

# Developing Food Science Literacy and Practical Competence in Home Economics Students through the Valorization of Overripe Mangoes into Vinegar

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**Abstract**— *The production of food waste, especially overripe mangoes, presents both environmental challenges and the opportunity for value-added production. Home Economics and Technology and Livelihood Education (TLE) practical projects can improve learners' technical skills, conceptual understanding, and awareness of sustainability. This study aimed to determine the effectiveness of a project-based flavored vinegar-making activity using overripe mangoes in enhancing the technical skills, cognitive and analytical competencies, and attitude of the Grade 9 students towards food waste reduction and sustainability. The study also examined students' experiences, problem-solving strategies, and creative thinking, as well as the development of a competency-based instructional model. This study used a mixed-methods approach using a one-group pretest-posttest design, combining quantitative data (performance, cognitive, and attitude tests) and qualitative data (laboratory journals, student reflections, and observations of two TLE teachers).*

*Results showed a significant improvement in students' technical skills from moderate to high levels, as well as increased cognitive and analytical skills in fermentation principles, food safety, and sustainability concepts. Students had very positive attitudes towards food waste awareness, sustainability practices, and practical application of food science. The absence of a significant correlation between technical skills and cognitive competencies suggests that both domains develop independently. Qualitative findings, supported by teachers' observations, showed active engagement in hands-on learning, cooperative problem-solving, and creative thinking. The results provided the basis for developing the FERMENT Model, a competency-based, experiential instructional framework to guide teaching and learning in food processing. The study found that TLE project-based and experiential learning is effective in developing technical mastery, conceptual understanding, attitudinal development and sustainability consciousness.*

**Keywords**— *Flavored vinegar, overripe mangoes, project-based learning, experiential learning, TLE.*

## I. INTRODUCTION

The study aims to convert overripe mangoes, a locally available agricultural waste, into a value-added product, vinegar, in Claver, Surigao del Norte. The implementation of this is in line with the ongoing research on the valorization of fruit residues for food innovation [1]. Although the market value of an overripe mango is low, the sugars present in mangoes are still fermentable and can thus be utilized in fermentation-based processing [2]. All these mangoes help

address food waste issues and highlight the technical viability of producing stable, acceptable vinegar products [3].

Most significantly, the study incorporates mango vinegar making into the Home Economics curriculum as real-life tasks. Students apply experiential learning principles as they learn to make, ferment, test, develop, and taste food and beverages [4]. This approach not only fosters students' learning of scientific concepts but also enhances their technical and entrepreneurial skills [5]. The project bridges the gap between theory and application, nurturing the students' capacity to apply knowledge in real-world scenarios [6].

Moreover, the study contributes to environmental sustainability by encouraging responsible food use and minimizing agricultural waste. The students who participate in the program are introduced to food waste valorization as a practical approach to community food waste management [7]. Moreover, the process of making vinegar from fruits offers an opportunity to learn about problem-solving and process monitoring, which are essential for ensuring safe, high-quality production [8]. These activities promote cognitive and technical skill development and environmental responsibility [9].

Lastly, the results of this study illustrate an innovative teaching method for producing overripe mango vinegar. It connects scientific knowledge to practical application, equipping students with the skills needed for real-life food production and future employment [10]. The project structure is a replicable model that schools can adopt to implement sustainable practices in TLE lessons. The project structure has been developed as a replicable model for schools to adopt sustainable practices in TLE lessons [11]. It sees Home Economics as a space of experiential, analytical and environmentally oriented learning [12].

## II. MATERIALS AND METHODS

### *Research Design*

This research used a mixed-methods design with quantitative and qualitative approaches, employing a one-group pretest-posttest and descriptive designs. The mixed-method approach enabled the researcher to comprehensively assess the students' technical skills, cognitive and analytical competencies, attitudes towards sustainability, experiential

learning, and acceptability of the final flavored vinegar product [14].

*Research Locale*

The study was conducted at Taganito National High School in Claver, Surigao del Norte, a rural municipality rich in agricultural resources and with strong community participation in environmental programs.

*Research Respondents*

This study was conducted on the Grade 9 learners taking up the Technology and Livelihood Education (TLE) subject at Taganito National High School during the School Year 2025 – 2026. Forty students were involved in the study. These learners were chosen due to their official enrollment to the Grade 9 TLE classes with food processing components relevant to the implementation of the flavored vinegar-making project.

*Research Instrument*

The main instrument employed in this study was a researcher-developed questionnaire designed to address the Statement of the Problem and to evaluate students’ technical and cognitive skills, attitudes, experiences, and product acceptability regarding the flavored vinegar-making project.

III. RESULTS AND DISCUSSIONS

*Level of Students’ Technical Skills Before and After the Project in Terms of Key Fermentation Tasks*

Table 1 presents students’ technical skill levels in major fermentation activities before and after the overripe mango vinegar-making project. In practice, food-related activities are relevant to the development of the “to do” dimension of food literacy, including food handling, preparation, and applied food skills [19]. Before the intervention, students showed a Moderately Skilled level of performance, indicating a limited ability to carry out essential fermentation procedures. This is consistent with recent literature on food education that stresses the importance of learners applying technical procedures, observing product changes, managing tools, and observing process requirements in practical food laboratory activities [20]. The highest-rated task among those evaluated was substrate preparation, which might reflect greater familiarity with basic fruit-handling and preparation procedures. In contrast, the preparation of the fermentation medium received the lowest score, as students had difficulty with more technical processes, e.g., Brix and pH adjustments, which are important for fruit vinegar fermentation and quality assessment [21]. This is evidenced by studies on fruit-based vinegar production, in which mango and other fruit substrates undergo alcoholic and acetic fermentation under controlled preparation and fermentation conditions to obtain acceptable vinegar quality [22]. Following project implementation, students’ technical skills for all indicators increased to a Highly Skilled level, indicating that hands-on, project-based food science activities can improve practical competence and food science literacy [19], [23]. After the project, the substrate preparation task was still rated the highest, and the other fermentation tasks were

also consistently rated high. This shows that students developed confidence in both routine preparation work and more technical fermentation control procedures through repeated laboratory practice [20, 23].

Table 1. Level of Students’ Technical Skills Before and After the Project in Terms of Key Fermentation Tasks

Indicators	Before the Project			After the Project		
	M	QD	VI	M	QD	VI
1. Substrate Preparation	2.03	Fair	Moderately Skilled	3.34	Very Good	Highly Skilled
2. Must Preparation	1.93	Fair	Moderately Skilled	3.33	Very Good	Highly Skilled
3. Application of aesthetic techniques	1.96	Fair	Moderately Skilled	3.33	Very Good	Highly Skilled
4. Monitoring and Control	1.96	Fair	Moderately Skilled	3.33	Very Good	Highly Skilled
5. Sensory Evaluation	1.98	Fair	Moderately Skilled	3.33	Very Good	Highly Skilled
<b>Over-all Mean</b>	<b>1.97</b>	<b>Fair</b>	<b>Moderately Skilled</b>	<b>3.33</b>	<b>Very Good</b>	<b>Highly Skilled</b>

This substantial improvement demonstrates the effectiveness of the project-based and experiential learning approach in enhancing procedural accuracy, technical proficiency, and practical competence in food processing activities [24], [25]. In addition, the consistency of post-intervention evaluations suggests that students were able to master different fermentation tasks at a comparable level thanks to the organized and guided learning opportunities [24], [26]. These findings support the view that hands-on, contextualized learning activities strengthen the acquisition of technical skills by enabling learners to apply theoretical concepts in authentic situations, thereby bridging the gap between classroom instruction and real-world practice [26], [27]. Furthermore, engagement in sustainability-oriented food processing projects promotes deeper understanding, critical thinking, and skill retention, thereby improving learner performance [29], [30]. Overall, the results confirm that the flavored vinegar-making project served as an effective instructional strategy for developing students’ technical competencies in fermentation, directly addressing the study’s objective of enhancing practical skills through experiential learning [28], [29], [30].

*Level of Students’ Cognitive and Analytical Competencies Before and After the Project, as Measured by Test Scores*

Table 2 presents the levels of students’ cognitive and analytical competencies in the scientific principles of fermentation, the valorization of food waste and the circular economy, and food safety and sanitation protocols. Before the flavored vinegar-making project, the students’ competence was generally at the Low to Moderate level.

Table 2. Level of Students’ Cognitive and Analytical Competencies Before and After the Project

Variables	Pre-Test		Post-Test	
	M	SD	M	SD
Scientific Principles of Fermentation	4.00	0.60	7.00	0.60
Food Waste Valorization and Circular Economy	3.50	0.51	6.00	0.60
Food Safety and Sanitation Protocols	3.33	0.47	5.50	0.51
<b>Average</b>	<b>3.61</b>	<b>0.53</b>	<b>6.17</b>	<b>0.57</b>

Following the intervention, students attained a High level of cognitive and analytical competence across all assessed areas, with the highest competency observed in the scientific principles of fermentation, indicating that the flavored vinegar-making project effectively enhanced conceptual understanding through hands-on learning. Although food safety and sanitation protocols received the lowest post-project

rating, they remained in the High category, indicating substantial improvement and highlighting the need for continued reinforcement of safety practices. These findings support previous studies demonstrating that laboratory-based and experiential learning activities improve knowledge retention, critical thinking, problem-solving skills, and the application of scientific concepts [13,14]. Furthermore, integrating sustainability and food waste valorization concepts into learning experiences enhances analytical abilities and environmental awareness [15]. Overall, the significant improvement in students' cognitive and analytical competencies confirms that the project successfully bridged theory and practice, fostering deeper understanding, reflective reasoning, and practical application of knowledge essential for food processing and sustainable practices in Home Economics education.

*Students' Attitudes and Perceptions after Project Participation*

Table 3 presents students' attitudes and perceptions regarding food waste awareness, sustainability practices, and the practical application of food science after engaging in the flavored vinegar-making project.

Table 3. Students' Attitudes and Perceptions in Terms of Food Waste Awareness

Variables	M	QD	VI
Food Waste Awareness	3.59	Strongly Agree	High Positive
Sustainability Practices	3.59	Strongly Agree	High Positive
Practical Application of Food Science	3.58	Strongly Agree	High Positive
<b>Over-all Mean</b>	<b>3.58</b>	<b>Strongly Agree</b>	<b>High Positive</b>

Students demonstrated highly positive attitudes and perceptions toward the flavored vinegar-making project, with food waste awareness and sustainability practices receiving the highest ratings, both interpreted as Strongly Agree and Highly Positive. These findings indicate that using overripe mangoes effectively enhanced students' appreciation of waste reduction and sustainability by demonstrating how low-value agricultural materials can be transformed into useful, marketable products. Although the practical application of food science received the lowest rating, it remained within the Strongly Agree and Highly Positive categories, suggesting that students were able to connect scientific concepts such as fermentation, acidity, sanitation, and product quality to real-world food processing activities. The results support previous studies that show that sustainability-oriented and experiential learning activities increase environmental awareness, responsible consumption, and meaningful engagement with local resources [16]. Consistent with Experiential Learning Theory, students' direct participation in the project fostered positive attitudes, deeper understanding, and greater appreciation of the environmental and educational value of food waste valorization. Overall, the findings confirm that contextualized and project-based learning in Home Economics promotes environmentally conscious, responsible, and knowledgeable learners while strengthening the practical application of food science concepts [17,18]

*Significant Relationship Between Students' Technical Skills and Their Cognitive and Analytical Competencies*

Table 4.1 shows the relationship between students' technical skills and cognitive and analytical competencies before the flavored vinegar-making project. The findings indicate a weak to no association between all skill domains and cognitive domains, suggesting that, prior to the intervention, a strong link between students' practical skills and conceptual understanding had not yet been established [20]. The most strongly correlated variable with the scientific principles of fermentation was sensory evaluation, indicating a weak relationship between students' understanding of the principles of fermentation and their ability to observe the characteristics of the product (appearance, aroma, flavor, and acidity) [6], [9]. Substrate preparation and food waste valorization had the lowest correlation, suggesting an almost nonexistent relationship between the basic preparation tasks and the broader conceptual knowledge of the sustainable usage of food waste [1], [30]. This indicates that before this project, students were possibly able to perform basic preparatory procedures but lacked a complete understanding of how these tasks relate to fermentation science and waste-to-product applications [24].

Table 4.1 Significant Relationship Between Students' Technical Skills and Cognitive and Analytical Competencies Before the Project

Technical Skill Area	Cognitive Variable	Computed r	P-value	Decision	Conclusion
Substrate Preparation	Scientific Principles of Fermentation	0.166	0.305	Failed to reject H <sub>0</sub>	Not Significant
	Food Waste Valorization	0.021	0.899	Failed to reject H <sub>0</sub>	Not Significant
	Food Safety & Sanitation	0.069	0.672	Failed to reject H <sub>0</sub>	Not Significant
Must Preparation	Scientific Principles of Fermentation	0.060	0.715	Failed to reject H <sub>0</sub>	Not Significant
	Food Waste Valorization	0.191	0.238	Failed to reject H <sub>0</sub>	Not Significant
	Food Safety & Sanitation	0.081	0.621	Failed to reject H <sub>0</sub>	Not Significant
Application of Aseptic Techniques	Scientific Principles of Fermentation	0.056	0.730	Failed to reject H <sub>0</sub>	Not Significant
	Food Waste Valorization	0.112	0.490	Failed to reject H <sub>0</sub>	Not Significant
	Food Safety & Sanitation	0.178	0.272	Failed to reject H <sub>0</sub>	Not Significant
Monitoring & Control	Scientific Principles of Fermentation	0.094	0.562	Failed to reject H <sub>0</sub>	Not Significant
	Food Waste Valorization	0.144	0.376	Failed to reject H <sub>0</sub>	Not Significant
	Food Safety & Sanitation	0.155	0.339	Failed to reject H <sub>0</sub>	Not Significant
Sensory Evaluation	Scientific Principles of Fermentation	0.244	0.130	Failed to reject H <sub>0</sub>	Not Significant
	Food Waste Valorization	-0.168	0.301	Failed to reject H <sub>0</sub>	Not Significant
	Food Safety & Sanitation	0.184	0.256	Failed to reject H <sub>0</sub>	Not Significant

Table 4.1 reveals that there was no statistically significant relationship between students' technical skills and cognitive competencies prior to the implementation of the flavored vinegar-making project, indicating that these domains functioned largely independently at the outset of the study. This finding suggests that while students may have possessed basic theoretical knowledge or isolated practical abilities, they had limited capacity to integrate conceptual understanding with actual fermentation practices, resulting in fragmented learning experiences [20]. The absence of a significant relationship supports existing literature emphasizing that theoretical instruction alone is often insufficient for developing technical competence, particularly in food processing activities that require direct engagement, repeated practice, observation, and manipulation of real-world

processes [20], [24]. Furthermore, the results highlight the need for experiential and project-based learning approaches that actively connect knowledge and practice, enabling learners to apply scientific concepts in authentic contexts [24], [26]. Overall, the weak alignment between cognitive competencies and technical skills before the intervention underscores the importance of contextualized, hands-on learning experiences in Home Economics education to promote meaningful learning, strengthen skill acquisition, and bridge the gap between theory and practice [25], [27]. In fermentation-based activities, students need to connect their understanding of acidity, substrate conversion, and fermentation conditions with actual procedural tasks such as preparation, monitoring, and sensory evaluation [21], [28]. Thus, the pre-intervention results indicate a clear instructional gap that the flavored vinegar-making project aimed to address through an applied, sustainability-oriented food processing activity [1], [30].

Table 4.2 Significant Relationship Between Students' Technical Skills and Cognitive and Analytical Competencies After the Project

Technical Skill Area	Cognitive Variable	Computed r	P-value	Decision	Conclusion
Substrate Preparation	Scientific Principles of Fermentation	0.043	0.794	Failed to reject $H_0$	Not Significant
	Food Waste Valorization	0.135	0.405	Failed to reject $H_0$	Not Significant
	Food Safety & Sanitation	0.050	0.761	Failed to reject $H_0$	Not Significant
Must Preparation	Scientific Principles of Fermentation	0.242	0.132	Failed to reject $H_0$	Not Significant
	Food Waste Valorization	0.210	0.194	Failed to reject $H_0$	Not Significant
	Food Safety & Sanitation	0.137	0.398	Failed to reject $H_0$	Not Significant
Application of Aseptic Techniques	Scientific Principles of Fermentation	0.020	0.904	Failed to reject $H_0$	Not Significant
	Food Waste Valorization	0.023	0.887	Failed to reject $H_0$	Not Significant
	Food Safety & Sanitation	0.090	0.580	Failed to reject $H_0$	Not Significant
Monitoring & Control	Scientific Principles of Fermentation	0.036	0.826	Failed to reject $H_0$	Not Significant
	Food Waste Valorization	0.058	0.722	Failed to reject $H_0$	Not Significant
	Food Safety & Sanitation	0.006	0.972	Failed to reject $H_0$	Not Significant
Sensory Evaluation	Scientific Principles of Fermentation	0.175	0.281	Failed to reject $H_0$	Not Significant
	Food Waste Valorization	0.039	0.809	Failed to reject $H_0$	Not Significant
	Food Safety & Sanitation	0.064	0.695	Failed to reject $H_0$	Not Significant

Table 4.2 presents the relationship between students' technical skills and cognitive and analytical competencies following the implementation of the flavored vinegar-making project. The results revealed weak to negligible and statistically non-significant correlations across all technical and cognitive domains, indicating that although both areas improved substantially after the intervention, their development occurred independently rather than in a directly proportional manner [20], [24]. Among the variables, must preparation and scientific principles of fermentation exhibit the strongest association, while monitoring and control and food safety and sanitation demonstrated the weakest relationship, suggesting varying levels of alignment between conceptual understanding and practical performance [21], [28]. These findings imply that students acquired knowledge and technical competencies simultaneously but did not necessarily translate cognitive gains into equivalent levels of

technical proficiency due to factors such as prior experience, learning pace, motivation, and engagement in practical activities [24], [26]. Consistent with the experiential learning literature, cognitive understanding and technical skill development often progress at different rates, particularly in complex tasks such as fermentation, which require repeated practice and sustained application to achieve mastery [20], [27]. While the project effectively enhanced both domains, the absence of significant correlations highlights the need for continued experiential, contextualized, and hands-on learning opportunities that further strengthen the integration of theoretical knowledge and practical performance [25], [26]. Overall, the findings underscore the importance of sustained project-based instruction in Home Economics to facilitate deeper connections between conceptual understanding and technical competence in food processing [24], [30].

#### IV. CONCLUSION

The findings of the study demonstrate that the flavored vinegar-making project, implemented through a guided, hands-on, and experiential learning approach, significantly enhanced students' technical skills, enabling them to progress from Moderately Skilled to Highly Skilled in key fermentation tasks, while also improving their cognitive and analytical competencies related to fermentation principles, food safety, and sustainability practices. The project fostered highly positive attitudes toward food waste reduction, environmental responsibility, and the practical application of food science, while promoting collaboration, independent learning, problem-solving, and reflective thinking. Although no statistically significant relationship was found between technical skills and cognitive competencies, suggesting that these domains developed independently, the results emphasize the importance of continuous practice, teacher guidance, and structured learning experiences to strengthen the integration of knowledge and skills. Furthermore, qualitative findings revealed meaningful learning experiences characterized by experimentation, collaborative decision-making, knowledge transfer, and innovation, supporting the effectiveness of the FERMENT Model as a competency-based instructional framework that integrates cognitive, technical, and affective learning outcomes to enhance technical proficiency, conceptual understanding, attitudinal development, and problem-solving skills in Home Economics education.

#### Recommendation

Based on the study's findings, it is recommended that TLE and Home Economics teachers adopt more project-based and experiential learning approaches, particularly in food processing and fermentation activities, to enhance students' technical skills, critical thinking, problem-solving abilities, and sustainability awareness. Schools should provide adequate resources, facilities, and instructional support for contextualized and localized learning experiences, including integrating the FERMENT Model to promote competency-based and sustainability-oriented education. Students should be encouraged to apply their learning in real-life situations, such as food waste management and small-scale

entrepreneurial activities, while future studies should explore longer intervention periods, control-group designs, and laboratory analyses of vinegar products to further examine the relationship between cognitive and technical competencies. Moreover, community stakeholders and policymakers, particularly the Department of Education, should strengthen initiatives that promote food waste valorization, sustainability education, project-based learning, and the use of local resources to ensure the effective implementation of experiential, contextualized learning in the curriculum.

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