with phenomena encountered in everyday life. As a result, students may perceive physics as difficult and disconnected from their daily experiences (Hazari et al., 2022; James et al., 2020). To overcome this issue, physics education increasingly emphasizes the importance of contextual learning approaches that relate physics concepts to real-world phenomena familiar to students (Joshi, 2026; Kotsis, 2025; Wei et al., 2025).

One effective strategy to contextualize physics learning is the integration of local cultural practices into instructional contexts (Oladejo et al., 2023; Pejaner & Mistades, 2020; Soko et al., 2019). Everyday cultural activities often contain implicit physics phenomena that can be explored to explain scientific principles (Govender & Mudzamiri, 2022). Traditional culinary processes involve various physics phenomena (Sari et al., 2024), including rotational motion, force interactions, energy transformation, and heat transfer. Interpreting these processes using physics concepts can provide concrete examples that help students understand abstract principles while connecting scientific learning to everyday experiences.

This approach is closely related to the concept of ethnoscience, which integrates indigenous knowledge systems with scientific perspectives. Ethnoscience enables students to contextualize abstract scientific concepts within familiar cultural practices (Abrams et al., 2013; Ardianti & Raida, 2022; Kurdiati, 2026). Hikmawati et al. (2020) defines ethnoscience as the study of cultural and natural phenomena that are transmitted across generations, highlighting its potential role in both education and cultural preservation. Integrating ethnoscience into learning therefore supports not only conceptual understanding but also cultural awareness among learners (Rahmawati et al., 2020). In physics education, this approach allows students to observe physics principles directly within real activities practiced in their communities (Ariani & Hariyadi, 2024; Jufrida et al., 2025; Rodiah et al., 2025).

Several empirical studies have reported the positive impact of integrating local cultural contexts into science and physics learning. Ibnu Fitrianto & Muhammad Farisi (2025) found that incorporating local cultural practices into classroom learning helps students become more familiar with their social and cultural environments while fostering positive attitudes toward local traditions. Similarly, Fitri et al. (2024) reported that ethnoscience-based learning can enhance students' critical thinking skills and collaboration abilities. Furthermore, Kasi et al. (2024) emphasized that integrating local wisdom into science learning promotes contextual understanding and increases students' motivation to learn. These findings suggest that cultural activities can serve as effective contexts for understanding scientific principles, including those in physics.

Within everyday cultural practices, traditional culinary production processes provide rich opportunities to explore physics phenomena. One example is the production of *bakpia*, a traditional Indonesian pastry widely associated with Yogyakarta. The process of producing *bakpia* involves several stages, including dough mixing, heating, and roasting. Each stage implicitly demonstrates important physics concepts. The dough mixing process involves mechanical rotation, force interaction, and energy conversion within a mixing machine, while the heating and roasting stages involve various mechanisms of heat transfer such as conduction, convection, and radiation. These processes provide observable real-life contexts that can help students understand fundamental physics principles.

Previous studies have explored the integration of ethnoscience in traditional culinary practices as a context for science learning. For example, a study conducted by Putri et al. (2025) examined the traditional process of making *gethuk* using an ethnoscience approach and identified several scientific concepts embedded in the activity, including physics changes, heat transfer, mechanical energy, and chemical transformations. The findings demonstrate that traditional food production processes can provide meaningful contexts for understanding scientific principles while connecting learning with local culture. However, most existing studies still address these cultural practices within the broader scope of science education and do not specifically analyze the underlying physics concepts in detail.

Despite the strong potential of cultural practices as contextual learning resources, the exploration of physics concepts within traditional culinary production processes remains insufficient. Everyday food production activities involve various physics phenomena such as mechanical motion, force interactions, energy transformation, and heat transfer, yet these phenomena are rarely examined systematically from a physics perspective. As a result, the potential of traditional culinary practices to illustrate fundamental physics principles has not been fully explored. In this context, examining the production process of *bakpia* offers an opportunity to identify the physics phenomena involved in its preparation and to demonstrate how these processes can provide meaningful contexts for understanding physics concepts.

Research Aim and Research Questions

This study aims to explore the physics concepts embedded in the traditional process of *bakpia* production and examine their potential as contextual learning resources in physics education. By analyzing the physics phenomena involved in different stages of *bakpia* production, this research seeks to reveal how everyday culinary processes can illustrate fundamental physics principles in real-world contexts. In particular, the study focuses on the mechanical and thermal processes occurring during the dough mixing stage and the heat transfer mechanisms involved in the roasting process. Based on this objective, the following research questions were formulated:

RQ1: What mechanical and thermal processes occur during the dough mixing stage in traditional *bakpia* production?

RQ2: What heat transfer mechanisms are involved in the *bakpia* roasting process?

METHOD

Research Design

This study employed an exploratory qualitative research design to investigate the physics concepts embedded in the traditional process of *bakpia* production. Exploratory research is used to examine phenomena that have not been widely studied and to generate a deeper understanding of the processes involved (Lösch et al., 2023). In this study, the exploratory approach was used to identify and interpret physics phenomena that occur in different stages of *bakpia* production, particularly those related to mechanical processes and heat transfer. The research was conducted in Yogyakarta, Indonesia, specifically at *Bakpia* Lestari 536, a local *bakpia* production site where the traditional preparation process can be directly observed.

The focus of the study was the production process of *bakpia*, including the dough mixing stage and the roasting process. These stages were selected because they involve observable physics phenomena such as rotational motion, force interaction, energy transformation, and heat transfer, which can be analyzed from a physics perspective and potentially used as contextual learning resources in physics education.

Data Collection Techniques

Data were collected primarily through direct observation of the *bakpia* production process in order to obtain detailed information about the physics phenomena occurring during each stage of production. The observations were conducted at the *bakpia* production site, focusing on the dough mixing and roasting stages. During the observation, the researchers carefully documented the sequence of production activities, the types of equipment used, and the operational procedures involved in each stage.

Particular attention was given to identifying observable physics processes, such as the rotational motion of the mixing machine, the interaction of forces during dough processing, and the heating mechanisms occurring during the roasting stage. Detailed field notes were recorded to capture descriptions of the production activities, equipment operation, and the physics changes observed throughout the process. These observations served as the primary data source for identifying the physics concepts embedded in the *bakpia* production process.

To complement the observational data, limited semi-structured interviews were conducted with *bakpia* producers and workers involved in the production process. The interviews were mainly used to clarify certain technical aspects of the production procedures, such as the operation of equipment and the sequence of processing stages. The information obtained from the interviews helped support and verify the interpretations derived from the observational data.

Data Analysis Techniques

The collected data were analyzed through a qualitative interpretative approach combined with physics content analysis. The analysis began by organizing the observational field notes and reviewing the information obtained during the production observations. The data were then examined to identify physics phenomena occurring in the dough mixing and roasting stages. Each identified phenomenon was subsequently interpreted using relevant physics concepts. Mechanical processes such as rotational motion, force interaction, and energy transformation were analyzed in the dough mixing stage, while thermal processes including heat transfer mechanisms were examined in the roasting stage.

The observed phenomena were then translated into formal physics explanations by relating them to established physics principles and relevant equations. Through this analytical process, the traditional *bakpia* production activities were reconstructed into a structured representation of physics concepts. This reconstruction made it possible to map the physics content embedded in the production process and to demonstrate its relevance as a contextual learning resource in physics education.

RESULTS AND DISCUSSION

Mechanical and Thermal Processes in the Dough Mixing Stage

The dough mixing stage in *bakpia* production involves several physics phenomena related to mechanical motion and thermal processes. During this stage, flour, sugar, oil, and other ingredients are placed inside a metal mixing container and continuously stirred using rotating blades until a homogeneous dough mixture is formed. The mixing process causes the dough to undergo repeated deformation through stretching, folding, and compression. These processes can be analyzed using fundamental concepts of rotational mechanics and energy transformation.

The mechanical interaction between the dough and the mixing blades becomes clearer when observing the structure of the mixing system used during the production process. The configuration of the mixing blades inside the container can be seen in Figure 1.

Figure 1. Mixing blades inside the dough container

As shown in Figure 1, the mixing blades rotate around a central shaft, producing circular motion that drives the movement of the dough mixture inside the container. In rotational motion, the displacement of a rotating object is described by angular displacement θ. If a point on the blade moves along a circular path with arc length s and radius r, the angular displacement can be expressed as Equation (1).

$$\theta = \frac{s}{r} \tag{1}$$

The rate of change of angular displacement with respect to time defines the angular velocity. This relationship can be written as Equation (2).

$$\omega = \frac{d\theta}{dt} \tag{2}$$

For a mixing system operating at a constant rotational speed, the angular velocity can also be expressed using the rotational frequency f. The relationship between angular velocity and frequency is given in Equation (3).

$$\omega = 2\pi f \tag{3}$$

Because the mixing blades rotate around a central axis, each point on the blade moves with a linear velocity that depends on its distance from the axis of rotation. The relationship between linear velocity and angular velocity can therefore be written as Equation (4).

$$v = r\omega \quad (4)$$

This equation indicates that the linear velocity increases with the radial distance from the rotation axis. Consequently, portions of the dough that are farther from the center experience higher velocities, which enhances the mixing efficiency by increasing the deformation and movement of the dough mixture.

The rotational motion of the mixing blades is produced by a mechanical drive system powered by an electric motor. The motor converts electrical energy into mechanical rotational motion that is transmitted to the mixing shaft through a pulley and belt mechanism. The configuration of this driving system can be observed in Figure 2.

Figure 2. Electric motor and pulley transmission system

As illustrated in Figure 2, the electric motor functions as the main driving component of the mixing machine. In rotational mechanics, the ability of the motor to rotate the mixing shaft against the resistance of the dough mixture is described by torque. The torque produced by a force acting at a distance from the rotation axis can be expressed as Equation (5).

$$\tau = rF \quad (5)$$

Equation (5) shows that torque increases when a larger force acts at a greater radial distance from the axis of rotation, where r is the distance from the axis of rotation and F is the applied force. The torque generated by the motor allows the mixing blades to overcome the resistance of the dough mixture, which behaves as a viscous material during the mixing process.

The pulley system connecting the motor and the mixing shaft also regulates the rotational speed transmitted to the mixer. Because the belt transmits motion without slipping, the tangential velocities at the rims of both pulleys must be equal. If the motor pulley has radius r_1 and the mixer pulley has radius r_2, the relationship between their angular velocities can be written as Equation (6).

$$\frac{\omega_1}{\omega_2} = \frac{r_2}{r_1} \quad (6)$$

Equation (6) indicates that the pulley ratio determines the relationship between the rotational speeds of the motor and the mixer shaft, where ω_1 represents the angular velocity of the motor and ω_2 represents the angular velocity of the mixer shaft. Because the mixer pulley is typically larger than the motor pulley, the mixer rotates more slowly but produces greater torque.

If the motor rotates at n revolutions per minute, the angular velocity of the motor can be calculated using Equation (7).

$$\omega_1 = \frac{2\pi n}{60} \quad (7)$$

Using the pulley ratio relationship in Equation (6), the angular velocity of the mixer shaft can be estimated as shown in Equation (8).

$$\omega_2 = \omega_1 \left(\frac{r_1}{r_2}\right) \quad (8)$$

During operation, the motor performs mechanical work to rotate the mixing shaft and overcome the resistance of the dough. In rotational motion, the work performed by a torque acting through an angular displacement can be expressed as Equation (9).

$$W = \tau\theta \quad (9)$$

Because angular displacement can also be written as Equation (10).

$$\theta = \omega T \quad (10)$$

Substituting Equation (10) into Equation (9) gives the expression for work in terms of angular velocity and time, as shown in Equation (11).

$$W = \tau\omega t \quad (11)$$

The rate at which this work is performed represents the mechanical power delivered by the motor. Power is defined as work per unit time and can be written as Equation (12).

$$P = \frac{W}{t} \quad (12)$$

Substituting Equation (11) into Equation (12) results in the well-known rotational power relationship given in Equation (13).

$$P = \tau\omega \quad (13)$$

Equation (13) shows that the mechanical power supplied by the motor depends on both the torque generated and the angular velocity of the rotating shaft.

During the mixing process, the rotating blades experience resistance from the dough mixture. This resistance can be approximated as a frictional interaction between the dough and the blade surface. The friction force can be expressed as Equation (14).

$$F_f = \mu N \quad (14)$$

In Equation (14), μ represents the coefficient of friction between the dough and the blade surface and N represents the normal force exerted by the dough on the blade.

In addition to mechanical processes, thermal phenomena can also be observed during the dough mixing stage. In this production system, heat is supplied by a gas burner located beneath the mixing container to assist the mixing process. The configuration of the heat source can be seen in Figure 3.

Figure 3. Gas flame beneath the mixing container

As shown in Figure 3, the flame generated by the gas burner transfers thermal energy to the metal container that holds the dough mixture. The heat transfer through the container wall occurs primarily through conduction. According to Fourier’s law, the heat transfer rate through a solid material can be expressed as Equation (15).

$$\dot{Q} = \frac{kA\Delta T}{L} \quad (15)$$

In Equation (15), k represents the thermal conductivity of the container material, A represents the surface area through which heat flows, ΔT represents the temperature difference between the heat source and the container, and L represents the thickness of the container wall.

Part of the mechanical energy generated during mixing may also be converted into heat due to friction between the blades and the dough. This energy transformation follows the principle of energy conservation, which can be expressed as Equation (16).

$$W = \Delta E + Q \quad (16)$$

where W represents the mechanical work performed by the mixer, ΔE represents the change in mechanical energy of the system, and Q represents the heat produced during the mixing process.

The electrical power supplied to the motor can be estimated using the electrical power relationship shown in Equation (17).

$$P = VI \quad (17)$$

where V represents the supplied voltage and I represents the electric current flowing through the motor. Part of this electrical power is converted into mechanical power that drives the mixing system, while the remaining energy is dissipated as heat due to electrical resistance and mechanical friction within the system.

Overall, the dough mixing stage in *bakpia* production demonstrates several fundamental physics concepts, including rotational motion, angular velocity, torque, mechanical work, power, pulley transmission, frictional interaction, and heat transfer. These physics phenomena illustrate how traditional culinary production processes can provide meaningful real-world contexts for understanding fundamental physics principles.

Heat Transfer Mechanisms in the *Bakpia* Roasting Process

The roasting stage represents an important phase in traditional *bakpia* production because it transforms raw dough into a cooked product through the transfer of thermal energy. In this stage, the filled dough pieces are placed on a large metal tray positioned above a gas-fired furnace. Unlike modern baking systems that use enclosed ovens, this traditional roasting technique uses an open heated tray, allowing heat from the burner to directly affect the tray and the dough.

As the roasting process proceeds, the *bakpia* dough undergoes several observable physical changes, including the evaporation of moisture, the formation of a crust layer, and the browning of the surface. These changes occur as thermal energy from the heat source is transferred to the dough through several heat transfer mechanisms. Observing this process provides a practical example of how heat transfer concepts in physics operate in everyday culinary activities. The roasting configuration observed during production shows that *bakpia* pieces are arranged on a heated metal tray located above the furnace. The arrangement of *bakpia* during the roasting process can be seen in Figure 4.

Figure 4. Arrangement of *bakpia* dough on the heated tray during the roasting process

As shown in Figure 4, the *bakpia* pieces are placed directly on the metal tray that has been heated by the flame beneath it. In this configuration, heat is mainly transferred from the hot tray to the dough through thermal conduction, which occurs when heat flows through direct contact between two materials with different temperatures. The metal tray absorbs heat from the burner and transfers this energy to the *bakpia* placed on its surface. The conductive heat transfer process can be described using Fourier's law of heat conduction, which can be written as Equation (18).

$$\frac{dQ}{dt} = -kA\frac{dT}{dx} \quad (18)$$

where k represents the thermal conductivity of the material, A represents the area through which heat flows, and $\frac{dT}{dx}$ represents the temperature gradient along the direction of heat transfer.

If the temperature gradient across a material of thickness L is assumed to be approximately uniform, the temperature gradient can be expressed as Equation (19).

$$\frac{dT}{dx} = \frac{T_2 - T_1}{L} \quad (19)$$

Substituting Equation (19) into Equation (18) gives the conductive heat transfer rate shown in Equation (20).

$$\frac{dQ}{dt} = -kA\frac{T_2 - T_1}{L} \quad (20)$$

Ignoring the negative sign, which only indicates the direction of heat flow, the magnitude of the conductive heat transfer rate can be written as Equation (21).

$$\dot{Q}_{cond} = \frac{kA\Delta T}{L} \quad (21)$$

Equation (21) indicates that the rate of heat conduction increases when the temperature difference between the tray and the *bakpia* becomes larger.

Besides conduction, heat transfer also occurs between the *bakpia* surface and the surrounding air through convection. Because the roasting tray is open, the air around it is heated by the hot tray and the flame below. The heated air becomes less dense and rises upward, creating natural convection currents around the *bakpia*.

The rate of convective heat transfer can be described using Newton's law of cooling, expressed in Equation (22).

$$\dot{Q}_{conv} = hA(T_s - T_\infty) \quad (22)$$

In Equation (22), h represents the convective heat transfer coefficient, A represents the exposed surface area of the *bakpia*, T_s represents the surface temperature of the *bakpia*, and T_∞ represents the temperature of the surrounding air.

Another important heat transfer mechanism in this traditional roasting system is thermal radiation emitted by the burner flame and the hot metal surfaces. The thermal energy used in the roasting process originates from a gas-fired burner located beneath the metal tray. The structure of this heat source can be observed in Figure 5.

Figure 5. Gas burner used as the heat source in the roasting process

As illustrated in Figure 5, the gas burner produces a flame that releases thermal energy through fuel combustion. This heat is transferred to the roasting tray and the surrounding environment through several mechanisms, including thermal radiation from the flame, convection of hot gases, and conduction through the metal structure of the roasting system.

Thermal radiation refers to heat transfer in the form of electromagnetic waves emitted by objects at high temperatures. The radiative heat energy emitted by a hot surface can be described using the Stefan–Boltzmann law, which is expressed as Equation (23).

$$P = \varepsilon\sigma A T^4 \quad (23)$$

In Equation (23), P represents the radiative power emitted by the surface, ε represents the emissivity of the radiating surface, σ represents the Stefan–Boltzmann constant ($5.67 \times 10^{-8}\ W/m^2K^4$), A represents the surface area of the emitting object, and T represents the absolute temperature.

If the surrounding environment also emits thermal radiation, the net radiative heat transfer between a surface and its surroundings can be expressed as Equation (24).

$$P = \varepsilon\sigma A(T_1^4 - T_2^4) \quad (24)$$

where T_1 represents the temperature of the emitting surface and T_2 represents the temperature of the surrounding environment. In heat transfer analysis, the radiative power emitted by a surface can also be interpreted as the rate of radiative heat transfer. Therefore, Equation (24) can be written in terms of radiative heat transfer rate as $\dot{Q}_{rad}$.

Because conduction, convection, and radiation occur simultaneously during the roasting process, the total heat transfer rate in the roasting system can be expressed as Equation (25).

$$\dot{Q}_{total} = \dot{Q}_{cond} + \dot{Q}_{conv} + \dot{Q}_{rad} \quad (25)$$

Equation (25) indicates that the total thermal energy transferred to the *bakpia* results from the combined contributions of conductive heat transfer from the heated tray, convective heat transfer between the *bakpia* surface and the surrounding air, and radiative heat transfer from the burner flame.

The heat supplied by the gas burner increases the temperature of the metal tray positioned above the flame. As the tray absorbs thermal energy from the burner, its temperature rises and heat is subsequently transferred to the *bakpia* placed on its surface. The increase in temperature of a heated object can be estimated using the relationship between heat energy and temperature change, which can be written as Equation (26).

$$Q = mc\Delta T \quad (26)$$

In Equation (26), m represents the mass of the heated component, c represents the specific heat capacity of the material, and ΔT represents the resulting temperature increase.

Rearranging Equation (26) gives the temperature change as shown in Equation (27).

$$\Delta T = \frac{Q}{mc} \quad (27)$$

The relationship in Equation (27) indicates that the temperature increase of the tray or other heated components depends on the amount of heat supplied by the burner and the thermal capacity of the material.

After absorbing heat from the burner, thermal energy spreads along the metal tray through conduction. The temperature distribution along the tray surface can be approximated using the one-dimensional heat diffusion equation shown in Equation (28).

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} \quad (28)$$

In Equation (28), α represents the thermal diffusivity of the tray material. This equation describes how temperature differences gradually spread across the tray surface until a more uniform temperature distribution is achieved.

Finally, the roasting time required for the *bakpia* to reach the desired temperature can be estimated from the heat required to raise the temperature of the dough. The required heat energy can be expressed as Equation (29).

$$Q = mc(T_f - T_i) \quad (29)$$

where T_i is the initial temperature of the dough and T_f is the final temperature. If the heat transfer rate to the *bakpia* is represented by $\dot{Q}$, the roasting time can be estimated using Equation (30).

$$t = \frac{Q}{\dot{Q}} \quad (30)$$

Substituting Equation (29) into Equation (30) results in the roasting time estimation given in Equation (31).

$$t = \frac{mc(T_f - T_i)}{\dot{Q}} \quad (31)$$

Equation (31) indicates that the roasting time depends on the mass of the dough, the required temperature increase, and the rate of heat transfer from the heated tray and surrounding environment to the *bakpia*.

Overall, the *bakpia* roasting process illustrates the simultaneous interaction of several heat transfer mechanisms, including conduction from the heated metal tray, natural convection between the *bakpia* surface and the surrounding air, and thermal radiation from the gas burner. These processes determine how heat is distributed during roasting and influence the time required to produce properly cooked *bakpia*. Observing these phenomena in traditional *bakpia* production demonstrates how fundamental concepts of thermodynamics and heat transfer can be understood through everyday culinary practices.

Discussion

This study demonstrates that traditional *bakpia* production contains implicit physics processes that can be interpreted through formal physics concepts. Rather than merely representing culinary practices, the dough mixing and roasting stages illustrate how everyday technologies operate according to fundamental principles of mechanics and heat transfer. In the mixing stage, the rotation of the blades, the transmission of motion through the pulley system, and the interaction between the dough and the mixing components reflect concepts such as angular motion, torque, and mechanical power. Meanwhile, the roasting stage shows how thermal energy from the gas burner is transferred to the dough through conduction, convection, and radiation. These observations indicate that traditional food production processes inherently involve physical mechanisms that can be analyzed using scientific frameworks. Therefore, the identification of these physical phenomena directly supports the main objective of this research, which is to explore local culinary practices as contextual learning resources for physics education.

The significance of these findings lies in their potential contribution to contextual and culturally relevant science learning. Physics concepts are often perceived by students as abstract and disconnected from everyday experiences (Körhasan & Gürel, 2019; Sönmez et al., 2024). Learning contexts that relate scientific ideas to familiar activities can help students interpret theoretical knowledge more meaningfully. In this regard, incorporating examples derived from local cultural practices may support the development of learning materials that connect classroom instruction with students' daily environments. Smith et al. (2022) suggest that local cultural practices can serve as valuable sources of learning materials that enrich science curricula with culturally relevant contexts. Similarly, Harefa (2024) emphasize that integrating local knowledge into science instruction can strengthen the relationship between scientific understanding and daily life experiences.

The use of traditional food production as a learning context also aligns with the ethnoscience approach in science education (Julianti et al., 2025). Ethnoscience highlights how local knowledge systems and cultural practices can be interpreted through scientific frameworks without disregarding their cultural significance (Kurdiati et al., 2025). Susandra et al. (2025) indicate that ethnoscience-integrated learning can enhance student engagement in contextual problem-solving activities, allowing learners to connect scientific concepts with local knowledge and everyday experiences, which in turn supports the development of critical thinking skills.

In this perspective, the *bakpia* production process provides a meaningful example of how local technologies can be used to illustrate scientific principles while maintaining their cultural authenticity. Furthermore, the integration of local contexts into science education has been widely discussed as a strategy to improve student engagement and conceptual understanding (Rahmawati et al., 2020). Isa et al. (2022) argues that connecting scientific knowledge with students' cultural backgrounds helps bridge the gap between everyday knowledge and formal science. In a similar vein, Wulandari et al. (2025) found that contextual learning integrating local cultural values can make learning more meaningful by encouraging students to become more active and critical while also fostering social and character development aligned with their cultural environment.

The present study therefore contributes to the growing body of research that emphasizes the importance of culturally contextualized science education. By examining the physics phenomena embedded in *bakpia* production, this research provides an example of how local culinary practices can be transformed into meaningful teaching resources for physics learning. Such an approach not only helps students understand scientific concepts more effectively but also promotes appreciation of local culture and traditional knowledge systems. Nevertheless, this study has several limitations. The analysis focuses primarily on conceptual interpretation of physics processes observed in the *bakpia* production stages. More detailed experimental measurements of mechanical parameters and thermal conditions could provide deeper quantitative insights into these processes. Future studies may integrate experimental instrumentation, such as temperature sensors or rotational speed measurements, to further strengthen the scientific analysis of traditional production technologies.

Overall, the findings of this study reinforce the value of integrating local cultural practices into physics education as meaningful contextual learning environments. The processes involved in *bakpia* production demonstrate that fundamental physics principles are embedded in routine community activities and local technologies. When these processes are explored as learning contexts, students can better understand how scientific concepts operate in real-world situations. Thus, integrating local culinary practices into physics education not only supports conceptual understanding but also encourages students to recognize the relevance of physics in their daily lives and cultural environments.

CONCLUSION

This study demonstrates that traditional *bakpia* production contains various physics phenomena that can be systematically interpreted using fundamental physics concepts, particularly in the areas of mechanics and heat transfer. By analyzing the dough mixing and roasting stages, this research reveals how processes commonly found in local culinary practices implicitly involve principles such as rotational motion, mechanical energy transfer, and multiple heat transfer mechanisms.

These findings support the research objective of exploring traditional culinary activities as contextual resources for physics learning. The main contribution of this work lies in bridging local cultural practices with formal scientific concepts, thereby providing a framework for integrating ethnoscience-based contexts into physics education. By identifying and interpreting the physics principles embedded in *bakpia* production, this study advances the current understanding of how everyday cultural technologies can serve as meaningful contexts for teaching abstract physics concepts. Such contextualization has the potential to make physics learning more relevant, accessible, and culturally responsive for students.

REFERENCES

Abrams, E., Taylor, P. C., & Guo, C.-J. (2013). Contextualizing Culturally Relevant Science and Mathematics Teaching for Indigenous Learning. *International Journal of Science and Mathematics Education*, *11*(1), 1–21. https://doi.org/10.1007/s10763-012-9388-2

Ardianti, S. D., & Raida, S. A. (2022). The Effect of Project Based Learning with Ethnoscience Approach on Science Conceptual Understanding. *Journal of Innovation in Educational and Cultural Research*, *3*(2), 207–214. https://doi.org/10.46843/jiecr.v3i2.89

Ariani, T., & Hariyadi, B. (2024). Integration of

Ethnoscience Approach in Physics Learning Based on Laboratory Practice: A Systematic Literature Review. *Jurnal Penelitian Pembelajaran Fisika*, *15*(3), 252–262. https://doi.org/10.26877/jp2f.v15i3.18765

Asriadi AM, M., Purnama, E., & Sanam, A. I. (2025). Diagnosing students' difficulties and strategies to overcome them in physics learning. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *29*(2), 199–216. https://doi.org/10.21831/pep.v29i2.89736

Fitri, C. N., Saminan, Safitri, R., Ramadhan, T. M. H., Evendi, & Safrida S. (2024). Ethnoscience-Based Inquiry Learning to Increase Students' Critical Thinking Skills and Collaboration Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8810–8818. https://doi.org/10.29303/jppipa.v10i11.9736

Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development*, *69*(6), 3051–3080. https://doi.org/10.1007/s11423-021-10055-y

Govender, N., & Mudzamiri, E. (2022). Incorporating indigenous artefacts in developing an integrated indigenous-pedagogical model in high school physics curriculum: views of elders, teachers and learners. *Cultural Studies of Science Education*, *17*(3), 827–850. https://doi.org/10.1007/s11422-021-10076-2

Harefa, D. (2024). Strengthening Mathematics and Natural Sciences Education Based on the Local Wisdom of South Nias: Integration of Traditional Concepts in Modern Education. *Haga : Jurnal Pengabdian Kepada Masyarakat*, *3*(2), 63–79. https://doi.org/10.57094/haga.v3i2.2347

Hazari, Z., Dou, R., Sonnert, G., & Sadler, P. M. (2022). Examining the relationship between informal science experiences and physics identity: Unrealized possibilities. *Physical Review Physics Education Research*, *18*(1), 010107. https://doi.org/10.1103/PhysRevPhysEducRes.18.010107

Hikmawati, H., Suastra, I. W., & Pujani, N. M. (2020). Ethnoscience-Based Science Learning Model to Develop Critical Thinking Ability and Local Cultural Concern for Junior High School Students in Lombok. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 60–66. https://doi.org/10.29303/jppipa.v7i1.530

Ibnu Fitrianto, & Muhammad Farisi. (2025). Integrating Local Wisdom into 21st Century Skills: A Contextual Framework for Culturally Relevant Pedagogy in Rural Classrooms. *International Journal of Post Axial: Futuristic Teaching and Learning*, 109–121. https://doi.org/10.59944/postaxial.v3i2.444

Isa, I. M. M., Bunyamin, M. A. H., & Phang, F. A. (2022). Bridging Culture and Science Education: Implications for Research and Practice. *International Journal of Learning, Teaching and Educational Research*, *21*(10), 362–380. https://doi.org/10.26803/ijlter.21.10.20

James, W., Bustamante, C., Lamons, K., Scanlon, E., & Chini, J. J. (2020). Disabling barriers experienced by students with disabilities in postsecondary introductory physics. *Physical Review Physics Education Research*, *16*(2), 020111. https://doi.org/10.1103/PhysRevPhysEducRes.16.020111

Joshi, A. S. (2026). Transforming Learning Experiences: A Case Study of Integrating Contextual Teaching and Learning (CTL) in the Physics Course within a Bachelor of Technology Program. *Journal of Engineering Education Transformations*, *39*(3), 86–97. https://doi.org/10.16920/jeet/2026/v39i3/26083

Jufrida, J., Kurniawan, W., Furqon, M., Anwar, K., Shidow Falah, H., & Riantoni, C. (2025). AI-Driven Ethnoscience Learning: Enhancing Physics Education Through Malay Cultural Insights. *Journal of Information Technology Education: Innovations in Practice*, *24*, 013. https://doi.org/10.28945/5520

Julianti, M., Aina, T., Prasiwi, J., Fatonatullaillah, I., Widiyastuti, W., & Usman, U. (2025). Exploring Ethnoscience-

Oriented PjBL-STEM Model Implementation in Biology Education: A Traditional Food Context Study. *International Journal of STEM Education for Sustainability*, *5*(2), 257–261. https://doi.org/10.53889/ijses.v5i2.696

Kasi, Y. F., Widodo, A., Samsudin, A., Riandi, R., Novia, N., Sukmawati, W., & Shidiq, A. S. (2024). Integrating Local Science and School Science: The Benefits for Preserving Local Wisdom and Promoting Students' Learning. *PAEDAGOGIA*, *27*(1), 24. https://doi.org/10.20961/paedagogia.v27i1.83925

Körhasan, N. D., & Gürel, D. K. (2019). Student Teachers' Physics Knowledge and Sources of Knowledge to Explain Everyday Phenomena. *Science Education International*, *30*(4), 298–309. https://doi.org/10.33828/sei.v30.i4.7

Kotsis, K. T. (2025). From Theory to Practice: Exploring Students' Everyday Use of Physics Knowledge. *European Journal of Contemporary Education and E-Learning*, *3*(5), 59–76. https://doi.org/10.59324/ejceel.2025.3(5).05

Kurdiati, L. A. (2026). Collaborative Integration of Indigenous Knowledge and Pedagogical Approaches in Science Education: A Systematic Review of Epistemological Perspectives (2020–2025). *Abjadia : International Journal of Education*, *11*(1), 128–142. https://doi.org/10.18860/abj.v11i1.40284

Kurdiati, L. A., Susiloningsih, E., & Fathurohman, A. (2025). Mapping Indigenous Knowledge in Science Education: A Systematic Literature Network and Bibliometric Analysis. *Journal of Educational Science and Technology (EST)*, *11*(3), 122. https://doi.org/10.26858/est.v11i3.82309

Lösch, S., Rambo, C. A., & Ferreira, J. L. (2023). Exploratory research in the qualitative approach in education. *Revista Ibero-Americana de Estudos Em Educação*, *18*, e023141. https://doi.org/10.21723/riaee.v18i00.17958

Oladejo, A. I., Okebukola, P. A., Akinola, V. O., Amusa, J. O., Akintoye, H., Owolabi, T., Shabani, J., & Olateju, T. T. (2023). Changing the Narratives of Physics-Learning in Secondary Schools: The Role of Culture, Technology, and Locational Context. *Education Sciences*, *13*(2), 146. https://doi.org/10.3390/educsci13020146

Pejaner, K. J., & Mistades, V. (2020). Culturally Relevant Science Teaching: A Case Study of Physics Teaching Practices of the Obo Monuvu Tribe. *Science Education International*, *31*(2), 185–194. https://doi.org/10.33828/sei.v31.i2.8

Putri, A., Fawaida, U., Sa'adah, A. L., Meilinda, D. P., & Sertiansyach, A. T. (2025). Exploring Gethuk-Making Processes: An Ethnoscience Approach to Elementary Science Education. *Jurnal Review Pendidikan Dasar: Jurnal Kajian Pendidikan Dan Hasil Penelitian*, *11*(1), 101–114. https://doi.org/https://doi.org/10.26740/jrpd.v11n1.p101-114

Rahmawati, Y., Ridwan, A., Cahyana, U., & Wuryaningsih, T. (2020). The Integration of Ethnopedagogy in Science Learning to Improve Student Engagement and Cultural Awareness. *Universal Journal of Educational Research*, *8*(2), 662–671. https://doi.org/10.13189/ujer.2020.080239

Rodiah, S., Herayanti, L., Sukroyanti, B. A., Gummah, S., Habibi, H., & Joselevich, M. (2025). Development of Ethnoscience-Based Physics Teaching Materials on the Topic of Motion Dynamics to Enhance Students' Critical Thinking Skills. *International Journal of Ethnoscience and Technology in Education*, *2*(2), 223–242. https://doi.org/10.33394/ijete.v2i2.16997

Rosenberg, J. M., & Lawson, M. A. (2019). An Investigation of Students' Use of a Computational Science Simulation in an Online High School Physics Class. *Education Sciences*, *9*(1), 49. https://doi.org/10.3390/educsci9010049

Sari, I. J., Syafira, R., Zakkiya, Y. H., Ambarsari, R., & Saputra, O. (2024). Ethnophysics of Klepon: Exploring Physics Concepts in Traditional Pasuruan Snack. *International Journal of Research and Community Empowerment*, *2*(2), 48–55.

https://doi.org/10.58706/ijorce.v2n2.p48-55

Smith, T., Avraamidou, L., & Adams, J. D. (2022). Culturally relevant/responsive and sustaining pedagogies in science education: theoretical perspectives and curriculum implications. *Cultural Studies of Science Education*, *17*(3), 637–660. https://doi.org/10.1007/s11422-021-10082-4

Soko, I. P., Setiawan, A., & Widodo, A. (2019). Physics Teachers' Ability in Planning and Implementing Cultural-Based Physics Learning Activities on Education and Training. *Jurnal Penelitian Dan Pembelajaran IPA*, *5*(2), 169. https://doi.org/10.30870/jppi.v5i2.6754

Sönmez, E. D., Önder, A. N., & Güven Yıldırım, E. (2024). Examining Students' Explanations of Some Physics Topics with Diagrams and Association of Them with Daily Life. *Karaelmas Eğitim Bilimleri Dergisi*, *12*(1), 61–77. https://doi.org/10.58638/kebd.1490231

Susandra, R. R., Yamtimah, S., & Sudiyanto, S. (2025). Analysis of The Implementation of Problem-Based Learning Model Integrated with Ethnoscience in Enhancing Critical Thinking Skills in Elementary Science Education. *Social, Humanities, and Educational Studies (SHES): Conference Series*, *8*(1), 477. https://doi.org/10.20961/shes.v8i1.98980

Uwambajimana, S., Minani, E., Mollel, A. D., & Nyirahabimana, P. (2023). The impact of using PhET simulation on conceptual understanding of electrostatics within selected secondary schools of Muhanga District, Rwanda. *Journal of Mathematics and Science Teacher*, *3*(2), em045. https://doi.org/10.29333/mathsciteacher/13595

Wati, E., Samsudin, A., Saepuzaman, D., & Sozbilir, M. (2025). Trend of Applying the Conceptual Change Model in Physics Learning: Systematic Literature Review. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *14*(1), 131–143. https://doi.org/10.24042/jipfalbiruni.v14i1.26130

Wei, Y., Peng, X., Zhong, Y., Pi, F., Zhai, Y., & Bao, L. (2025). Can contextualized physics problems enhance student motivation? *Physical Review Physics Education Research*, *21*(2), 020117. https://doi.org/10.1103/2g1b-hmhq

Wulandari, I. G. A. A. M., Adnyani, L. P. S., Serianti, N. P., & Purandina, I. P. Y. (2025). Application of contextual teaching and learning (CTL) which utilizes Balinese indigenous insight in school learning. *Journal of Local Wisdom*, *1*(1), 1–6. https://nohanjournal.com/index.php/JLW/article/view/23