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WHO-Aligned Food Safety Knowledge and Misconceptions Among Vocational Food-Processing Students

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Abstract

Food safety knowledge is essential for vocational students who handle food during school-based processing activities. This study assessed food safety knowledge and examined selected misconceptions among Grade XI students enrolled in an Agricultural Product Processing Agribusiness program at one public vocational secondary school in West Lombok Regency, Indonesia. A descriptive cross-sectional design with an embedded qualitative explanatory component was used. Of 46 students in the cohort, 10 participated in questionnaire pilot testing and were excluded from the main study. The remaining 36 students completed an 11-item True/False questionnaire aligned with the WHO Five Keys to Safer Food framework and participated in individual semi-structured interviews. Students demonstrated strong recognition of handwashing, kitchen-surface cleanliness, separation of raw and cooked foods during storage, and washing fruits and vegetables. However, misconceptions concerned shared cutting boards, thorough reheating, cooking temperature, prolonged room-temperature storage, and judging water safety by appearance. The mean knowledge score was 7.86 of 11, and the questionnaire showed marginal-to-moderate internal consistency for preliminary group-level diagnostic use (KR-20 = 0.69). Interview findings indicated that some students considered previous cooking sufficient, associated reheating with burning, viewed freshly slaughtered meat as containing few bacteria, and treated clear water as safe. These findings identify curriculum priorities related to cross-contamination, time–temperature control, reheating, and invisible microbiological and chemical hazards. Because the study involved one vocational cohort, the findings should be interpreted as a local diagnostic profile.

Keywords: Food Safety Knowledge, Food Safety Misconceptions, Vocational Students, WHO Five Keys, Food-Processing Education

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INTRODUCTION

Food safety is an important public health and educational concern for adolescents. Foodborne illness can adversely affect health and nutrition, while inadequate food-handling knowledge may expose students and their families to preventable risks (Bulduk & Bulduk, 2021; WHO, 2006). Adolescence is also a formative period during which repeated practices may develop into lasting habits. Consequently, food safety principles learned at school may influence how students handle, prepare, and store food both during their education and later in adulthood. Schools therefore provide an important setting in which students can acquire scientifically accurate knowledge and practice safe food-handling procedures.

Previous research indicates that secondary-school students do not always apply general food safety principles correctly in specific situations. Students may recognize widely promoted practices, such as handwashing and washing fresh produce, while continuing to misunderstand less visible risks involving cross-contamination, cooking temperatures, reheating, and food storage (Majowicz et al., 2015; Radulović et al., 2021; Wanniarachchi et al., 2023). Observational and intervention studies in high-school teaching kitchens have similarly shown that awareness of food safety rules does not necessarily translate into consistent food-handling behavior (Brown et al., 2016; Diplock et al., 2018, 2019). These findings suggest that effective food safety education must extend beyond familiarity with general hygiene messages and develop students' ability to apply food safety principles to practical decisions.

Studies involving adult food handlers and consumers in low- and middle-income settings also report persistent knowledge gaps across the WHO Five Keys to Safer Food domains (Raji et al., 2021; Tuglo et al., 2021; Makhunga et al., 2023; Desye et al., 2023). Cross-contamination and time–temperature control appear to be among the most frequently misunderstood areas. For example, limited awareness of cross-contamination and temperature management has been reported among consumers in Jordan, while studies of food handlers in Ghana and other settings have identified weaknesses related to thorough cooking and temperature control (Almanasrah et al., 2022; Tuglo et al., 2021). Although these studies demonstrate the broader relevance of domain-specific assessment, much of the available evidence concerns adult consumers, commercial food handlers, or street-food vendors rather than students preparing for food-related occupations.

Vocational secondary school students enrolled in agriculture and food-processing programs are a particularly important population because their education includes practical activities involving raw materials, utensils, equipment, storage, and product preparation. Food safety knowledge is therefore relevant not only to students' personal and household practices but also to their preparation for internships and future employment in food-related settings. Practical vocational instruction can strengthen food safety learning by connecting scientific principles with authentic processing tasks (Ko, 2020; Ovca et al., 2018). However, repeated practical experience may also reinforce unsafe routines when students rely on visual appearance, sensory judgment, or familiar household practices rather than microbiological principles. Misconceptions acquired during training could consequently influence later food-handling decisions in occupational settings (Diplock et al., 2018; Imathiu, 2020).

A central challenge in food safety education is the difference between visible hygiene practices and invisible microbial hazards. Practices such as handwashing and surface cleaning are readily observed, repeatedly promoted, and relatively easy to monitor. By contrast, cross-contamination, microbial survival, and time–temperature control require students to understand processes that may not change the appearance, smell, or taste of food (Brown et al., 2016; Johnston et al., 2014). A cutting board may appear clean while still transferring microorganisms from raw to cooked food. Similarly, freshly prepared or refrigerated food may still present a risk when it has been inadequately cooked, improperly cooled, stored for too long, or insufficiently reheated. Students may therefore know a general rule, such as separating raw and cooked food, but fail to recognize how the rule applies to shared utensils, storage conditions, or reheating practices (Feng et al., 2019; Pivarnik et al., 2008).

The WHO Five Keys to Safer Food framework provides a practical structure for examining these different dimensions of food safety knowledge. The framework includes keeping food-handling environments clean, separating raw and cooked foods, cooking food thoroughly, maintaining safe temperatures, and using safe water and raw materials (WHO, 2006). A domain- and item-level assessment based on this framework can identify specific misconceptions that may be concealed by an overall knowledge score. For example, students may obtain a relatively high total score because they correctly recognize familiar hygiene practices while still misunderstanding a small number of high-risk concepts involving cross-contamination or temperature management. Identifying these specific weaknesses can help vocational teachers design targeted instructional activities rather than repeating information that students already understand.

Existing studies have examined food safety knowledge among secondary-school students, future food handlers, and students working in teaching kitchens (Majowicz et al., 2015; Ovca et al., 2018; Radulović et al., 2021; Wanniarachchi et al., 2023). However, evidence remains limited for students enrolled in Agricultural Product Processing Agribusiness programs in Indonesia, particularly at the level of individual WHO Five Keys concepts. Broader knowledge–attitude–practice assessments can describe general food safety conditions, but they may not reveal the specific reasoning that leads students to accept unsafe practices. Moreover, little is known about how vocational students explain misconceptions concerning reheating, meat-cooking temperature, and the use of visual appearance to judge water safety. Addressing this gap is important because curriculum improvement requires information not only about which items students answer incorrectly but also about the assumptions underlying those responses.

The present study therefore provides a local diagnostic profile of food safety knowledge among one Grade XI cohort enrolled in an Agricultural Product Processing Agribusiness program at a public vocational secondary school in West Lombok Regency, Indonesia. The assessment was aligned with the five WHO food safety domains and was supplemented by brief follow-up discussions that explored students' explanations for selected misconceptions. The study was not intended to validate a new instrument or represent all vocational students in West Lombok or Indonesia. Instead, it aimed to identify curriculum-relevant strengths and knowledge gaps within the participating cohort.

The study addressed the following research questions:

(1) What is the pattern of food safety knowledge among Grade XI students enrolled in the Agricultural Product Processing Agribusiness program?
(2) Which WHO Five Keys domains and questionnaire items show the greatest knowledge gaps among the participating students?
(3) What explanations do students provide for selected misconceptions concerning thorough reheating, meat-cooking temperature, and water safety?

METHOD

Research Design

This study used a descriptive cross-sectional design with an embedded qualitative explanatory component. Cross-sectional surveys are appropriate for describing food safety knowledge within a defined population at a particular point in time and have been used in previous food safety assessments involving students and consumers (Luo et al., 2019; Ishra et al., 2025). The quantitative component assessed students' food safety knowledge using an 11-item questionnaire aligned with the World Health Organization Five Keys to Safer Food framework (WHO, 2006). The qualitative component used focused follow-up interviews to examine students' reasoning regarding selected misconceptions concerning reheating, meat-cooking temperature, and water safety.

The quantitative and qualitative findings were integrated during interpretation to produce a context-specific diagnostic profile of students' knowledge and underlying misconceptions. This embedded explanatory approach allowed the interview findings to clarify selected questionnaire responses without treating the qualitative component as a separate standalone study (Brumpton et al., 2023; Lacy et al., 2022).

Study Setting and Participants

The study was conducted on 3 May 2025 at one public vocational secondary school in West Lombok Regency, Indonesia. The school's identity was withheld to protect institutional confidentiality. The Agricultural Product Processing Agribusiness program had one Grade XI cohort comprising 46 students. Ten students participated in questionnaire pilot testing and were excluded from the main study. A census of all 36 eligible non-pilot students in the cohort was therefore conducted.

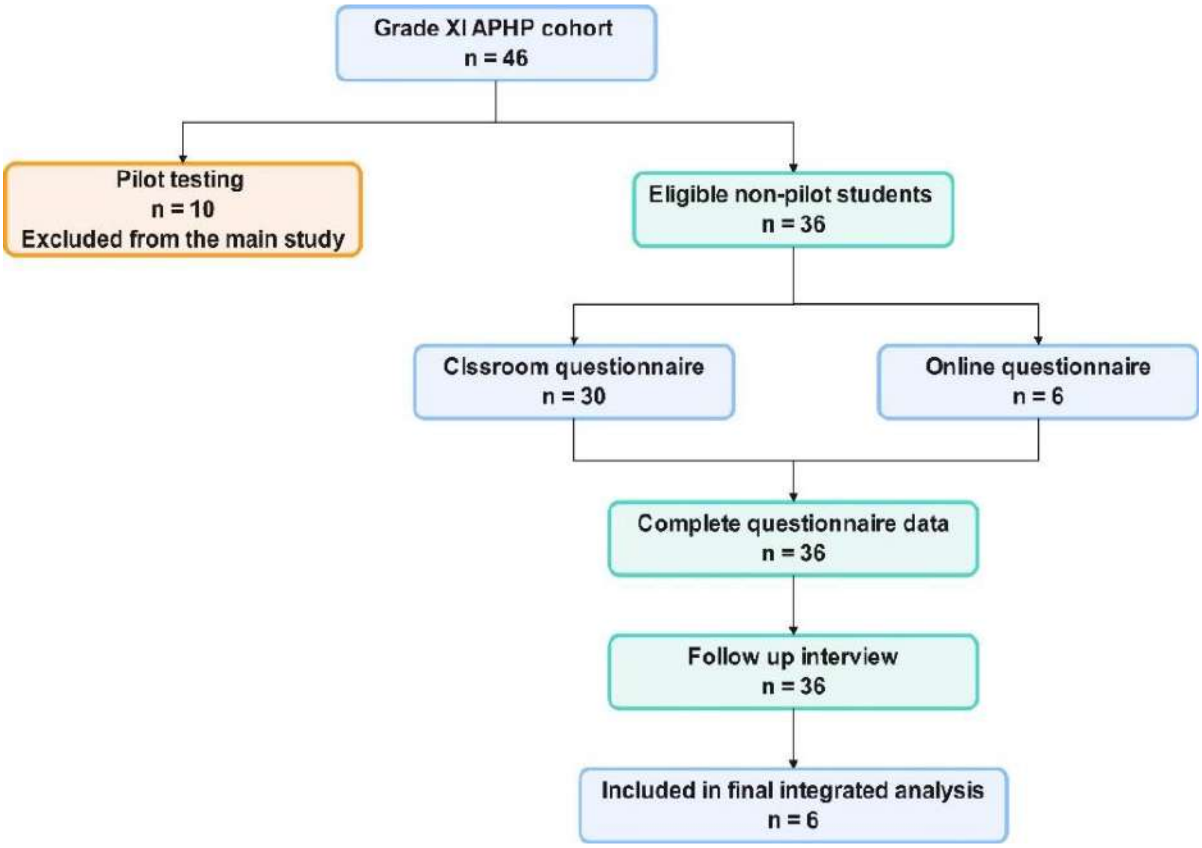

Figure 1. Participant recruitment and study flow

All 36 eligible students completed the questionnaire and follow-up interviews. The main-study sample comprised 25 female students (69.44%) and 11 male students (30.56%). Thirty students completed the questionnaire during a supervised classroom session, while six completed the identical online version because they were unavailable during classroom administration. Both administration modes used the same instructions, item wording, and item order.

Students were eligible for the main study if they were enrolled in the Grade XI Agricultural Product Processing Agribusiness program, had not participated in pilot testing, provided the required consent or assent, and completed the questionnaire. Students were excluded if they had participated in pilot testing, lacked the required authorization, submitted a duplicate response, or did not complete the instrument. No eligible main-study participant was excluded after data collection. Participant recruitment and study flow are presented in Figure 1.

Table 1. Participant characteristics and recruitment flow

Component	Description
Study setting	One public vocational secondary school in West Lombok Regency, Indonesia
Program	Agricultural Product Processing Agribusiness
Grade level	Grade XI
Data-collection date	3 May 2025
Recruitment approach	Census of all eligible non-pilot students in one Grade XI cohort
Total cohort	46 students
Pilot participants	10 students
Main-study participants	36 students
Female	25 students (69.44%)
Male	11 students (30.56%)
Classroom administration	30 students
Online administration	6 students
Follow-up interviews	36 students
Completion rate among eligible students	100%
Privacy	Anonymous responses; school identity withheld

Questionnaire Development and Structure

The research team developed a structured, self-administered questionnaire based on the principles described in the WHO Five Keys to Safer Food manual (WHO, 2006). The questionnaire was designed as a preliminary diagnostic instrument rather than a fully validated measurement scale. It comprised 11 dichotomous True/False items covering the five WHO food safety domains shown in Table 2.

Table 2. WHO Five Keys domains and item mapping

WHO key domain	Item numbers
Keep clean	1–2
Separate raw and cooked	3–4
Cook thoroughly	5–6
Keep food at safe temperatures	7–9
Use safe water and raw materials	10–11

Items 3, 5, 6, 7, and 10 were negatively worded. An explicit answer key derived from the WHO guidance was therefore used so that “True” was not automatically treated as the correct response for every item (WHO, 2006).

Table 3. Food safety knowledge items

No.	Statement	Response options
1	It is important to wash hands before handling food.	True / False
2	Keeping kitchen surfaces clean reduces the risk of disease.	True / False
3	The same cutting board can be used for raw and cooked food as long as it looks clean.	True / False
4	Raw food needs to be stored separately from cooked food.	True / False
5	Cooked food does not need to be reheated thoroughly.	True / False
6	Proper cooking of meat means it is cooked to a temperature of 40 °C.	True / False
7	Cooked meat can be left at room temperature overnight until it cools before being placed in the refrigerator.	True / False
8	Cooked food should be kept hot before serving.	True / False
9	Cooling food only slows down bacterial growth.	True / False
10	Safe water can be identified by its appearance.	True / False
11	Fruits and vegetables need to be washed.	True / False

Expert Review and Language Adaptation

The draft questionnaire was reviewed independently by three experts: a food science lecturer, a science education lecturer, and a vocational teacher experienced in agricultural product processing. The reviewers assessed item relevance, clarity, age appropriateness, and alignment with the intended WHO domain. Their recommendations were discussed by the research team, and agreed revisions were incorporated.

Formal quantitative content validation commonly requires structured expert ratings and reporting of item- and scale-level content-validity indices or content-validity ratios (Osman et al., 2021). Because numerical expert ratings were not collected in the present study, the procedure was described as qualitative expert review rather than formal quantitative content validation.

The questionnaire was administered in Bahasa Indonesia. A bilingual researcher translated the initial item concepts, and a second bilingual researcher reviewed the translation for semantic equivalence and suitability for Grade XI vocational students. Differences were resolved through discussion. Recommended cross-cultural adaptation procedures commonly include forward translation, backward translation, expert review, cultural adaptation, and pretesting (Díaz-Fernández et al., 2023; Farrag et al., 2023; Almalki & Abdel-aziem, 2025). Because a formal forward–backward translation process was not conducted, the procedure used in this study was described as bilingual semantic review rather than full cross-cultural validation.

Pilot Testing

The preliminary questionnaire was pilot-tested with 10 students from the same Grade XI cohort. These students were excluded from the main study and all final analyses. Pilot testing examined item comprehension, administration procedures, and completion time. Minor wording revisions were made to Items 5, 6, 7, and 10 to improve clarity. The questionnaire required approximately 15–20 minutes to complete.

The pilot was used to identify comprehension and administration problems rather than to establish the instrument's psychometric validity. Cognitive and pilot testing are useful for identifying unclear wording and improving the alignment between intended concepts and respondents' interpretations before full administration (Farzad et al., 2025).

Questionnaire Scoring

Each correct response was scored 1, and each incorrect response was scored 0. The total knowledge score ranged from 0 to 11, with higher scores indicating a greater number of correct responses. Domain scores were calculated by summing the items assigned to each WHO domain: Keep clean, 0–2; Separate raw and cooked, 0–2; Cook thoroughly, 0–2; Keep food at safe temperatures, 0–3; and Use safe water and raw materials, 0–2.

No categorical labels such as "poor," "moderate," or "good" were assigned because the questionnaire had no validated interpretive threshold. Total and domain scores were therefore interpreted descriptively. The final Bahasa Indonesia questionnaire, English translation, answer key, domain mapping, and scoring instructions are provided in Appendix A.

Qualitative Follow-Up Interviews

All 36 main-study participants completed individual semi-structured interviews after questionnaire administration. Interviews were conducted in Bahasa Indonesia by the first author, a food science education researcher trained in semi-structured interviewing, in a private room at the school. Each interview lasted approximately 10–15 minutes.

The interviews focused on Item 5 concerning thorough reheating, Item 6 concerning meat-cooking temperature and the perceived safety of freshly slaughtered meat, and Item 10 concerning the use of appearance to judge water safety. Item-specific prompts were adapted to each student's questionnaire response. The qualitative analysis reported in this study focused primarily on explanations associated with incorrect responses because the purpose was to clarify the principal misconceptions identified quantitatively.

The interviews were audio-recorded with permission and transcribed verbatim in Bahasa Indonesia. Recordings were checked against the transcripts, and participant names were replaced with anonymous codes from S01 to S36. Researcher-added factual explanations were separated from students' statements and were not treated as qualitative data. Transparent reporting of transcription, translation, and interpretation procedures is important in multilingual qualitative research because meaning may shift across languages (Seibert, 2021; Henderson et al., 2022; Hamid & Oyinloye, 2025). The interview guide is provided in Appendix B.

Qualitative Data Analysis

Directed qualitative content analysis was used. The initial analytical structure reflected the three selected concepts: reheating, meat-cooking temperature and microbial safety, and water safety. Two researchers independently read the transcripts, identified relevant meaning units, assigned initial codes, and grouped similar codes into explanatory categories. Coding differences were resolved through discussion and re-examination of the original transcripts.

A participant could express more than one explanation; therefore, the categories were not mutually exclusive. Category frequencies were calculated from the interview transcripts and reported separately from questionnaire percentages. Representative quotations were translated into English while preserving their original meaning. The translation decisions were checked against the original Bahasa Indonesia wording to support traceability and reduce interpretive distortion (Seibert, 2021; Hamid & Oyinloye, 2025).

Data Collection Procedure

Before data collection, students received written information explaining the study purpose, voluntary participation, confidentiality protections, and the absence of academic consequences. Classroom questionnaires were completed under researcher supervision. The online version was restricted to one response per registered student account, and submission timestamps were checked to identify possible duplicate responses. No duplicate submissions were identified.

After questionnaire completion, all participants took part in the follow-up interviews. Questionnaire and interview data were linked using anonymous participant codes. Paper questionnaires, electronic responses, interview recordings, and transcripts were stored securely and were accessible only to the research team.

Ethical Considerations

The study was approved by the Research Ethics Committee of the Faculty of Science, Engineering, and Applied Sciences, Universitas Pendidikan Mandalika, under approval number 0734.1/FSTT/PP/UNDIKMA/2025 on 25 April 2025. Permission to conduct the study was also obtained from the participating school.

Written parental or guardian consent and student assent were obtained for participants younger than 18 years. Participants aged 18 years provided written informed consent. Permission for audio recording was included in the consent and assent procedures. Participation was voluntary, and students were informed that declining or withdrawing would not affect their grades, school standing, or access to learning activities.

All records were anonymized. Digital data were stored in password-protected folders, while paper documents were kept in a locked cabinet accessible only to the research team. The school's identity was withheld to reduce the risk of institutional or participant identification.

Quantitative Data Analysis

Quantitative analyses were performed using SPSS version 26. Raw True/False responses were summarized using frequencies and percentages and then recoded as correct or incorrect according to the WHO-based answer key. Item-level percentages of correct responses were reported with 95% Wilson confidence intervals.

Total scores were calculated by summing the 11 correctly scored items. Domain scores were calculated by summing the items assigned to each WHO Five Keys domain. Total performance was summarized using the mean score, while domain performance was reported as the mean number and mean percentage of correct responses.

Internal consistency of the 11 dichotomous items was assessed using the Kuder–Richardson Formula 20 coefficient. KR-20 is appropriate for dichotomously scored knowledge items and can be interpreted alongside item difficulty and corrected item–total correlations (Podda et al., 2023). Item difficulty was represented by the percentage of correct responses, and the overall range of corrected item–total correlations was reported. Item–total statistics are useful for identifying items that contribute weakly to an overall knowledge score, although they should be interpreted in relation to the intended content and multidomain structure of the instrument (Farrag et al., 2023; Podda et al., 2023).

Items answered correctly by all participants were identified as having zero variance and limited discriminatory value. Separate domain-level reliability coefficients were not calculated because each domain contained only two or three items and would have produced unstable estimates in this small sample. Ceiling effects were considered when interpreting items answered correctly by nearly all participants because such items provide little differentiation among respondents (Locquet et al., 2021).

No exact binomial tests against an 80% proficiency benchmark were conducted because the questionnaire had no validated performance threshold. The psychometric findings were interpreted as preliminary and suitable for exploratory group-level diagnosis rather than individual competency assessment.

Integration of Quantitative and Qualitative Findings

Integration occurred during interpretation. The questionnaire identified food safety concepts with substantial knowledge gaps, while the interviews clarified the reasoning underlying selected incorrect responses. Findings were integrated through a joint display linking item-level questionnaire performance, qualitative explanatory categories, representative quotations, and educational implications. Joint displays and explanatory integration can help connect quantitative patterns with qualitative evidence while preserving the distinct contribution of each dataset (Brumpton et al., 2023; Lacy et al., 2022). Questionnaire percentages and qualitative category frequencies were reported separately because an incorrect questionnaire response did not necessarily correspond to one specific explanation.

RESULTS AND DISCUSSION

Participant Characteristics and Data Completion

Thirty-six Grade XI students from the Agricultural Product Processing Agribusiness program completed the main study. The sample comprised 25 female students (69.44%) and 11 male students (30.56%). Thirty students completed the questionnaire during supervised classroom administration, while six completed the identical online version. All participants provided complete questionnaire responses and participated in the follow-up interviews; therefore, no cases were excluded from the final analysis.

Item-Level Food Safety Knowledge

Questionnaire responses were recoded as correct or incorrect using the answer key derived from the WHO Five Keys to Safer Food framework (WHO, 2006). This recoding was necessary because Items 3, 5, 6, 7, and 10 were negatively worded. Table 4 presents the number and percentage of students answering each item correctly, together with 95% Wilson confidence intervals.

Three items reached ceiling performance. All students correctly recognized the importance of washing hands before handling food (Item 1), separating raw and cooked foods during storage (Item 4), and washing fruits and vegetables (Item 11). Nearly all students also correctly recognized that maintaining clean kitchen surfaces reduces disease risk (Item 2; 97.22%).

The weakest performance occurred for Item 7. Only eight students (22.22%) correctly rejected the practice of leaving cooked meat at room temperature overnight before refrigeration. Item 3 was answered correctly by 13 students (36.11%), indicating that 23 students (63.89%) did not recognize the cross-contamination risk associated with using the same cutting board for raw and cooked foods.

Table 4. Item-level food safety knowledge after WHO-based recoding (N = 36)

Item	WHO domain	Correct response	Correct (n)	Correct (%)	95% CI
1	Keep clean	True	36	100.00	90.36–100.00
2	Keep clean	True	35	97.22	85.83–99.51
3	Separate raw and cooked	False	13	36.11	22.48–52.42
4	Separate raw and cooked	True	36	100.00	90.36–100.00
5	Cook thoroughly	False	23	63.89	47.58–77.52
6	Cook thoroughly	False	17	47.22	31.99–62.99
7	Keep food at safe temperatures	False	8	22.22	11.72–38.08
8	Keep food at safe temperatures	True	28	77.78	61.92–88.28
9	Keep food at safe temperatures	True	27	75.00	58.93–86.25
10	Use safe water and raw materials	False	24	66.67	50.33–79.79
11	Use safe water and raw materials	True	36	100.00	90.36–100.00

Item 6 was answered correctly by 17 students (47.22%), whereas 19 students (52.78%) incorrectly accepted 40 °C as an adequate cooking temperature for meat. Additional misconceptions concerned reheating and water safety. Thirteen students (36.11%) incorrectly agreed that cooked food did not require thorough reheating, and 12 students (33.33%) incorrectly believed that safe water could be identified from its appearance.

Domain-Level Performance

Performance varied across the five WHO domains. Table 5 presents the mean number and percentage of correct responses within each domain. Because the domains contained only two or three items, the results were interpreted as descriptive indicators rather than independent measurement scales.

Table 5. Domain-level performance based on the WHO Five Keys framework

WHO domain	Items	Number of items	Mean correct (maximum)	Mean correct (%)
Keep clean	1–2	2	1.97 (2)	98.61
Separate raw and cooked	3–4	2	1.36 (2)	68.06
Cook thoroughly	5–6	2	1.11 (2)	55.56
Keep food at safe temperatures	7–9	3	1.75 (3)	58.33
Use safe water and raw materials	10–11	2	1.67 (2)	83.33

The highest performance occurred in the Keep clean domain, with a mean of 98.61% correct. Use safe water and raw materials had the second-highest mean performance at 83.33%. However, this domain combined perfect performance on washing fruits and vegetables with weaker understanding of whether water safety could be judged from appearance.

The lowest performance occurred in Cook thoroughly (55.56%), followed by Keep food at safe temperatures (58.33%). Performance within the Separate raw and cooked domain was also uneven. Although all students recognized the need to store raw and cooked foods separately, only 36.11% recognized the risk of using the same cutting board for both.

Total Knowledge Score and Preliminary Measurement Properties

The mean total knowledge score was 7.86 of a possible 11. The 11-item questionnaire produced a KR-20 coefficient of 0.69, indicating marginal-to-moderate internal consistency for preliminary group-level diagnostic use. Item difficulty, expressed as the percentage of correct responses, ranged from 22.22% to 100.00%, while corrected item–total correlations ranged from 0.12 to 0.43.

Table 6. Total knowledge score and preliminary instrument properties

Metric	Value
Number of participants	36
Possible score range	0–11
Mean total score	7.86
KR-20	0.69
Item difficulty range	22.22%–100.00% correct
Corrected item–total correlation range	0.12–0.43

Items 1, 4, and 11 had zero variance because all students answered them correctly. These items therefore did not discriminate among participants in the present cohort. The measurement findings were interpreted cautiously because of the small sample, short multidomain structure, and ceiling effects on several items.

Interview Explanations of Selected Misconceptions

All 36 students participated in the follow-up interviews. The qualitative analysis focused on explanations related to Item 5 on thorough reheating, Item 6 on meat-cooking temperature and freshness, and Item 10 on water safety. Questionnaire percentages and qualitative category frequencies were analyzed separately because an incorrect questionnaire response did not necessarily correspond to one specific explanation. Students could express more than one reason; therefore, the qualitative categories were not mutually exclusive.

Reheating Was Considered Unnecessary or Harmful to Food Quality

Thirteen students incorrectly agreed that cooked food did not require thorough reheating. Among these students, 11 (84.62%) explained that previous cooking was sufficient to make the food safe, while nine (69.23%) expressed concern that thorough reheating could burn the food or reduce its quality. One student explained:

> *"The food has already been cooked, so it does not need to be reheated thoroughly. If it is heated again, it may burn." (Translated from Bahasa Indonesia)*

These explanations indicated that some students associated reheating primarily with sensory quality and did not clearly distinguish previous cooking from the safety requirements for food that had subsequently been stored.

Freshness Was Equated with Microbiological Safety

Nineteen students incorrectly accepted 40 °C as an adequate cooking temperature for meat. Among these students, 17 (89.47%) described freshly slaughtered meat as relatively safe because it had not been stored for a long period, while 14 (73.68%) explicitly stated that fresh meat contained few bacteria. One student stated:

> *"Fresh meat does not contain many bacteria because it has just been slaughtered." (Translated from Bahasa Indonesia)*

These responses indicated that freshness and recency of slaughter were used as indicators of microbiological safety. Students' explanations did not account for contamination that may occur during slaughter, handling, transportation, equipment contact, or preparation.

Water Clarity Was Treated as Evidence of Safety

Twelve students incorrectly agreed that safe water could be identified from its appearance. Of these students, 10 (83.33%) relied primarily on water clarity, while eight (66.67%) stated that the absence of visible dirt or discoloration indicated that the water was suitable for drinking or cooking. One student explained:

> *"Clear water is visible evidence that it can be used for drinking, cooking, and other daily needs."(Translated from Bahasa Indonesia)*

These responses showed that some students relied on observable physical characteristics while giving limited consideration to microbiological and chemical hazards that cannot be detected visually.

Integrated Quantitative and Qualitative Findings

Table 7 integrates the questionnaire findings with the principal explanations identified from the interviews. Overall, students demonstrated strong recognition of visible and frequently promoted hygiene practices, particularly handwashing, surface cleaning, washing fruits and vegetables, and separating raw and cooked foods during storage. However, substantial gaps remained in less visible and more technically demanding areas, especially cross-contamination through shared cutting boards, meat-cooking temperature, prolonged room-temperature storage, thorough reheating, and appearance-based judgments of water safety. The interview findings further indicated that these misconceptions were associated with reliance on previous cooking, concern about sensory quality, assumptions about freshness, and dependence on visible indicators of safety.

Table 7. Integrated findings for selected food safety misconceptions

Questionnaire item	Quantitative finding	Main interview explanations	Integrated interpretation
Item 5: Thorough reheating	13 of 36 students (36.11%) answered incorrectly	Previous cooking was considered sufficient; thorough reheating was associated with burning or reduced food quality	The misconception reflected incomplete understanding of stored-food safety and concern about sensory quality
Item 6: Meat cooked to 40 °C	19 of 36 students (52.78%) answered incorrectly	Freshly slaughtered meat was considered relatively safe and was believed to contain few bacteria	Freshness was used as a substitute for microbiological and temperature-based indicators of safety
Item 10: Water judged by appearance	12 of 36 students (33.33%) answered incorrectly	Clear water and the absence of visible dirt were treated as evidence of safety	Students relied on visible characteristics and gave limited consideration to invisible biological and chemical hazards

Note: Interview categories were not mutually exclusive; therefore, their frequencies may sum to more than the number of students who answered an item incorrectly.

Discussion

Principal Findings

This study identified an uneven pattern of food safety knowledge among one Grade XI cohort enrolled in an Agricultural Product Processing Agribusiness program. Students performed strongly on visible and frequently reinforced hygiene concepts, particularly handwashing, surface cleaning, washing fruits and vegetables, and separating raw and cooked foods during storage. In contrast, weaker performance was observed for cross-contamination through shared cutting boards, meat-cooking temperature, prolonged room-temperature storage, thorough reheating, and appearance-based judgments of water safety. The mean total score of 7.86 out of 11 should therefore not be interpreted as evidence of uniformly adequate knowledge. Instead, the item- and domain-level findings show that strong recognition of familiar hygiene messages can coexist with important misunderstandings of less visible microbial hazards.

The interviews clarified some of the reasoning underlying these misconceptions. Students who answered selected items incorrectly often considered previous cooking sufficient, associated thorough reheating with burning or reduced food quality, viewed freshly slaughtered meat as containing few bacteria, and treated clear water as safe. These explanations suggest that students sometimes relied on sensory characteristics, perceived freshness, and familiar routines rather than microbiological and time–temperature principles. The qualitative findings therefore added value by explaining not only which concepts were misunderstood but also why some students accepted unsafe statements.

Strong Recognition of Visible Hygiene Practices

The Keep clean domain produced the highest performance, with a mean of 98.61% correct. All students recognized the importance of handwashing before food handling, and nearly all understood that maintaining clean kitchen surfaces reduces disease risk. All students also correctly recognized the need to wash fruits and vegetables. Similar findings have been reported among adolescents and students, for whom hand hygiene and other visible cleanliness practices are often the most familiar components of food safety education (Beavers et al., 2015; Kim et al., 2012; Majowicz et al., 2015). These practices are repeatedly reinforced through household routines, school rules, public-health messaging, and practical lessons, making them easier to recall than principles involving invisible contamination.

However, perfect or near-perfect responses should be interpreted cautiously. Items 1, 4, and 11 showed ceiling effects and therefore did not distinguish between students with different levels of knowledge. Correctly endorsing a general hygiene statement also does not demonstrate that students can perform the corresponding procedure consistently during authentic food-processing activities. Observational studies in teaching kitchens have shown that food safety knowledge and actual handling behavior do not always correspond, particularly when students work under time pressure or follow familiar routines (Brown et al., 2016; Diplock et al., 2018). The present findings therefore indicate strong recognition of basic hygiene principles but do not establish practical competence.

Knowing the Separation Rule but Missing Cross-Contamination Pathways

The results for the Separate raw and cooked domain demonstrate a clear difference between knowing a general rule and applying it to a specific situation. All students correctly recognized that raw and cooked foods should be stored separately, yet only 36.11% recognized that a cutting board that appears clean can still transfer contamination between raw and cooked foods. This contrast suggests that students understood separation as a storage rule but did not consistently transfer the principle to utensils and food-contact surfaces.

Cross-contamination may be difficult for students to recognize because microorganisms cannot be seen directly and visual cleanliness may be mistaken for microbiological safety. Cutting boards, knives, hands, and other food-contact surfaces can transfer microorganisms even when they appear clean (Kirchner et al., 2022; Chea et al., 2022; Ovca et al., 2024). This misconception is particularly relevant in vocational education because students routinely use shared equipment during practical processing activities. Failure to recognize these pathways could allow contamination to move from raw ingredients to ready-to-eat products.

The finding supports instruction that combines explanation with practical demonstration. Food safety training that includes demonstrations, supervised application, and feedback may improve understanding of contamination pathways more effectively than verbal instruction alone (Castro et al., 2024; Manafe et al., 2023; Labovic et al., 2023). For this cohort, visual simulations using harmless markers could demonstrate how contamination moves from raw food to cutting boards, knives, hands, containers, and cooked products.

Reheating, Cooking Temperature, and Reliance on Sensory Cues

The Cook thoroughly domain had the lowest mean performance, at 55.56% correct. More than one-third of students incorrectly agreed that previously cooked food did not need to be reheated thoroughly, while more than half accepted 40 °C as an adequate cooking temperature for meat. These findings indicate limited understanding of how temperature contributes to microbial control during initial cooking and subsequent reheating.

The interview findings showed that the reheating misconception was not based solely on lack of factual knowledge. Among students who answered Item 5 incorrectly, previous cooking was commonly considered sufficient, while thorough reheating was associated with burning or reduced food quality. This reasoning suggests that some students evaluated reheating primarily through sensory outcomes rather than food safety outcomes. Appropriate reheating should therefore be taught as a microbial-control step for stored food, while concerns about burning, dryness, and texture should be addressed through correct control of temperature and time.

Reliance on sensory cues has also been reported in other student and consumer groups. Color, texture, taste, firmness, smell, and perceived freshness may be used instead of thermometer readings when judging whether food has been cooked safely (Zailani et al., 2022; Kasza et al., 2022; Lavelle et al., 2023). Although sensory characteristics may help assess food quality, they are not reliable substitutes for temperature-based safety decisions.

The explanations concerning freshly slaughtered meat revealed a related misconception. Many students who accepted 40 °C as adequate believed that fresh meat contained few bacteria because it had only recently been slaughtered. Freshness was therefore treated as equivalent to microbiological safety. This assumption does not account for contamination that may occur during slaughter, transport, handling, equipment contact, or preparation. Meat may appear fresh while still containing microorganisms, and its safety cannot be determined from freshness alone.

The response to Item 6 is also technically important because 40 °C is substantially below commonly used reheating or hot-service temperatures. Cook–chill guidance emphasizes rapid cooling to chilled conditions and subsequent reheating or hot service at approximately 70 °C (Clodoveo et al., 2021; Feyissa & Frosch, 2023). The appropriate internal cooking temperature depends on the type and characteristics of the meat product and the applicable food safety standard. Nevertheless, 40 °C should not be treated as a safe general cooking target. Vocational instruction should therefore include food-thermometer placement, reading, and interpretation rather than relying on color, texture, or freshness.

Time–Temperature Control and Delayed Refrigeration

Performance in the Keep food at safe temperatures domain was mixed. Most students recognized that cooked food should be kept hot before serving and that cooling slows bacterial growth. Nevertheless, only 22.22% correctly rejected the practice of leaving cooked meat at room temperature overnight before refrigeration. This was the weakest questionnaire item and indicates a major gap in understanding time–temperature control.

The finding suggests that students may possess isolated pieces of temperature-related knowledge without understanding how cooking, holding, cooling, refrigeration, and reheating function as a connected safety system. Knowing that refrigeration slows microbial growth is insufficient if food remains at room temperature for an extended period before refrigeration. Similarly, recognizing that cooked food should be served hot does not necessarily demonstrate knowledge of appropriate cooling and storage procedures. Guidance for cook–chill systems emphasizes rapid cooling to chilled conditions rather than prolonged exposure at ambient temperature (Clodoveo et al., 2021; Feyissa & Frosch, 2023).

Household routines may influence students' acceptance of delayed refrigeration, although this study did not directly measure family practices. Previous research indicates that children's and adolescents' cooking beliefs may be shaped by family participation, perceived norms, and previous food-preparation experience (Callender et al., 2021; Archila-Godínez et al., 2022; Boucher et al., 2023). These influences should be treated as possible contextual explanations rather than confirmed causes in the present cohort.

Scenario-based learning may help students connect separate temperature rules into a coherent decision process. For example, students could evaluate realistic situations involving leftovers, container depth, cooling time, refrigerator placement, hot holding, and reheating. Such activities would allow students to practice applying time–temperature principles rather than merely recalling isolated statements.

Water Clarity and Invisible Hazards

One-third of the students incorrectly believed that safe water could be identified from its appearance. Interview responses clarified that water clarity and the absence of visible dirt were often treated as evidence that water was suitable for drinking or cooking. This misconception reflects the same visible-safety bias observed in the cutting-board and fresh-meat findings. Students appeared to trust observable characteristics while giving less consideration to microbiological and chemical hazards that may be invisible.

Water safety cannot be established from clarity alone because visibly clear water may still contain microorganisms or dissolved chemical contaminants. Food safety education should therefore distinguish physical appearance from microbiological and chemical quality and explain how source, treatment, storage, and testing influence water safety (WHO, 2006; Timmis et al., 2024; Amorim et al., 2026).

The interview finding is educationally important because it identifies the reasoning that instruction must address. Simply telling students that clear water may be unsafe is unlikely to be sufficient unless they also understand how invisible contaminants can remain present. Demonstrations, low-cost laboratory activities, visual simulations, and microbiology-literacy activities may help students connect unseen hazards with everyday decisions (Armstrong, 2025; Karayanni et al., 2024; Kumar et al., 2026). In vocational lessons, students could compare the visual appearance of water samples with information about source, treatment, storage, or simple test results.

Integrated Interpretation of the Interview Findings

The qualitative findings revealed three recurring forms of reasoning. First, previous treatment was assumed to provide continuing protection: food that had already been cooked was considered safe without thorough reheating. Second, freshness was treated as a proxy for safety: recently slaughtered meat was assumed to contain few bacteria. Third, appearance was treated as sufficient evidence: clear water and visibly clean surfaces were considered safe.

These patterns demonstrate the value of integrating interviews with item-level questionnaire findings. The questionnaire identified which statements students answered incorrectly, whereas the interviews clarified the assumptions contributing to those responses. For example, misunderstanding reheating involved both incomplete knowledge of microbial risk and concern about burning. Similarly, the cooking-temperature misconception was linked to a belief about meat freshness rather than only lack of knowledge of a numerical temperature. The joint display therefore provides more actionable information for curriculum development than the aggregate knowledge score alone. It links each knowledge gap with a specific form of reasoning that can be addressed through instruction.

Implications for Vocational Food Safety Education

The findings support a shift from general hygiene messaging toward instruction that requires students to apply food safety principles in realistic processing situations. Repeating statements such as “keep food clean” or “cook thoroughly” is unlikely to correct misconceptions unless students understand the mechanisms and decision rules underlying those instructions.

Several instructional priorities follow directly from the results. Cross-contamination instruction should extend beyond storage separation and include cutting boards, knives, hands, containers, and processing equipment. Temperature instruction should include food-thermometer placement, calibration, reading, and interpretation. Students should be encouraged to compare thermometer measurements with less reliable sensory judgments such as color, texture, smell, or freshness.

Reheating activities should distinguish microbiological safety from sensory quality. Practical demonstrations can show how controlled reheating achieves an appropriate temperature without unnecessary burning. Cooling and storage exercises should require students to decide when and how cooked food should be cooled, refrigerated, stored, and reheated. Water-safety instruction should address physical, microbiological, and chemical criteria and explicitly challenge the assumption that clear water is necessarily safe.

Practical demonstrations are especially relevant for vocational students because they connect scientific concepts with procedures that students may later use during internships or employment. Food safety education studies support the use of applied instruction, guided practice, and feedback to strengthen the link between knowledge and behavior (Diplock et al., 2018, 2019; Feng et al., 2019). Future interventions in this setting should assess both questionnaire performance and observed food-handling practice before and after instruction.

Measurement Considerations

The questionnaire was useful for identifying specific knowledge gaps, but its measurement properties limit the strength of the conclusions that can be drawn. The KR-20 coefficient of 0.69 indicates marginal-to-moderate internal consistency for preliminary group-level diagnostic use. The multidomain structure and limited number of items within each domain may have contributed to the modest coefficient. The instrument should not be treated as a validated measure of individual competence.

Items 1, 4, and 11 showed ceiling effects because all students answered them correctly. These items did not discriminate among participants and should be revised in future versions. Instead of asking students to recognize broad principles, scenario-based items could require them to apply the principles during a sequence of food-processing decisions. Applied decision-making measures may provide stronger evidence of practical understanding than isolated True/False statements (Leitão et al., 2023; Lee et al., 2025).

The True/False format also permits correct responses through guessing and does not assess confidence or depth of reasoning. The interviews partially addressed this limitation by clarifying selected responses, but they did not replace direct observation of practical competence. Future instrument development should include scenario-based items, confidence ratings, and structured practical-performance assessments.

Items 6, 8, and 9 require particular refinement. Item 6 established that 40 °C was incorrect but did not assess whether students knew an appropriate temperature. Item 8 referred to keeping food “hot” without specifying an operational threshold, while Item 9 could be interpreted ambiguously because of the word “only.” These items were retained because they were part of the administered questionnaire, but future versions should use clearer wording aligned with a single authoritative food safety standard.

Interpretation and Contribution

The findings should be interpreted as a context-specific diagnostic profile of one Grade XI vocational cohort rather than as an estimate for all Agricultural Product Processing Agribusiness students in West Lombok or Indonesia. The study did not directly observe food-handling behavior, measure foodborne illness, or evaluate an educational intervention. Consequently, the results demonstrate knowledge patterns and reported reasoning rather than actual workplace performance or health outcomes.

Within these boundaries, the study provides an applied contribution to vocational food safety education. It demonstrates that students can correctly recognize broad hygiene principles while continuing to accept unsafe practices in specific situations. The interview findings further show that misconceptions were associated with sensory judgment, perceived freshness, previous cooking, and visible cleanliness. These insights provide a more precise basis for designing instruction focused on cross-contamination, thermometer use, reheating, cooling, storage, and invisible biological and chemical hazards.

CONCLUSIONS

This study identified a clear imbalance in food safety knowledge among one Grade XI cohort enrolled in an Agricultural Product Processing Agribusiness program. Students demonstrated strong recognition of visible and frequently reinforced hygiene practices, including handwashing, surface cleaning, washing fruits and vegetables, and separating raw and cooked foods during storage. However, this knowledge did not extend consistently to more specific situations involving shared cutting boards, safe cooking temperatures, prolonged room-temperature storage, thorough reheating, and water safety. The findings therefore show that familiarity with general hygiene rules does not necessarily indicate an adequate understanding of contamination pathways or time–temperature control.

The interview findings clarified several assumptions underlying these misconceptions. Some students considered previous cooking sufficient, associated reheating with burning or reduced food quality, viewed freshly slaughtered meat as containing few bacteria, and treated clear water as safe. These explanations suggest that sensory cues, perceived freshness, and familiar routines sometimes took precedence over microbiological reasoning. Within the participating cohort, the most important curriculum priorities are therefore cross-contamination control, thermometer-based cooking decisions, reheating, cooling and storage, and recognition of invisible biological and chemical hazards. These conclusions are limited to the studied cohort and should not be generalized to all vocational students in West Lombok or Indonesia.

RECOMMENDATIONS

The findings should be interpreted cautiously because the study involved only 36 students from one vocational cohort and used two questionnaire administration modes. Although identical item wording and instructions were used, differences in supervision may have influenced responses. The brief True/False questionnaire also allowed correct responses through guessing, contained several ceiling items, and showed only marginal-to-moderate internal consistency. The study assessed knowledge and reported reasoning rather than observed food-handling performance, and its cross-sectional design cannot determine whether the identified misconceptions would change after instruction.

Vocational food safety instruction should emphasize practical application rather than repeated general hygiene messages. Priority areas include cross-contamination through shared utensils, thermometer use, safe cooking and reheating, rapid cooling and storage, and recognition of invisible biological and chemical hazards in water. Demonstrations, realistic scenarios, and structured observation during practical classes may help students apply these principles more accurately.

Future research should refine the questionnaire by revising weak or ceiling items, expanding each domain, and adding scenario-based and performance measures. Larger multisite studies should include different grade levels, prior food safety training, household food-handling experience, and access to thermometers, refrigeration, and other safety resources. Intervention studies using pre-instruction, post-instruction, and delayed assessments are also needed to determine whether targeted practical instruction improves both knowledge and observed food-handling performance.

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Authors state no conflict of interest.

Data Availability
The de-identified quantitative dataset, variable codebook, qualitative coding framework, and analysis syntax are available from the corresponding author upon reasonable request and subject to institutional and ethical approval. Because the participants were secondary-school students, audio recordings, full interview transcripts, and materials that may permit participant identification are not publicly available. Aggregated qualitative coding data may be shared where consistent with participant consent and institutional requirements.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Muhamad Sumarlin				✓		✓	✓			✓				
Rubilyn G. Barrios		✓		✓	✓					✓				
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

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APPENDIX A. QUESTIONNAIRE AND ANSWER KEY

Table A1. Bahasa Indonesia questionnaire, domain mapping, and scoring key

Item	Pernyataan	Domain WHO	Jawaban benar
1	Penting untuk mencuci tangan sebelum menangani makanan.	Keep clean	Benar
2	Menjaga kebersihan permukaan dapur mengurangi risiko penyakit.	Keep clean	Benar
3	Talenan yang sama dapat digunakan untuk makanan mentah dan matang selama terlihat bersih.	Separate raw and cooked	Salah
4	Makanan mentah perlu disimpan terpisah dari makanan matang.	Separate raw and cooked	Benar
5	Makanan matang tidak perlu dipanaskan kembali secara menyeluruh.	Cook thoroughly	Salah
6	Pemasakan daging yang tepat berarti daging dimasak hingga suhu 40 °C.	Cook thoroughly	Salah
7	Daging matang dapat dibiarkan pada suhu ruang semalaman hingga dingin sebelum dimasukkan ke dalam lemari es.	Keep food at safe temperatures	Salah
8	Makanan matang harus tetap dijaga panas sebelum disajikan.	Keep food at safe temperatures	Benar
9	Pendinginan makanan hanya memperlambat pertumbuhan bakteri.	Keep food at safe temperatures	Benar
10	Air yang aman dapat dikenali dari tampilannya.	Use safe water and raw materials	Salah
11	Buah dan sayuran perlu dicuci.	Use safe water and raw materials	Benar

Table A2. English questionnaire and answer key

Item	Statement	WHO domain	Correct response
1	It is important to wash hands before handling food.	Keep clean	True
2	Keeping kitchen surfaces clean reduces the risk of disease.	Keep clean	True
3	The same cutting board can be used for raw and cooked food as long as it looks clean.	Separate raw and cooked	False
4	Raw food needs to be stored separately from cooked food.	Separate raw and cooked	True
5	Cooked food does not need to be reheated thoroughly.	Cook thoroughly	False
6	Proper cooking of meat means it is cooked to a temperature of 40 °C.	Cook thoroughly	False

Item	Statement	WHO domain	Correct response
7	Cooked meat can be left at room temperature overnight until it cools before putting it in the refrigerator.	Keep food at safe temperatures	False
8	Cooked food should be kept hot before serving.	Keep food at safe temperatures	True
9	Cooling food only slows down bacterial growth.	Keep food at safe temperatures	True
10	Safe water can be identified by its appearance.	Use safe water and raw materials	False
11	Fruits and vegetables need to be washed.	Use safe water and raw materials	True

Scoring instructions

Each correct response was scored 1, and each incorrect response was scored 0. The total score ranged from 0 to 11. Domain scores were calculated by summing the items assigned to each WHO domain. No categorical performance thresholds were applied because the questionnaire had not undergone formal standard setting or criterion validation.

APPENDIX B. SEMI-STRUCTURED INTERVIEW GUIDE

Opening statement

Thank you for participating. We would like to understand how you decided on your answers to several food safety questions. There are no academic consequences for your responses. Please explain your reasoning in your own words.

Reheating

1. Do you think previously cooked food needs to be reheated thoroughly before being eaten again? Why or why not?
2. What might happen if stored cooked food is heated only briefly?
3. What concerns do you have about reheating food, such as taste, texture, dryness, or burning?
4. Where did you learn how leftovers should be reheated?

Meat-cooking temperature and freshness

5. How do you decide whether meat has been cooked safely?
6. What does a temperature of 40 °C mean to you when cooking meat?
7. Do you think freshly slaughtered meat can contain bacteria? Please explain.
8. Which indicators do you usually use: temperature, color, texture, smell, or another indicator?

Water safety

9. How do you decide whether water is safe for drinking or cooking?
10. Can clear water still contain microorganisms or chemicals that cannot be seen? Why or why not?
11. What information about the source, treatment, or storage of water would affect your decision?

Contextual prompts

12. Did you learn this practice at home, at school, through social media, or from another source?
13. Is this practice commonly used during school food-processing activities?
14. What demonstration or explanation would help you understand this issue more clearly?