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STEAM-H in Turmeric-Tamarind Processing: Paving the Way for Mathematical Literacy in Agribusiness Vocational High Schools

Ai Tusi Fatimah[1,*], Agus Yuniawan Isyanto[2], Euis Erlin[3], & Bibin Bintang Andriana[4]

[1]Department of Mathematics Education, Universitas Galuh, Indonesia

[2]Department of Agribusiness, Universitas Galuh, Indonesia

[3]Department of Biology Education, Universitas Galuh, Indonesia

[4]Department of Biomedical Chemistry, Kwansei Gakuin University, Japan

*Corresponding email: aitusifatimah@unigal.ac.id

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Abstract: STEAM-H in Turmeric-Tamarind Processing: Paving the Way for Mathematical Literacy in Agribusiness Vocational High Schools. Objective: This study aims to explore the application of the STEAM-H (science, technology, engineering, agriculture, mathematics, and health) approach in developing mathematical literacy in the context of turmeric-tamarind beverage processing in vocational high school students. This study also seeks to identify relevant mathematical content for the curriculum. **Methods:** An exploratory case study was conducted with 12 students from the Agribusiness Concentration of Agricultural Product Processing. Data were collected through worksheets, pre-tests and post-tests, direct observations, and interviews. Observations and interviews focused on analyzing students' mathematical reasoning and problem-solving processes during the practical application of these concepts. Thematic data analysis was used to identify students' STEAM-H understanding and work skills, with a particular focus on how mathematical literacy was demonstrated. **Findings:** This study revealed that integrating STEAM-H into the turmeric-tamarind beverage processing project improved students' understanding across disciplines. Students demonstrated the ability to understand meaning, adaptive thinking, social intelligence, and transdisciplinarity. Specifically, students effectively applied mathematical concepts in practical scenarios, demonstrating increased mathematical literacy through their ability to calculate ingredient proportions, manage costs, and predict profits. They also demonstrated an increased ability to interpret and apply mathematical reasoning in real-world contexts, such as adjusting recipes and analyzing sales data. However, there were challenges in integrating technology and engineering, particularly in the agricultural context. **Conclusion:** The STEAM-H approach is effective in developing mathematical literacy and practical skills in vocational education. This study highlights the importance of contextualizing mathematics education and integrating real-world applications to enhance students' understanding and application of mathematical concepts. Future research should explore strategies to further enhance mathematical literacy in STEAM-H contexts, particularly in addressing challenges associated with integrating technology and engineering, and to investigate the long-term impact of this approach on students' mathematical reasoning and problem-solving abilities.

Keywords: agribusiness, mathematical literacy, STEAM-H, turmeric-tamarind drink processing, work skill.

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INTRODUCTION

Mathematical literacy is urgent for students at every level of education to develop life skills in the 21st century (Nurmasari et al., 2024), meet the demands of life in modern society (Bolstad, 2023), apply mathematical concepts in various real-world contexts (Ciptaningtyas et al., 2018; Maryani & Widjajanti, 2020; Nurwahid & Ashar, 2022), and develop higher-order thinking skills (Nurwahid & Ashar, 2022). Mathematical literacy, the ability to apply mathematics in various contexts, is essential for vocational students but is often difficult to integrate into their vocational programs (Dalby & Noyes, 2015). The difficulty is compounded by the variety of vocational programs in vocational schools, and mathematics teachers must understand the context of the vocational program (Bakker, 2014). Thus, the context of mathematical literacy in vocational schools must specifically be connected to the context of students' expertise programs and be able to solve increasingly complex problems in the workplace.

Agribusiness processing of agricultural products is one of the expertise programs in vocational high schools in Indonesia (BSKAP Kemendikbudristek, 2022a). Students in this program focus on expertise in processing agricultural products from plants, animals, plantation crops, and spices (BSKAP Kemendikbudristek, 2022b). To support this expertise, mathematics subject teachers can contribute to providing various contexts for processing agricultural products so that students are adaptive in solving problems related to mathematics that they will encounter later in the workplace. These are required to teach students to apply mathematical knowledge in various complex and dynamic work situations (FitzSimons & Björklund Boistrup, 2017). In practice, research results showed that prospective teachers with more theoretical mathematics background often have difficulty making clear connections between abstract mathematical concepts and applications in the workplace (Nicol, 2002). More specifically, research findings on the experiences of mathematics teachers in agribusiness vocational high schools in designing mathematical literacy questions, are their lack of ability to find agribusiness contexts and relate them to specific mathematical concepts (Fatimah, Yuniawan Isyanto, et al., 2023). In addition, there are research results that reveal differences between mathematical practices learned in the classroom and the workplace due to the development of mathematical needs and differences in mathematical activities that are adaptive to the work context (Williams & Wake, 2007).

Work practices in the agricultural sector involve many disciplines. The study showed coherence between the subjects of agricultural processing, mathematics, and natural sciences (Fatimah, Isyanto, & Toto, 2023). These results hasten an approach to integrate several disciplines to solve various problems in science, technology, engineering, agriculture, mathematics, and health, namely STEAM-H (Toni, 2014). STEAM-H in the context of education was then developed by converting STEM education theories that have developed very rapidly (Fatimah et al., 2022). The principles of integrated STEAM-H adopted into STEAM-H are understanding the main components of the curriculum (Gale et al., 2020), understanding situation-based learning and interdisciplinary relationships (Kelley & Knowles, 2016), and determining an explicit-integrative graphic conceptual flow that connects concepts and practices between disciplines (Roehrig et al., 2021). The results of research in agribusiness vocational high schools showed that agribusiness teachers, mathematics teachers, and science teachers have different views on the essential concepts listed in the curriculum, and agribusiness teachers are more aware of the relationship between subjects even though it is still implicit

(Fatimah, Isyanto, & Toto, 2023). The results of research in agribusiness vocational high schools for agricultural product processing showed that mathematics and science subjects have a role in agricultural product processing subjects with the existence of essential concepts of mathematics and science, both explicit and implicit (Fatimah, Isyanto, Toto, et al., 2023). This latest research requires an in-depth exploration of specific contexts that integrate the disciplines of science, technology, engineering, mathematics, and health due to the many contexts of agricultural product processing.

Agricultural product processing, which is part of the agriculture discipline, is a conceptual and contextual integrator within the scope of the STEAM-H discipline (Fatimah, Isyanto, Toto, et al., 2023). Previous research showed that agriculture integrates STEM (Vallera & Bodzin, 2020). The context of agriculture in this study is more specific to the processing products of agriculture and health drinks from spice plants, namely turmeric and tamarind. Turmeric-tamarind drinks have attracted attention because of their potential health benefits. Various studies have shown that this drink has antioxidant properties and is generally well-accepted by consumers (Fantasi et al., 2023; Rudyatmi et al., 2018). The combination of turmeric and tamarind extracts can show synergistic antioxidant effects, depending on the ratio of the ingredients (Fantasy et al., 2023). This drink has the quality standards set by regulatory bodies, which shows promise for commercial development (Rudyatmi et al., 2018). Thus, the turmeric-tamarind drink has health benefits, and vocational high school students in the agricultural product processing agribusiness program can probably process it.

The production of turmeric-tamarind drinks is short, but good preparation is needed to produce quality healthy. In this study, students are to be invited to plan turmeric-tamarind processing involving STEAM-H (practicing processing, packaging, and marketing). The students' activities develop an understanding of STEAM-H at each stage of turmeric-tamarind drink production so that STEAM-H literacy is built. Research on STEM literacy can be used as a reference framework for STEAM-H literacy. STEM literacy emphasizes applying concepts from science, technology, engineering, and mathematics together to solve problems that cannot be solved using just one discipline (Jackson et al., 2021).

Research on integrated education of several disciplines in STEM integrated with project-based learning has shown results such as improving technical knowledge and non-technical skills and preparing students for the demands of industry and entrepreneurship (Widiyanti et al., 2020). Work skills are needed to meet the needs of the industry even with the rapid technology, work skills will continue to change over time (Deming & Noray, 2019). Therefore, continuous development and adaptation of skills are needed to minimize the gap between integrated education of several disciplines and workplace requirements (Jang, 2016) and efforts to align the curriculum with workplace needs (McGunagle & Zizka, 2020) which have implications for the relationship between learning and work (Hawkins & Neubauer, 2015).

In Indonesian vocational high schools, mathematics is a subject included in the vocational subject group. However, the mathematics curriculum applied is the same as the general high school curriculum. The same applies to mathematics subjects in the field of agricultural processing agribusiness. The study showed that mathematics is needed to solve problems in agricultural production without explicitly involving mathematical content in the curriculum (Fatimah, Isyanto, & Toto, 2023). Through relevant mathematical literacy to vocational high school students, the context of agricultural processing is connected to various mathematical content to solve problems accompanied by 21st-century work skills explored through the STEAM-H approach. Thus, the main objective of this study is to hasten the STEAM-H approach to more contextual mathematical literacy and relevant mathematical content to the curriculum of agricultural processing vocational high schools. The research questions are: 1) How is the conceptual flow of STEAM-H integrated in the processing of turmeric and tamarind drinks? 2) How is the understanding of STEAM-H of students of vocational high schools majoring in agribusiness agricultural product processing? 3) How are students' work skills when processing turmeric-tamarind drinks? 4) How can mathematical literacy be developed in integrated STEAM-H according to the mathematical content in the high school curriculum for students of agribusiness agricultural product processing? This study seeks to assist STEAM-H education practices for limited mathematics teachers in learning various "STEAM-H languages" and promote integrated STEAM-H learning with a project-based approach or problem-based learning, especially in vocational high schools for agribusiness processing of agricultural products.

■ METHOD

The integration of STEAM-H in this study refers to several studies that carry the integrated STEM conceptual framework (Kelley & Knowles, 2016; Kennedy & Odell, 2014; Roehrig et al., 2021), mathematical literacy (OECD, 2023), and work skills (Davies et al., 2011; Hawkins & Neubauer, 2015). The research method used is an exploratory case study (Yin, 2018). Case studies were chosen because the research was conducted on small groups of students with a series of instructional activities to study the phenomenon in depth (Kullberg & Knutson, 2024). Exploratory case studies are used to investigate limited topics (Swedberg, 2020). In this context, STEAM-H has not been widely applied. Exploratory case studies can provide initial insights into how this approach works. Exploration was conducted to obtain a conceptual flow with an agricultural contextual integrator (context of agrarian product processing = turmeric-tamarind drinks), explore students' STEAM-H understanding, and explore relevant mathematical literacy between the context of turmeric-tamarind drink processing and mathematical content for vocational high school students in the field of agricultural product processing in the curriculum.

In the early stages of the study, we focused on exploring the conceptual flow of STEAM-H. Focus group discussions between the research team and vocational high school teachers began by determining conceptual and contextual integrators. We agreed on spice processing, which is part of the agribusiness curriculum for agricultural product processing (BSKAP Kemendikbudristek, 2022b), as the focus of the study. This topic is still very limited in other studies. Turmeric and tamarind drink as a context that integrated disciplines within the scope of STEAM-H based on the results of the discussion. Then, mathematics, science, and agribusiness teachers explored essential concepts in each of their disciplines that were relevant to the context of turmeric-tamarind processing. In this situation, teachers' understanding of curriculum coherence and integration is very important (Fatimah, Isyanto, & Toto, 2023) to anticipate differences of opinion among teachers. In addition, teachers also need to be aware that these essential concepts are explicit or implicit, located within or outside the curriculum (Fatimah, Isyanto, Toto, et al., 2023). In this way, an agreement on the conceptual flow graphics for the processing of turmeric tamarind drink can be achieved. This conceptual flow was the basis for developing student worksheets.

To ensure the validity and reliability of the developed conceptual flow and student worksheet, several validation techniques were used. First, the initial conceptual flow was subjected to expert review by experienced STEAM curriculum specialists and educators who provided feedback on the clarity, coherence, and relevance of the concepts and their integration. Second, teachers and researchers checked to ensure that the developed conceptual flow accurately reflected their understanding and contributions during the focus group discussions. Any discrepancies or ambiguities were addressed through further discussion and refinement. Finally, the conceptual flow was revised iteratively based on the feedback received, ensuring that the final product was a valid and reliable representation of the integrated STEAM-H approach.

The next stage of the research is the implementation of STEAM-H learning with a turmeric tamarind drink processing project in class XI. Students involved in the research came from a Vocational High School with an Agricultural Product Processing Agribusiness Concentration with the status of a public school in Ciamis Regency. This concentration of expertise is the only one in a State Vocational High School in Ciamis Regency with a minimal number of enthusiasts. Thus, the number of participants involved was 12 people (11 female and one male). In the implementation of learning, the turmeric tamarind drink processing project was divided into four groups. Based on initial identification, all students knew about turmeric tamarind drinks. Some had drunk it, while others only knew about it. All students had never processed turmeric tamarind drinks. Based on information from mathematics and science teachers, 25% of students' mathematics and science abilities were high, 58% were moderate, and 17% were low. Learning at the vocational high school has so far been discipline-based (subject-based learning).

Students' STEAM-H understanding was explored through worksheets (see Table 1), pretests, and posttests. The pretest and posttest questions consisted of 20 questions with details of 3 science, 3 technology, 3 engineering, 4 agriculture, 5 mathematics, and 2 health. Researchers conducted observations while students worked on the worksheets and practiced processing turmeric and tamarind drinks. Researchers observed how students interacted with tools and materials, how they worked in groups, & how they applied STEAM-H concepts in practice. Observations refer to students' work skills. Interviews focused on questions to explain students' thinking and processes in processing turmeric and tamarind drinks.

Table 1. Turmeric tamarind processing student worksheet

Stage	Question	STEAM-H
Recipe Planning, Raw Materials, Processing, Packaging, and Marketing of Turmeric Tamarind	Explore the nutrition, properties, and benefits of turmeric, tamarind, and turmeric tamarind drinks for health.	Science and Health
	What are the characteristics of high-quality turmeric and tamarind?	Science and Health
	Explore turmeric tamarind drink recipes. Write down a turmeric tamarind recipe that your group will make along with the steps.	Technology and Engineering
	Based on the turmeric tamarind recipe, what is the proportion between turmeric, tamarind, and water? Explain.	Mathematics
	Create a sketch of the design of tools/technology for making turmeric tamarind drinks, starting	Technology and Engineering

	from sorting and grading technology for raw materials, raw material storage, processing, packaging, and marketing.	
	You plan to make 10 bottles of turmeric tamarind containing 500 ml and 20 bottles containing 200 ml. Calculate the material requirements, tool requirements, costs required, selling price, and profit prediction.	Mathematics
Raw Material Selection	Take the materials needed to make turmeric tamarind. Carry out weighing, measuring, measuring, or other techniques. (a) Did you carry out sorting and grading techniques to help ensure the quality and safety of raw materials? Explain. (b) Did you use storage techniques to maintain the freshness of turmeric and tamarind? Explain. (c) Is the quantity of material taken according to plan? Explain.	Mathematics and Science
Drink Processing	Process the raw materials you have chosen. (a) Are there any changes to the processing techniques/methods from what was planned? Explain. (b) Is the use of technology in accordance with the plan? Explain. (c) Is the processing in accordance with sanitation and food safety standards? Explain.	Technology, Engineering, Health
	Determine the temperature and time required to obtain optimal turmeric tamarind drink results.	Science and Mathematics
Packaging	Package and label the processed turmeric tamarind drink according to the plan. (a) Are there any changes in the shape, size, or type of packaging from the previous plan? Explain. (b) Is the processed turmeric tamarind by the number of packages provided, or even less or more? Explain. (c) Explain that the packaging used meets food safety.	Science, Technology, Engineering, Health, Mathematics
Marketing and Distribution	Determine the selling price of the product. Explain how you determine the selling price.	Mathematics
	Explain the marketing and distribution methods.	Technology and Engineering
	How to ensure that products are stored and distributed safely and hygienically to maintain their quality.	Health
Evaluation and Impact	What are the results of self-evaluation and consumer evaluation of the taste, aroma, color, and texture of turmeric tamarind drinks?	Science
	Based on the experience of the raw material selection, processing, packaging, and marketing process, what technology/tools are needed to make the work effective and efficient?	Technology and Engineering
	Sales and profit analysis.	Mathematics

Thematic data analysis was used in this study (Akinyode & Khan, 2018). Field notes, interview transcripts, worksheets, and other documents were organized to determine students' STEAM-H understanding by first coding the data to facilitate grouping and analysis. Themes were created based on the stages of turmeric and tamarind processing production so that categories of science, technology, engineering, agriculture, mathematics, and health were created. The creation of a matrix serves to compare data from various stages of tamarind drink production and various sources of data collection such as tests, worksheets, observations, and interviews. Data analysis of STEAM-H understanding is to identify the understanding of each discipline within the scope of STEAM-H from themes that appear repeatedly in the data. Data interpretation is carried out by looking for patterns/themes that emerge from the data, making conclusions based on the patterns found, and comparing findings with relevant theories. Conclusions about STEAM-H understanding are made to answer research questions.

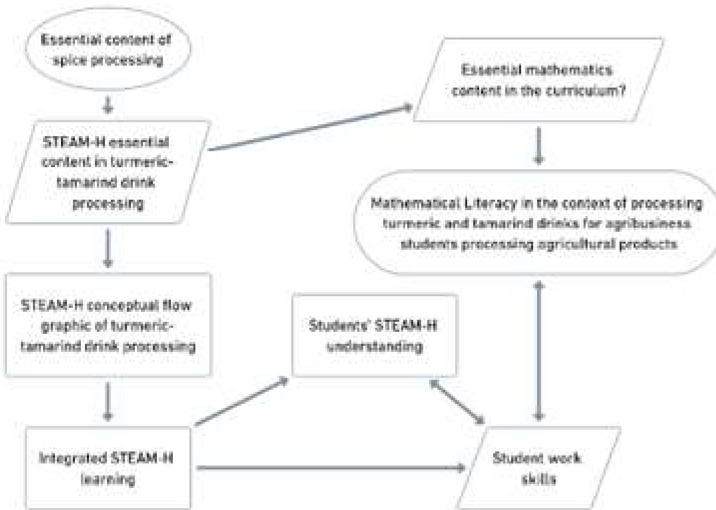

Figure 1. Research flow

The researchers also conducted observations and interviews to explore students' work skills during the process of preparing turmeric-tamarind drinks. They analyzed the students' work skills, including sense-making, social intelligence, novel and adaptive thinking, cross-cultural competency, computational thinking, new-media literacy, transdisciplinarity, design mindset, cognitive load management, and virtual collaboration (Davies et al., 2011; Hawkins & Neubauer, 2015). The results of the analysis of work skills and understanding of STEAM-H were linked to mathematical literacy developed in the context of preparing turmeric and tamarind drinks, which are relevant to essential mathematical content in the curriculum.

To validate the results of this study, the researcher used data triangulation by combining data from various sources, including student worksheets, pretests and posttests, direct observations during the turmeric tamarind drink processing process, and interviews with students. Further validation was conducted by linking the results of the analysis of students' STEAM-H work skills and understanding with curriculum-relevant mathematical literacy, ensuring that the research findings were well-founded and reliable.

RESULT AND DISCUSSION

Integrated STEAM-H Conceptual Flow in Turmeric-Tamarind Drink Processing

To create the integrated STEAM-H conceptual flow in processing turmeric and tamarind drinks, we start by analyzing the curriculum for processing spice agricultural products in phase F, grade XI (BSKAP Kemendikbudristek, 2022b). We've identified initial codes, including selection, handling, preparation, operation, production process, raw materials, additional materials, equipment, quality, methods, conventional, and modern. After that, teachers and researchers determine the stages of drink production, such as recipe search, material selection, drink processing, packaging, marketing and distribution, evaluation, and impact. These stages fall under the agriculture discipline category. Through interviews and document reviews, we've identified the roles of science, technology, engineering, mathematics, and health at each stage of production, as shown in Figure 2.

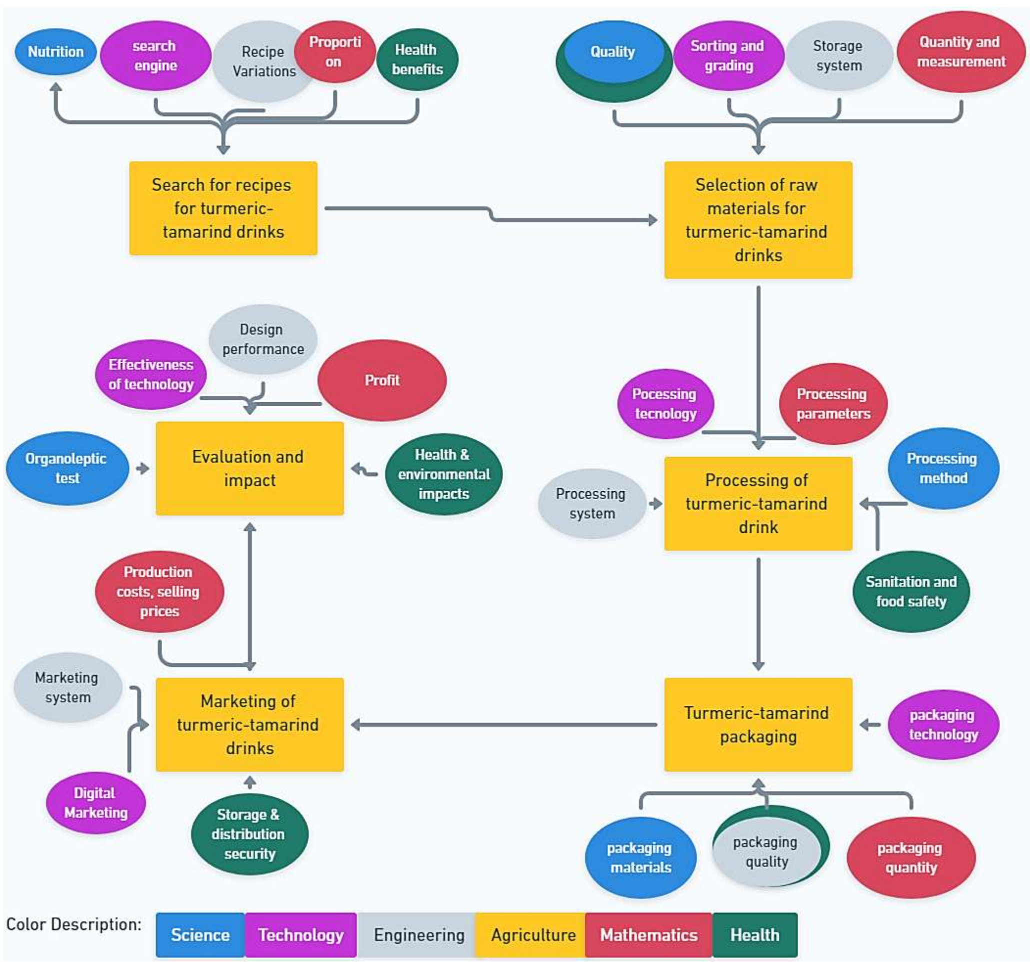

Figure 2. STEAM-H conceptual flow in processing turmeric-tamarind drinks

Figure 2 illustrates that agriculture incorporates various disciplines, including science, technology, engineering, mathematics, and health. This finding is in line with studies on agriculture that show its integration with STEM (Mitchell & Currey, 2020; Scherer et al., 2019). Agriculture is the center of integration (see Figure 2, in yellow for the processing stage of turmeric and tamarind drink) for other disciplines. This finding is in line with other studies that state that agriculture serves as a unifying and contextual topic that connects STEM subjects (Vallera & Bodzin, 2020). In addition, the context of agricultural technology has great potential for integration with STEM (Bernad et al., 2024; Gareau & Moscovitz, 2021). Thus, agriculture has proven to be a strong foundation for integrating various disciplines, especially within the STEAM-H framework.

Furthermore, the disciplines of science consisting of physics, chemistry, and biology play a role in the processing of tamarind turmeric, as indicated by the following essential concepts. In physics, concepts such as fluids (extraction, filtration), heat, and thermodynamics (heating, cooling, and evaporation) are relevant. In chemistry, there is a relationship with physics (extraction), mathematics (calculating the dosage of ingredients using the concept of comparison and proportion), and biology (nutrition). Turmeric tamarind drink, which is herbal in its processing, involves physical concepts such as extraction, filtration, and thermodynamics, as well as chemical and biological aspects (Bidyalakshmi et al., 2023).

Technology and engineering in the processing of turmeric and tamarind drinks are closely related, where technology involves the tools used, and engineering involves the design and optimization of the process. This covers the entire production cycle, from raw material processing, product packaging, and marketing to quality evaluation. In the processing process, extraction and filtration technology are used to improve efficiency and cleanliness. Engineering plays a role in designing the optimal processing system. Packaging technology and quality control ensure that the product remains fresh and safe. In terms of marketing, digital technologies such as social media are used to reach a wider market. The engineered marketing system as an online promotion strategy. Evaluation of the effectiveness of technology and design performance to ensure that the entire process runs according to plan. Processing technology and engineering are essential for efficient, sustainable production (Vasanthkumar S. S. et al., 2023).

The mathematics involved in the production of turmeric and tamarind drinks is relatively simple, and it may not be explicitly addressed in the curriculum. Therefore, in the third part of the results and discussion, we will explain how mathematical literacy relevant to the curriculum can be developed based on the skills of vocational high school students in processing turmeric and tamarind drinks.

Health discipline plays an important role in the processing of turmeric tamarind drinks. Relevant aspects include product health benefits, product sanitation and safety, packaging quality, storage and distribution safety, and health and environmental impacts. Implementation of good manufacturing practices and standard operating procedures for sanitation are essential to ensure product quality in accordance with Indonesian national standards (Warkoyo et al., 2019). In addition, health and environmental aspects must also be taken seriously. The production of herbal drinks, although it has health benefits, can produce liquid, solid waste, and gas emissions that have the potential to have a negative impact on climate change and eutrophication. (Arba'i et al., 2019).

The conceptual flow developed in Figure 2 shows the existence of disciplinary interactions within the scope of the STEAM-H to support meaningful integrated learning for students. Various studies have examined the integration of agricultural curriculum with other subjects, particularly mathematics and science. This approach has been recognized as effective for enhancing student learning and developing critical thinking skills (Foutz et al., 2011; Robinson et al., 2018). A conceptual framework for integrative agricultural education has been proposed to support the development of 21st-century skills and quantitative reasoning abilities (Robinson et al., 2018). Conceptual flowcharts have been used to analyze the coherence and nature of integration in STEM curricula, revealing varying degrees of connection between science content and engineering design challenges (Roehrig et al., 2021). Studies have shown positive outcomes from science integration into secondary agricultural education, although there are remaining gaps in research and future directions (Wilson & Curry, 2011). Additionally, there is a dual perspective that recognizes agriculture as a rich learning context while also realizing the importance of teaching agricultural content alongside knowledge from other disciplines (Roberts & Ball, 2009). Balschweid & Thompson (2000) investigated the impact of an integrated agriculture and science curriculum on preservice teachers' ability and willingness to integrate their own curricula and collaborate with other teachers. The study highlighted the importance of integrative teaching practices, the need for a curriculum framework, and the potential benefits of integrated learning in agricultural education.

Students' STEAM-H Understanding

The results of STEAM-H understanding focused on turmeric-tamarind processing and test improvement. The observation results showed that students could identify turmeric and tamarind nutrients, recognize the characteristics of high-quality turmeric and tamarind, determine the ideal processing temperature, and conduct organoleptic tests. Technological understanding was identified when students followed the turmeric-tamarind recipe and planned and utilized processing and packaging tools. Students' engineering understanding was evident when they planned the processing and packaging design. Agricultural understanding, in the context of processing spice agrarian products, was seen in all stages of processing turmeric-tamarind drinks to ensure that the drinks were suitable for consumption and distribution to users. Students' understanding of turmeric-tamarind drinks correlated with their understanding of science. It should be noted that previous studies tend to highlight more scientific understanding in the context of agricultural product processing, as shown by (Dewi & Rusita, 2017) and (Septiani & Rustaman, 2017).

Based on the interview results, some students had known about the turmeric and tamarind drink through stories passed down from their ancestors about its health benefits. Female students, in particular, were taught by their parents that if they experienced menstrual pain, they were advised to drink a concoction made from turmeric and tamarind. As one student expressed, "My mother always said, if I have a stomachache due to menstruation, drinking turmeric and tamarind is the most effective." Students learned about nutrition, properties, recipes, and processing procedures by searching for information on the internet. They collected at least three pieces of information to compare and decide which recipe to use for their turmeric and tamarind drink project. One group of students experimented with the recipe by adjusting the ratio of turmeric and water. This was confirmed by a student: "At first we followed the recipe on the internet, but the taste wasn't quite right. Then we tried adding a little turmeric, it turned out to be better." There was even a student who added, "We also found out the vitamin content in turmeric and tamarind, so we knew the health benefits." This interview showed that students did not only rely on traditional knowledge but also actively sought information from various sources to understand and improve the processing of turmeric and tamarind drinks. This is in line with various studies that show a significant decrease in pain scale after consuming this traditional drink (Asroyo et al., 2020; Astuti et al., 2020).

In mathematics, students were given problems related to the quantity of ingredients, proportions, costs, selling prices, and measuring temperature and processing time. They were able to identify relevant variables in the ingredients used. Two groups of students were identified using mathematical concepts such as finding the ratio between water and turmeric and using addition, multiplication, and division to calculate the quantity of ingredients, costs, and selling prices. There were differences in the units of measurement used, where one group used milliliters and grams, while the other group used liters and kilograms. The other two groups used these units based on the assumption that liters and milliliters are for liquid ingredients, while kilograms and grams are for solid ingredients. All groups provided logical answers, explained the meaning of their calculations, and evaluated the results of each question during the process of making turmeric and sour drinks. This shows that students have mathematical knowledge that supports the processing of turmeric and sour drinks. Research shows that integrating food-based activities can improve mathematical literacy (Roseno et al., 2015). Likewise, research on junior high school students showed a high level of mathematical literacy when solving PISA problems related to quantity (Salsabila et al., 2021). These findings emphasize the importance of contextualizing mathematics education to enhance students' understanding and application of mathematical concepts, which ultimately contributes to the development of students' mathematical literacy in practical contexts (Lutfiah & Hidayah, 2024; Tapan Broutin et al., 2021).

The next part of the discussion focuses on the understanding of STEAM-H as examined through pretest and posttest assessments. The analysis of these assessments revealed that, on average, 12 students demonstrated a moderate level of understanding of STEAM-H based on their N-gain scores. Furthermore, the understanding of STEAM-H was categorized by discipline, and this breakdown is illustrated in Figure 3.

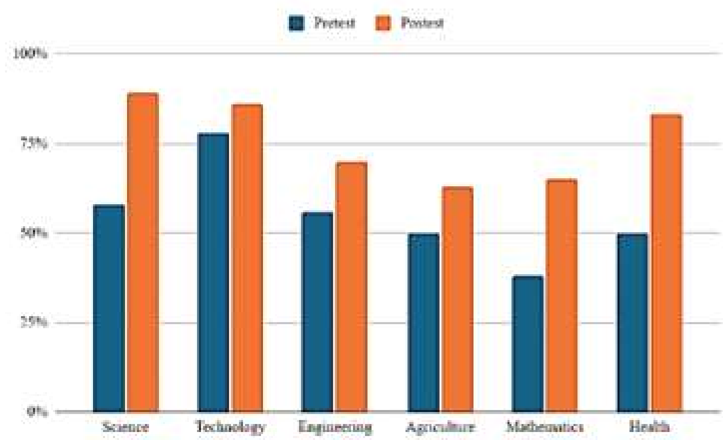

Figure 3. Students' STEAM-H understanding based on pretest and posttest

Figure 3 shows the mean score increase from pretest to posttest across all six STEAM-H disciplines (Science, Technology, Engineering, Agriculture, Mathematics, and Health). The most significant increases occurred in the Health and Mathematics disciplines, indicating the effectiveness of the learning intervention in improving students' understanding in these areas. However, there was variation in the magnitude of the increase across disciplines, indicating that the effectiveness of the intervention may vary depending on the subject matter. Overall, this graph confirms that the learning process implemented successfully improved students' understanding across all STEAM-H disciplines. Further quantitative analysis of the pretest and posttest data is presented in Table 2.

Based on Figure 3 and Table 2, the bar graph shows the increase in mean scores from pretest to posttest across all six STEAM-H

Table 2. Correlation and regression analysis

Analysis	Result	Interpretation
Correlation Analysis		
Pearson Correlation Coefficient (r)	0.55	There is a moderate positive relationship between pretest and posttest scores.
Simple Linear Regression Analysis		
Regression Equation	Y = 33.33 + 0.65X (Y = posttest score, X = pretest score)	For every 1-point increase in pretest score, the posttest score is estimated to increase by 0.65 points.
Coefficient of Determination (R^2)	0.30	30% of the variation in posttest scores can be explained by pretest scores. The remaining 70% is explained by other factors.

disciplines, which is consistent with the results of the correlation analysis which showed a moderate positive relationship (r = 0.55) between pretest and posttest scores. This indicates that students with higher pretest scores tend to have higher posttest scores. However, a simple linear regression analysis showed that only 30% of the variation in posttest scores could be explained by pretest scores (R^2 = 0.30), meaning the remaining 70% was influenced by other factors. The bar graph supports this finding by showing the variation in score increases across disciplines, suggesting that the STEAM-H integrated learning factors contributed to the posttest results. The most significant increases in Health and Mathematics indicate the effectiveness of the learning intervention in those areas, while smaller increases in other areas indicate potential areas for improvement.

Students' understanding in Science and Health tended to be high, indicating their understanding of the nutritional benefits and properties of turmeric and tamarind drink. Students' science understanding is influenced by various factors, including their intuitive framework and everyday experiences (Vosniadou, 2019). However, pretest and posttest data showed no significant difference in Technology understanding. This is likely due to students' familiarity with the technology used in food and beverage processing from previous projects. In contrast, students' understanding of agricultural product processing technology was not very advanced. Some students argued that small-scale turmeric and tamarind drink processing does not require sophisticated equipment, indicating a lack of understanding of agricultural processing engineering systems. They also argued that traditional processing methods produce products with better taste. This presents a challenge for teachers to integrate technology into the educational process in line with the emphasis on technological competence in modern vocational education, which includes theoretical knowledge and practical skills (Onipko et al., 2022).

The findings of this study generally support the main principle of STEAM-H education, namely multidisciplinary integration to improve students' understanding and skills in practical contexts. The increase in mean scores from pretest to posttest across all STEAM-H disciplines suggests that the integrated approach is effective in improving student learning outcomes (Suriyana & Novianti, 2021). However, the variation in the magnitude of improvement across disciplines challenges the assumption that STEAM-H integration always produces uniform results across all areas. These findings suggest that the effectiveness of integration may depend on factors such as subject matter, teaching methods, and students' level of familiarity with the technology used (Jauhari & Sholihah, 2024).

This study contributes to our understanding of the benefits of STEAM-H integration in vocational education by demonstrating that this approach can enhance students' understanding across disciplines, particularly in areas relevant to students' everyday lives and practical experiences, such as Health and Mathematics (Fatimah, Isyanto, & Toto, 2023). However, the study also highlights the challenges in integrating technology and engineering into vocational education, particularly in the agricultural context. Students' lack of understanding of agrarian processing engineering systems and their preference for traditional processing methods suggest the need for more innovative and industry-relevant teaching approaches (Smith et al., 2015; Stubbs & Myers, 2015).

Students' Work Skills

In this study, students' work skills were assessed through observation and interviews. Out of the ten work skills (Davies et al., 2011; Hawkins & Neubauer, 2015), only nine were applicable to the turmeric and tamarind drink processing project. Virtual collaboration was not relevant as the collaboration took place in a real, physical setting. Figure 4 depicts a series of student activities, starting from planning and selecting raw materials to processing and packaging turmeric and tamarind drinks.

Figure 4. Student activities in processing turmeric-tamarind drinks

Students' sense-making is demonstrated by their ability to explain why certain ingredients are chosen. They choose local ingredients that are easier to obtain. They can also relate the process of making drinks to scientific concepts, specifically extracting by separating turmeric dregs and water. Students' new and adaptive thinking is demonstrated by proposing a turmeric smoothing tool. Initially, three groups planned to use a blender, while another group used a grater. However, they all ended up using a grater. This decision was made after they reconsidered that the quantity of processing they were doing was relatively small and they believed that the taste produced by grating was better. As one student articulated, "We thought blending would be faster, but since we're only making a small batch, grating gives a better, more traditional taste." If production is carried out on a large scale in the future, they will use a grater machine that is usually used to smooth coconut. Another adaptation is in the taste produced. Students' social intelligence is demonstrated when interacting with other group members. Each group can divide tasks among its members and interact with each other, providing input to each other. Students' transdisciplinary ability is demonstrated by their ability to connect concepts from various disciplines. All groups can use mathematics to calculate the amount of ingredients with the assistance of scales and measuring cups. In one specific finding, one group calculated the number of additional ingredients needed by referring to the main ingredients, namely turmeric and tamarind, by adding and dividing. Transdisciplinary abilities related to mathematical aspects are connected to students' computational abilities. This aligns with findings that students demonstrate adaptive thinking and sense-making when engaging with traditional drink preparation, adjusting processing methods based on practical considerations (Pudjowati & Anindika, 2022). Across these studies, students exhibit transdisciplinary abilities, connecting concepts from various disciplines, including mathematics and science, while engaging in hands-on learning experiences that promote both traditional knowledge and entrepreneurial skills (Alwian, 2024).

Students' new media literacy skills were demonstrated through the use of digital media to search for and evaluate information about the nutrition, properties, benefits, and recipes of turmeric and tamarind. Initially, students in groups one and two were unaware of the nutrition, benefits, and properties of turmeric and tamarind. They then used a search engine to find information from various sources, compared the information, and made decisions. Some students from groups three and four already had prior knowledge about the properties of turmeric from their parents and grandparents, while others did not. Some students who already had information from their parents still searched the website for more details. Group four specifically chose information from trusted websites such as Halodoc. One student explained, "We wanted to make sure the information was correct, so we checked several websites and compared them, especially those from trusted sources." This demonstrates their ability to evaluate and select reliable sources, an essential component of digital media literacy, particularly when dealing with health-related information online (Manalu et al., 2020). The process of searching, comparing, and deciding on information sources aligns with the broader competencies of digital media literacy, which include judgment and transmedia navigation (Balaban-Sali, 2012). Although some students had prior knowledge, the reliance on digital sources to supplement or verify information reflects the growing importance of these skills in modern learning environments. However, studies have also shown that many students lack comprehensive digital media literacy, particularly in wisely using social media (Supratman & Wahyudin, 2017).

Students' new media literacy skills were demonstrated through the use of digital media to plan the process of making drinks, affecting their design mindset. Students improved the process based on the information obtained. When determining the recipe, they chose the easiest processing. Group three decided to use an aluminum pan instead of a glass pan, influenced by information that the type of pan affects the taste of the turmeric and tamarind drink. Students in groups two and three also considered the net and gross results to be obtained. Therefore, they changed the composition of water from 200 grams of turmeric requiring 1500 ml of water to 3000 ml of water. Students also learned from the search engine that there are many methods and recipes for processing turmeric and tamarind from different cultures that have many health benefits. One student explained, "We found that the pan material changes the taste, and we adjusted the water to get more drink from the same amount of turmeric." This illustrates how new media literacy skills, including judgment and appropriation, directly influence practical decision-making in a real-world context (Balaban-Sali, 2012).

In summary, this study highlights the multifaceted development of students' work skills through a hands-on project involving the processing of turmeric and tamarind drinks. As illustrated in Figure 4, students navigated the entire production process, demonstrating a range of competencies from material selection to final packaging. Through observation and interviews, it was evident that students effectively applied sense-making, adaptive thinking, social intelligence, and transdisciplinary abilities, particularly in integrating mathematical and scientific concepts. Moreover, the integration of digital media literacy, as evidenced by their ability to search, evaluate, and apply online information, significantly influenced their decision-making and design mindset. These skills not only enhanced their practical understanding of the project but also mirrored broader trends in education, emphasizing the importance of digital literacy and collaborative learning in modern contexts (Angeli, 2024; Shetye & Indrakanti, 2023). The development of transdisciplinary competencies and transmedia skills, as highlighted by students' navigation of digital resources and application of diverse information, aligns with the necessity for a transversal approach in education (Bardi et al., 2018). While the project successfully fostered these skills, it also underscored the necessity for educators to address potential gaps in digital media literacy and to continuously integrate real-world applications into vocational training to maximize student learning outcomes (Silber Varod et al., 2019).

Mathematical Literacy in STEAM-H Integrated in the Context of Processing Turmeric-Tamarind Drinks

Important components of mathematical literacy for students of vocational high schools in agribusiness and agrotechnology are vocational mathematics knowledge, agribusiness, and agrotechnology context, mathematical problem solving with creative or imitative reasoning, and work skills (Fatimah, Isyanto, & Erlin, 2023). The results of the analysis of students' work skills above show that these work skills are related to various 21st-century skills, such as critical, creative, collaborative, and communication thinking in the process of making turmeric and tamarind drinks. This is in line with the components of mathematical literacy PISA (OECD, 2023). Therefore, the discussion of mathematical literacy in this section includes the components of mathematical literacy in the context of processing turmeric and tamarind drinks.

The processing of turmeric-tamarind drinks is part of phase F in the Merdeka curriculum, which focuses on spice processing. The vocational mathematics knowledge needed to process these drinks is relatively simple, especially involving proportions, measurements, and finance (costs, selling prices, etc.). These mathematical concepts are not explicitly included in the vocational high school curriculum (Pusporini et al., 2023). We can improve the mathematical content by expanding the activities that students have done. The turmeric-tamarind processing project has been completed in small-scale production, so the mathematics needed is still relatively simple. If the production of turmeric-tamarind drinks is carried out on a larger scale, it will require significant capital and other resources. The expansion of relevant content in the Merdeka curriculum related to financial models for phase F is one of the offers for expanding mathematical content, as presented in Table 3. However, challenges in implementing the Merdeka curriculum have been observed, with teachers and students struggling to adapt to the new system, suggesting a need for modifications and adaptations to enhance student learning (Adib Rozan et al., 2024; Krisma et al., 2024).

Table 3 presents the mathematical requirements for large-scale production of turmeric and tamarind drinks. Enhancing practical mathematical knowledge is crucial for mathematical literacy in vocational education, and expanding mathematical content can help achieve that. Past research has highlighted the importance of integrating agricultural knowledge with

Table 3. Expansion of mathematical content in large-scale production of turmeric-tamarind drinks

Financial Content	Description
Creating a simple financial model:	- Creating a simple mathematical model to calculate the production cost of turmeric-tamarind drinks, - Determining the selling price of the product by considering the production costs and expected profits, - Creating projections of income and expenses over a certain period.
Applying the compound interest concept	- Calculate the cost of a business loan with a simple and compound interest system, considering the interest rate and loan term, - Simulate various loan repayment scenarios with compound interest to choose the most profitable option
Using computational tools	- Use spreadsheets or financial software to create models and perform more complex calculations. - Create graphs to visualize financial data and facilitate analysis

mathematical concepts in vocational education. Fatimah et al. (2020) found that students' agricultural knowledge can impact their mathematical understanding, although some struggled to connect the two domains. Similarly, Fatimah & Prabawanto (2020) observed that task design and students' experiences influenced mathematical understanding and reasoning in agricultural-based problems. Muhrman (2015) emphasized that mathematical skills are crucial for professional farmers, but many agricultural students do not have adequate skills upon graduation. These studies collectively underscore the need for increased integration of mathematical concepts with agricultural contexts in vocational education to better prepare students for their future professions.

Furthermore, the analysis of students' understanding of STEAM-H subjects and their practical skills shows that problem-solving and mathematical reasoning, along with their work skills, are interconnected when processing turmeric and tamarind drinks. This highlights the importance of developing mathematical literacy in vocational schools. Mathematical problem-solving has traditionally been a key aspect of mathematics education, serving as a tool for addressing problems in various (Goos et al., 2023). Moreover, mathematical problem-solving is closely linked to critical thinking skills, which are crucial for success in both academic and professional settings (Alcantara & Bacsa, 2017). For example, during the debate about the optimal water-to-turmeric ratio, students demonstrated critical thinking by analyzing different recipes and justifying their choices based on taste and yield. One student noted, "We tried two ratios, and the 3000ml water to 200g turmeric gave a stronger flavor, which we preferred." This debate helped students develop their ability to evaluate information and make informed decisions, essential for both problem-solving and mathematical reasoning.

The results of this study indicate that the area of mathematics within the scope of STEAM-H is the core of problem-solving tools supported by mathematical reasoning. Both mathematical abilities are supported by work skills to achieve success in solving problems within the scope of STEAM-H with added value, namely developing innovation, increasing efficiency, and making the right decisions. Work skill support for problem-solving and mathematical reasoning can also support problem-solving within the scope of STEAM-H. Work skills supporting problem-solving are sense-making (the ability to understand problems and formulate the right questions), cognitive load management (the ability to manage information and complex problem-solving strategies), computational thinking (the ability to involve the use of algorithms and computer modeling), and design mindset (the ability to formulate innovative and effective solutions). Work skills supporting mathematical reasoning are novel and adaptive thinking (the ability to think outside the box and find new solutions) and transdisciplinarity (the ability to apply mathematical concepts in various fields). The relationship between these component needs to be studied again in subsequent research.

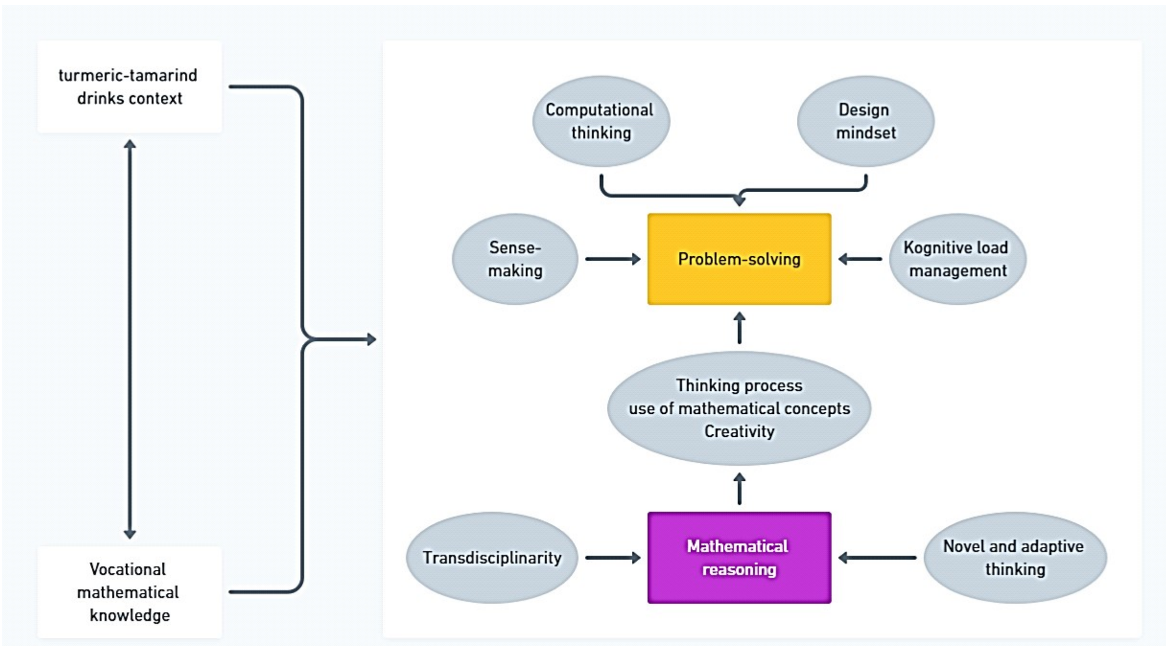

Figure 4. Components of mathematical literacy in vocational high schools

Figure 4 shows that, in the context of turmeric-tamarind drink processing, vocational mathematics knowledge in numerical content, mathematical reasoning, and problem-solving, supported by work skills, are components of mathematical literacy relevant to vocational high school students. This component of mathematical literacy is facilitated by the STEAM-H approach, which involves six disciplines: science, technology, engineering, agriculture, mathematics, and health. This approach hones students' skills that support critical and innovative thinking amidst the complexity of rapidly changing problems. Furthermore, collaboration skills were evident during the task division and recipe adjustments. Students actively listened to each other's opinions and negotiated solutions. For instance, when deciding on the type of pan to use, one group member suggested an aluminum pan based on online research, while others preferred a traditional clay pot. They resolved the conflict by testing both options and comparing the results. This collaborative process not only improved their problem-solving abilities but also fostered social intelligence and teamwork. Mathematical literacy and problem-solving skills are crucial for students, particularly in vocational education, as demonstrated by their ability to identify problems, explore knowledge, apply concepts, and make decisions in the context of this project (Hayati & Kamid, 2019; Wannapiroon et al., 2021). To further enhance these skills, educators should focus on integrating STEM literacy into project-based learning approaches and designing effective instructional strategies that emphasize the connection between mathematical concepts and real-world applications (Srikoon et al., 2024; Wannapiroon et al., 2021).

CONCLUSION

The study focused on creating a conceptual flow for integrating STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health) into the production process of turmeric-tamarind drinks. This flow is developed by analyzing the individual curriculum and identifying the roles of each discipline at every stage of production. The findings indicate that agriculture serves as the primary integrator connecting all these disciplines. This integration enables students to apply knowledge from various fields simultaneously, enhancing their conceptual understanding and problem-solving skills. While previous studies have shown the potential for integrating agricultural curriculum with other subjects, this study specifically contributes by designing a more structured conceptual flow that is relevant to the local product processing context.

The study delves into students' comprehension of the STEAM-H concept, comprising science, technology, engineering, agriculture, mathematics, and health, demonstrated through the production of turmeric-tamarind drinks. The results reveal that students exhibit a strong grasp of science and health, particularly in understanding the nutritional and health benefits of turmeric-tamarind drinks. However, there is room for improvement in their understanding of technology, engineering, and mathematics, especially in leveraging modern technology for agricultural processes and solving mathematical problems related to proportions and cost calculations. Additionally, a deeper understanding of food security regulations would be beneficial. This study underscores the significance of integrating STEAM-H concepts into education to bolster students' ability to solve real-world challenges.

The study of students' work skills revealed their exceptional abilities. They demonstrated strong sense-making skills by selecting local ingredients to create unique beverages tied to scientific concepts. They also showed their adaptability by suggesting and using more suitable tools. Their social intelligence was evident through effective collaboration and input among group members. Moreover, the students effectively integrated various disciplines, particularly mathematics, into the production process. Their proficiency in new media literacy skills was apparent as they actively sought and utilized information from diverse sources to enhance the quality of their products. These skills also influenced their design mindset, reflecting in the decisions they made during the production process. In general, the students demonstrated strong cognitive management skills by focusing on tasks and using tools to make their work more efficient.

The comprehensive analysis of conceptual flow, mathematical comprehension, and work skills aims to cultivate mathematical literacy among students pursuing agricultural product processing at vocational high schools. Mathematical literacy encompasses vocational mathematical knowledge, problem-solving proficiency, and mathematical reasoning, all reinforced by critical thinking, creativity, and cognitive load management. Expansion of mathematical content and large-scale production contexts is proposed to be relevant to the curriculum in vocational high schools.

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