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# DEVELOPMENT OF A SUSTAINABLE EDUCATION-BASED TOFU INDUSTRY MANAGEMENT MODEL IN MAKASSAR CITY

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**Abstract**

The SOLID (Self-confidence, Opportunity, Learning of Technology, Initiative, and Decision) training model enhances vocational education in sustainable tofu industry waste management. Small-scale tofu industries generate significant liquid and solid waste yet lack the awareness and skills to manage it properly. Limited access to practical training has hindered the adoption of environmentally friendly technologies. This study designs and evaluates an experiential learning and problem-based training model to improve scientific literacy, technical skills, and innovation in the tofu industry. The Research and Development (R&D) approach used the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Expert validation rated the model as highly valid (0.84) and very practical (81.9–85.2%). A one-group pretest-posttest study with 25 tofu industry participants showed a significant increase ($p < 0.05$) in knowledge, attitudes, and skills. The SOLID model proves to be more effective than conventional methods, emphasizing active participation, problem-solving, and hands-on practice. It fosters innovation in environmentally friendly waste management and should be integrated into industrial training curricula and vocational education. Implementing this model can develop a competent, innovative, and sustainability-focused workforce, contributing to small-scale industry efficiency and environmental conservation.

**Keywords:** Waste Management, Vocational Education, SOLID Model.

## INTRODUCTION

Tofu industry is a promising business sector, proven by its ability to survive during the two years COVID-19 pandemic. Data from Indonesia Statistics (BPS) in 2021 reveals that tofu consumption per week reached 0.158 kg on average per capita, increased by 3.27% compared to 2020, which was 0.153 kg per week (Badan Pusat Statistik Indonesia 2024).

It indicates that public interest in tofu remains high despite the pandemic, with average tofu consumption before the pandemic (2017-2018) ranging from 0.157 - 0.158 kg per week.

Tofu, a traditional food made from soybeans, is very popular in East Asia and Southeast Asia, and is now starting to develop in Europe (Chua and Liu 2019). Its popularity is due to its high protein content and low cholesterol, so it is beneficial for health (Singh and Krishnaswamy 2022).

Additionally, tofu is also delicious, affordable, and nutritious, making it a popular choice among various groups, both from the upper-middle and lower-middle class. Public interest in tofu as a source of vegetable protein has driven the growth of the tofu industry in both urban and rural areas.

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The increased tofu consumption causes rapid development of the tofu industry in Indonesia. According to previous research (Ginting et al. 2024), Indonesia has more than 84,000 tofu industry units capable of producing more than 2.56 million tons of tofu per year. This certainly affect the community's economy positively. However, from an ecological perspective, the development of the tofu industry, most of which is managed by small businesses or households, is harmful for the environment and human health (Feng et al. 2024; Ji et al. 2025). The processing of soybeans into tofu produces solid, liquid, and gas waste. The solid waste is in the form of soybean skin, soybean pulp (okara), and combustion ash, while smoke pollution comes from the combustion process in the furnace and gas comes from the waste degradation (Sudarto, Salundik, and Soenarno 2023). According to Gabriella and Sugiarto (Darmajana, Afifah, and Indriati 2020) the production of tofu requires about 10 times the amount of water used for soybeans, resulting in high volume of wastewater with organic content (Feng et al. 2024; Safshekan et al. 2020). and pathogenic microorganisms, risking the public health (Zhang et al. 2021), as supported in another previous study (Ji et al. 2025).

In this case, the liquid waste produced is from the washing, soaking, and coagulating soybeans (whey), which has high pollutant characteristics. The production of high wastewater in tofu production can be seen in the previous studies, where for a production capacity of 100-300 kg of soybeans per day, the tofu industry can produce 800-2,400 liters of liquid waste per day (Hartini, Ramadan, et al. 2021). The wastewater produced from soybean coagulation, or whey, has a high acidity level and a very high organic compound content, with 40-60% protein, 25-50% carbohydrates, and 8-12% fat (Anggarini et al. 2015). Based on the previous research projects (Chua and Liu 2019; Feng et al. 2024; Hardyanti et al. 2023; Hartini, Azzahra, et al. 2021), the wastewater from the tofu industry exhibits extremely high levels of pollution parameters, such as COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), and TSS (Total Suspended Solids), along with a low pH. These values surpass the allowable limits established by the Minister of Environment Regulation No. 5 of 2014.

It shows that the tofu industry contributes significantly to environmental pollution. Many tofu industries discharge wastewater directly into drains without adequate treatment, causing unpleasant odors and polluting the surrounding environment (Hartini, Ramadan, et al. 2021). Based on the Environmental Quality Index (IKLH) report from the Ministry of Environment, around 30% of water quality in major cities in Indonesia is contaminated, one of which is due to tofu industry activities (Gabriella and Sugiarto 2020). This environmental problem is increasingly worrying because many tofu industry actors are not aware of the importance of environmentally-friendly waste management.

Lack of ecoliteracy and environmental awareness among tofu industry actors is a major obstacle in overcoming this problem. Entrepreneurs tend to view waste management as an economic burden and are difficult to implement without adequate support, both in terms of infrastructure and knowledge (Safshekan et al. 2020). Therefore, education and training are necessary to be conducted to improve their environmental awareness, thus tofu industry actors can manage their businesses sustainably, pay attention to environmental aspects, and utilize waste into useful products (Hwang, Kim, and Jeng 2000).

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The importance of education and training for tofu industry owners and workers is the basis for developing an ecoliteracy-based training model. This training aims to improve the knowledge, attitudes, and skills of industry actors in waste management, so they understand the importance of environmentally-friendly industrial management. The SOLID (Self-confidence, Opportunity, Learning of Technology, Initiative, and Decision) training model, designed to increase environmental awareness through technology and waste management, is expected to bring significant changes in the tofu industry and strengthen environmental sustainability (Karim, Osse, and Khalloufi 2025; Stanojević et al. 2023). This training strongly founded entrepreneurs to improve their industrial processing quality, encouraging better environmental awareness for the tofu industry as a whole.

## MATERIALS AND METHOD

### Research Design

This study employs a Research and Development (R&D) approach integrated with a quantitative research method. R&D is a systematic scientific approach used to investigate, design, produce, and validate innovative products. The main objective of this study is to develop a sustainable tofu industry management training model based on education. The research follows the ADDIE instructional design model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is effective in structuring and systematically implementing sustainable tofu industry management. The application of the ADDIE model in this study follows the stages below: (Adeoye et al. 2024).

### Application of the ADDIE Model

### 1. Analysis Phase

The first phase involves identifying training needs and analyzing key aspects related to participants, industry processes, and environmental impact. The analysis covers:

- Participant characteristics, including gender, age, education level, and work experience.
- Knowledge, attitudes, and skills assessment of tofu industry workers regarding waste management.
- Industrial processing potential, focusing on economic (profit), environmental (planet), and social (people) sustainability aspects.
- Relevant training materials, aligned with the study objectives.
- Challenges and limitations faced by tofu industry practitioners in adopting sustainable practices (Hartini et al. 2021).
- Justification for ADDIE Model Selection**,** explaining why ADDIE was chosen over other instructional design models such as Dick & Carey or Kemp models, particularly in vocational training contexts.

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**2. Design Phase**

Based on the analysis, the design phase focuses on structuring the training program to address the identified needs. Key activities include:

- Defining instructional objectives for each training module.
- Structuring the content of training materials based on participant requirements.
- Developing training modules that incorporate theoretical and practical components.
- Conducting expert validation of the materials to ensure accuracy and relevance (Merino-Soto 2023).
- Conducting pilot testing of the materials before full implementation.
- Ethical Considerations, including informed consent obtained from participants before data collection and training activities.

**3. Development Phase**

The development phase involves transforming the design into a functional training program. Key activities include:

- Compiling training materials based on literature reviews and expert recommendations.
- Validating the content with subject matter experts (Adeoye et al. 2024).
- Revising the training materials according to expert feedback.
- Designing assessment tools, including pre-test and post-test instruments to evaluate participants' knowledge, attitudes, and skills.
- Testing material effectiveness through small-scale implementation before full deployment.
- Reliability Testing (Cronbach's Alpha) was conducted to assess the internal consistency of the training assessment tools, ensuring the accuracy of pre-test and post-test measures.

Additional Details:

- Development of Data Collection Instruments: The structured interviews and questionnaires were designed with a combination of open-ended and Likert-scale questions to assess the participants' comprehension and practical application of training materials.
- Qualitative Data Coding: Responses from interviews and observations were systematically coded using thematic analysis to identify key patterns and insights.

**4. Implementation Phase**

The training program was implemented in Karang Anyar, Mamajang District, Makassar City, where small-scale tofu industries are concentrated.

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Implementation details include:

- Training session structure: Each session lasted 3 hours (1 hour theoretical, 2 hours practical), conducted twice a week for four weeks.
- Training content: Modules covered sustainable tofu industry management, waste pollution, environmental impact, tofu waste processing into animal feed (okara), organic fertilizer (whey), and biogas production.
- Evaluation of training effectiveness: Participants were monitored to measure their engagement and comprehension.

Challenges Encountered:

- Technological Barriers: Limited exposure to sustainable waste management technologies.
- Infrastructure Limitations: Some tofu production sites lacked necessary waste processing facilities.

**5. Evaluation Phase**

The final phase assesses the effectiveness of the training program using multiple evaluation methods:

- Expert reviews to refine training materials based on participant feedback.
- Pre-test and post-test comparisons to measure learning improvements.
- Statistical analysis (paired sample t-test) to evaluate the significance of knowledge, attitude, and skill changes (Marsden and Torgerson 2012).
- Effect Size Analysis (Cohen's d) to measure the magnitude of improvement.
- Long-term feedback collection from industry practitioners to measure training impact over time.
- Normality Testing (Shapiro-Wilk Test) was conducted before the paired sample t-test to confirm that the data followed a normal distribution

**Study Location and Sample Selection**

This study was conducted in Karang Anyar, Mamajang District, Makassar City, an area with a high concentration of tofu production. These industries predominantly use traditional production techniques, contributing to significant environmental pollution due to inefficient waste management (Ginting et al. 2024). Sample selection criteria include:

- Tofu industry business owners or workers with a minimum of four employees.
- Businesses with a production capacity of 150–500 kg of soybeans per day.
- Operations located near residential areas impacted by industrial waste.
- Willingness to participate in training and research activities.

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A purposive sampling method was used to ensure that participants had direct experience in tofu production and waste management. Prior research indicates that vocational training interventions are most effective when targeted at industry practitioners who engage in daily production challenges (Marsden and Torgerson 2012).

**Data Collection Methods**

Multiple data collection techniques were used to ensure a comprehensive evaluation of the SOLID training model:

- Structured interviews with tofu industry owners and workers to identify key challenges related to waste management (Pambudi et al. 2022).
- Pre-test and post-test questionnaires to assess changes in participants' knowledge, attitudes, and skills.
- Direct observations to evaluate actual industry practices and the implementation of training outcomes.
- Document analysis, including government regulations, industry reports, and previous studies on sustainable food production (Badan Pusat Statistik Indonesia 2024).
- Ethical Approval and Data Confidentiality were ensured during data collection.

**Research Design and Statistical Analysis**

The study employs a one-group pretest-posttest design, a widely recognized experimental approach in vocational training research (Marsden and Torgerson 2012). This design allows direct comparison of participants' competencies before and after the training program, providing empirical evidence of its effectiveness.

The statistical evaluation is based on the following hypotheses:

- $H_0$ (Null Hypothesis): No significant difference in knowledge, attitudes, and skills before and after training.
- $H_1$ (Alternative Hypothesis): A significant improvement in knowledge, attitudes, and skills post-training.

A paired sample t-test was used to analyze pretest and posttest data, with a significance level of $p < 0.05$. The results showed substantial improvements in all measured variables, confirming the effectiveness of the SOLID training model (Safshekan et al. 2020).

**Reliability, Validity, and Practicality Assessment**

To ensure the credibility of the training model, the study conducted a three-level evaluation:

- Expert Validation: Training modules were reviewed by specialists in vocational education and environmental sustainability. The initial validation score was 0.77, which increased to 0.84 after revisions, classifying the model as "highly valid" (Merino-Soto 2023).

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- Reliability Testing: Pilot testing was conducted to measure test-retest reliability of the knowledge, attitude, and skills assessments.
- Practicality and Engagement: Observational assessments recorded high practicality scores (81.9%–85.2%), confirming that the training was easy to implement, engaging, and directly applicable in industry settings (Ginting et al. 2024).
- Limitations of the Study, such as small sample size, industry-specific constraints, and potential challenges in long-term behavioral adoption, were acknowledged.

## RESULTS

### Overview of the Tofu Industry in Karang Anyar

The tofu industry in Karang Anyar Sub-Village, Makassar City, is a small-scale industry consisting of around 20 business units that produce 400–500 kg of soybeans per day. Each business employs 4–9 workers and still uses traditional production system, that is using simple equipment and wood fuel (Figure 1). This industry operates in a densely populated residential area and is the main supplier of tofu for Makassar, Maros, Gowa, and Takalar areas. However, the production process is not environmentally friendly and produces liquid waste (whey water), solid waste (tofu dregs/okara), and air pollution from burning firewood, causing environmental pollution and social conflict with the surrounding community.

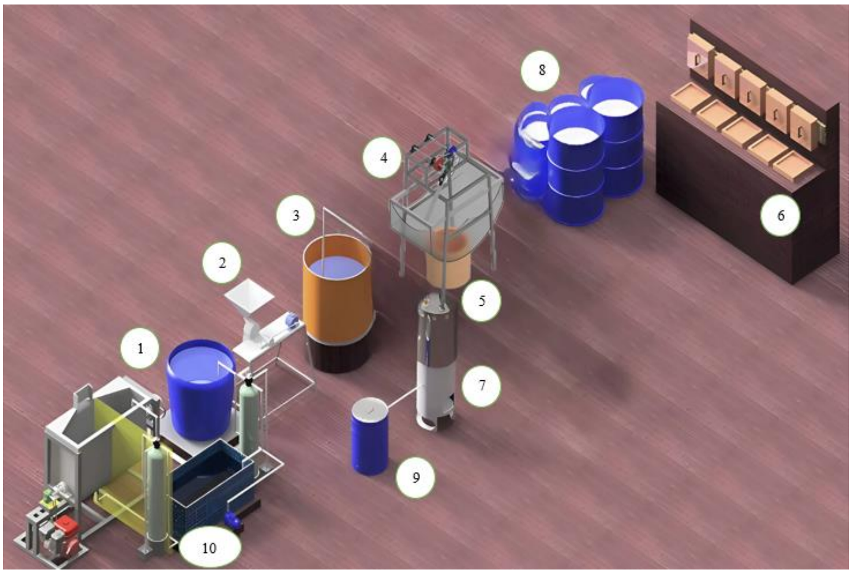


**Figure 1: Tofu Making Process Scheme using Traditional Equipment (1) Soaking and washing soybeans (2) Milling (3) Soybean porridge cooking process (4) Soybean porridge filtering (5) Soybean juice coagulation process (6) Tofu crud pressing process (7) Furnace (8) Soybean dregs (Okara) (9) Smoke filter (10) Residual water processing process**

(Source: Field Observation, 2023)

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The tofu industry produces waste in three main forms:

**1) Liquid Waste (Whey Water)**

Liquid waste (whey water) is a by-product of the soybean extract coagulation process in the tofu industry (Figure 2). This waste is acidic with highly-concentrated organic pollutants, including organic carbon compounds, proteins, fats, and carbohydrates, thus decreasing the oxygen levels in the water and trigger the growth of unwanted microorganism, polluting the environment.

**Figure 2: Whey Water Produced in the Tofu Industry**

Source: Field Observation, 2023

Ones of the main pollutant parameters in whey water is Total Suspended Solids (TSS), Volatile Fatty Acid (VFA), and Chemical Oxygen Demand (COD), showing the amount of oxygen needed to decompose organic matter in wastewater. When COD value far exceeding the quality standards set by PP 82/2001, treatments are needed before discharging the whey water into the environment. Table 1 below shows the characteristics of whey water from the tofu industry in Karang Anyar Village, Makassar City.

**Table 1: Whey Water Parameter Characteristics**

| Parameter of Whey Water | Unit | Analysis Result | Quality Standard (PP 82/2001) |
|---|---|---|---|
| pH | - | 4.08 | 6.0–9.0 |
| Total COD | Ppm | 16.250 | <200 |
| TSS | Ppm | 935 | <50 |
| Volatile Fatty Acid (VFA) | Ppm | 13.312 | - |
| Protein | % | 0.95 | - |
| Carbohydrate | % | 0.45 | - |
| Fat | % | 0.22 | - |
| C/N Ratio | - | 0.47 | - |

Source: Laboratory Test Result, 2024

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**2) Solid Waste (Tofu dregs / Okara)**

Tofu dregs, also known as okara, are a by-product of the tofu production process obtained after the soybean extract filtration. Okara is a yellowish-white solid with a soft and slightly watery texture (Figure 3). Okara is produced very largely, has a fairly high nutritional value, and can be used for various purposes, such as for animal feed, food ingredients, and raw materials in the biotechnology industry. More than 90% of its content is water, making it easy to decompose and potentially cause environmental pollution if not immediately processed.

**Figure 3: Soybean Dregs (Okara)**

Okara also contains vegetable protein, crude fiber, carbohydrates, and a small amount of fat. Its protein content is beneficial for livestock's nutrition, while its crude fiber is beneficial for livestock's digestive health. In the industrial sector, the use of okara is increasingly developing, especially in the manufacture of fermented products, feed supplements, and as an additional ingredient in healthy food products. However, optimal use still requires further research, especially in terms of processing and storage to increase its durability and availability as a quality feed source. Table 2 below shows the nutritional composition of okara produced by the tofu industry in Karang Anyar Village, Makassar City.

**Table 2: Characteristics of Okara Component**

| Okara Component | Unit | Lab Test Result | References (Rahman et al.. 2021) |
|---|---|---|---|
| Water Level | % | 93.18 | 90–94 |
| Protein | % | 2.77 | 2.5–3.5 |
| Crude Fiber | % | 1.65 | 1.2–2.0 |
| Carbohydrate | % | 1.88 | 1.5–2.5 |
| Fat | % | 0.22 | 0.1–0.5 |

Source: Laboratory Test Result, 2024

**3) Air Pollution from Firewood Burning**

The traditional method used in tofu industry in Karang Anyar results in air pollution (Figure 4). The firewood burning in the process produces thick smoke containing particulates (PM),

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carbon monoxide (CO), and volatile organic compounds (VOCs) that potentially pollute the environment. In addition, the use of non-standard chimneys causes the smoke trapped around the industrial area and residential areas, increasing the risks of respiratory problems, eye irritation, and long-term air pollution.

(a)  (b) 

**Figure 4: (a) Wood-Fired Stove (b) Chimney in Tofu Industry**

Source: Field Observation, 2023

Field observations show that most industrial actors have not implemented a filtering system or exhaust gas technology, so that smoke is not processed before being released. The impact of this pollution is not only felt by industrial actors but also by the surrounding community, who often complain about the smoke, pungent odors, and poor air quality.

To overcome this problem, education about environmentally friendly stove technology and the use of alternative energy, such as biogas from tofu liquid waste (whey water), is necessary to reduce emissions and improve the sustainability of the tofu industry.

**Development of the SOLID Training Model**

SOLID model was developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) approach in eight modules covering various aspects, including basic understanding of the tofu industry and its impact on the environment to the application of technology in waste processing as shown in Table 3.

Each module is systematically designed to equip participants with the knowledge, skills, and attitudes that support the implementation of a sustainable tofu industry. This training also emphasizes the use of waste as an economically valuable resource and involves the community participation. With these modules, participants are expected to be able to adopt more sustainable industrial practices, reducing environmental pollution.

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**Table 3: SOLID Model Training modul, Objective, and Achievement Target**

| No | Modul | Objectives | Achievement Target |
|---|---|---|---|
| 1 | Sustainable Tofu Industry | To improve participants' understanding of the tofu industry and the concept of sustainability in economic, social, and environmental aspects. | Participants can identify the tofu production process, understand the concept of sustainable industry, and recognize the potential and challenges in the tofu industry. |
| 2 | Tofu Industry Waste | To provide an understanding of the characteristics of tofu industry waste and its environmental impact. | Participants can recognize the types of tofu industry waste (solid, liquid, and gas), and realize its dangers if not managed well. |
| 3 | Environmental Pollution | To explain the environmental pollution impact due to tofu industry waste and how to overcome it. | Participants can identify types of environmental pollution, understand their impacts on health and ecosystems, and recognize applicable regulations. |
| 4 | Waste Treatment | To teach effective waste processing techniques in order to reduce environmental pollution. | Participants can explain methods for processing liquid, solid, and gas waste, and apply simple technology in waste management. |
| 5 | Use of Soybean Dregs as Animal Feed | To train participants in processing soybean dregs into animal feed with economic value. | Participants can process tofu dregs into highly nutritious animal feed to reduce waste and increase income. |
| 6 | Use of Whey Water as Organic Fertilizer | To teach how to process whey water waste into organic fertilizer. | Participants can understand the whey water fermentation process and apply it in the production of organic fertilizer for agriculture. |
| 7 | Use of Whey Water as Biogas | To provide skills in utilizing whey water as a renewable energy source (biogas). | Participants can understand the basic principles of biogas production and apply simple biodigester technology. |
| 8 | Community Involvement in the Tofu Industry | To increase community participation in the sustainable tofu industry management. | Participants can understand the importance of community collaboration in waste management and the development of an environmentally friendly tofu industry. |

## SYNTAX

The syntax in the SOLID training model is a series of systematic steps designed to help participants understand, apply, and develop skills in managing the tofu industry sustainably. Each stage in the syntax plays an important role in building participants' understanding and skills, from increasing self-confidence to making decisions based on sustainability.

Table 4. below presents the syntax of the SOLID training model consisting of five main stages: Self-Confidence, Opportunity, Learning of Technology, Initiative, and Decision. Each stage is designed to provide an effective learning experience through a problem-based learning approach and appropriate technology.

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**Table 4: Syntax of SOLID Training Model**

| No | Stages | Instructurs' Activities | Participants' Activites | Output |
|---|---|---|---|---|
| 1 | Self-Confidence | Exposure of tofu industry prospects and waste processing | Discussion of tofu industry waste problems | Increased self-confidence |
| 2 | Opportunity | Exposure of business opportunities from tofu waste | Identifying business potential from waste | Increased business skills |
| 3 | Learning of Technology | Training on waste processing practices | Direct practice | Improved technical skills |
| 4 | Initiative | Motivation for waste management innovation | Preparing waste processing strategies | Innovation in waste processing |
| 5 | Decision | Simulation of waste processing business | Implementing business strategies | Strategic decisions in tofu industry management |

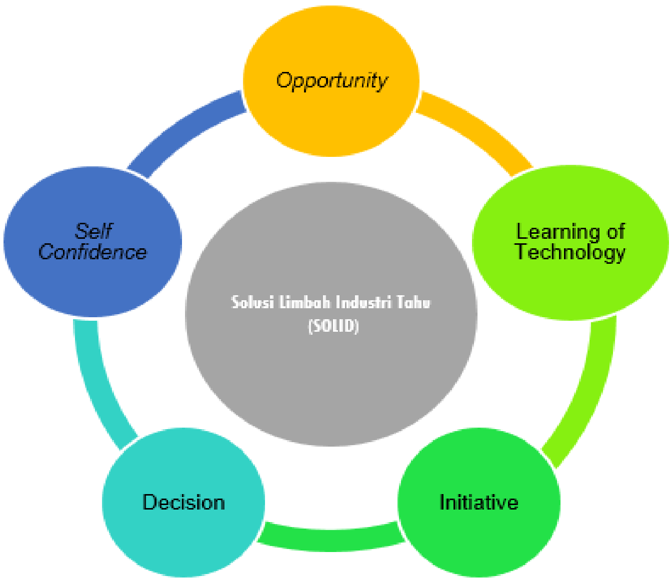


**Figure 5: SOLID Model Training Cycle**

The SOLID model was designed with five integrated learning stages, where each stage aims to improve technical skills, scientific literacy, and decision-making abilities in tofu industry waste management (Figure 5). Unlike instructional and one-way conventional training methods, SOLID model encourages active participation from the participants in exploring the potential of waste as a valuable economic resource.

### Validation and Effectiveness of the SOLID Model

The validation of the SOLID training model's effectiveness included validity, practicality, and effectiveness. Validation was carried out by experts using the Likert scale and Aiken index, while practicality was observed during the training and tested using the Paired Sample t-Test to measure the increase in participants' knowledge and skills before and after training.

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### 1) Model Validation Results

The validation process of the training module was carried out to ensure the quality and suitability of the material before being used in the training activities. This validation involved three experts in environmental education and tofu industry management. Each expert assessed the module based on several aspects, such as the objectives suitability, the material depth, the clarity of delivery, and the relevance to the needs of the participants.

After the initial validation was carried out, the evaluation results showed that several modules still needed to be improved and adjusted to the expected standards. Therefore, revisions were made, particularly on simpler language, more systematic material presentation, and the illustrations and case examples used. After the revision, the module was re-validated, then showing increased average score from 0.77 to 0.84.

It indicates that the revisions successfully improved the module quality, obtaining "very valid" category, so the module is valid for use in training, and can be a good reference in supporting training in the field of tofu industry management and environment. Table 5 below presents a comparison of the initial and final validation results for each module in the SOLID training.

**Table 5: Comparison of Validity of SOLID Training Module Materials**

| Modul | Initial Validation | Final Validation | Description |
|---|---|---|---|
| Modul 1 | 0.77 | 0.82 | Very Valid |
| Modul 2 | 0.77 | 0.86 | Very Valid |
| Modul 3 | 0.79 | 0.85 | Very Valid |
| Modul 4 | 0.81 | 0.87 | Very Valid |
| Modul 5 | 0.82 | 0.88 | Very Valid |
| Modul 6 | 0.75 | 0.83 | Very Valid |
| Modul 7 | 0.74 | 0.81 | Very Valid |
| Modul 8 | 0.72 | 0.80 | Very Valid |
| **Average** | **0.77** | **0.84** | Very Valid |

### 2) Model Practicality Test Results

The SOLID model practicality test aims to assess the extent to which this model can be applied effectively in training. This assessment was carried out by observing the training implementation, focusing on the implementation of the model syntax, ease, and the participation interaction level during the training process. Practicality is an important aspect to ensure that the concepts and methods applied are both in accordance with theory and able to be well-implemented in real situations.

The observation results showed that the SOLID model is very practical with an average percentage of between 81.9% and 85.2% in various aspects measured. The implementation of the training scored 83.5%, indicating that this model can be implemented well according to the premade design.

Ease of implementation scored 81.9%, indicating that no significant obstacle hinders the implementation of this model and this model is easily adapted by facilitators and participants.

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Meanwhile, participant interaction in the training was scored at 85.2%, indicating that the SOLID model encourages active participation and optimal participant involvement. Overall, the practicality test results confirm that the SOLID model is very practical and is an effective approach in sustainable tofu industry training. Table 6 presents the practicality test results of the implementation of the SOLID model training.

**Table 6: Practicality Test of SOLID model training implementation**

| Practicality Aspects | Average (%) | Category |
|---|---|---|
| Training Implementation | 83.5 | Very Practical |
| Implementation Ease | 81.9 | Very Practical |
| Participants' Interaction | 85.2 | Very Practical |
| **Average Practicality** | **83.5** | **Very Practical** |

### 3) Model Effectiveness Test Result

The model's effectiveness was tested using Paired Sample t-Test to compare the results of the pretest and posttest of the participants (Table 7). The test shows a significant increase ($p <0.05$) in all aspects, indicating that the model is effective. The knowledge score increased from 56.4 to 84.7, indicating a better understanding of waste management. Participant attitudes increased from 62.1 to 88.3, reflecting positive changes in environmental awareness. Skills increased from 58.2 to 86.5, indicating the success of hands-on practice-based training.

**Table 7: Test of the effectiveness of SOLID model training**

| Aspects Measured | Pretest (Mean ± SD) | Posttest (Mean ± SD) | p-Value | Interpretation |
|---|---|---|---|---|
| Knowledge | 56.4 ± 8.2 | 84.7 ± 6.5 | < 0.05 | Significant |
| Behavior | 62.1 ± 7.5 | 88.3 ± 5.9 | < 0.05 | Significant |
| Skill | 58.2 ± 6.8 | 86.5 ± 6.2 | < 0.05 | Significant |

During the training activities, the instructor guided participants to think positively about waste problems. It can develop the presentation of module material. In this case, the training participants were enthusiastic in participating in the training because of the encouragement and desire to overcome previous problems. This SOLID model also guides participants to be able to carry out collective actions continuously supported by the Community. In addition, industry actors feel confident in the sustainability of their businesses.

## DISCUSSION

SOLID training model aims to improve the tofu industry actors' competence in managing a more sustainable industry. This model is developed through a Problem-Based Learning (PBL) approach that emphasizes experience-based learning to strengthen technical skills and innovation in waste utilization. This approach has proven effective in improving conceptual understanding and problem-solving skills (Lu, Bridges, and Hmelo-Silver 2014).

The SOLID model is an environmental education program designed to enhance community awareness and responsibility towards the environment. It aims to improve people's understanding, attitudes, and skills related to environmental issues by integrating social and ecological aspects into everyday life. This model actively involves communities in discussions

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about environmental challenges, both locally and globally, and plays a crucial role in reducing poverty. It achieves this by developing the community's capacity to use resources sustainably, enhancing entrepreneurial skills, and improving environmental management. Aligned with the Sustainable Development Goals (SDGs), the SOLID model supports quality education by boosting environmental literacy and community skills. It also promotes decent work and economic growth by encouraging the transformation of industrial waste into economically valuable products. Furthermore, it advocates for responsible consumption and production by urging industries to adopt more environmentally friendly practices. By reducing emissions and pollution, the SOLID model contributes to climate change management, fostering a more sustainable and inclusive industrial ecosystem (Zikargae, Woldearegay, and Skjerdal 2022).

The education program for the community is a demand for the implementation of an environmentally friendly and sustainable tofu industry. Therefore, the development stage begins with a needs analysis which is done by identifying the environmental conditions of the tofu industry, challenges in waste management, and the readiness of industry actors to participate in training. Furthermore, training materials designed focus on educational and technical aspects, so that the material is both theoretical and practical. Material validation was carried out through evaluation by environmental and industrial education experts, before finally being implemented in training sessions.

Vocational education aims to prepare workers, so that they are ready to face industry challenges, one of which is bridging the gap between theory and practice, so students can both understand the concepts and apply them in real industry contexts (Mulder 2019). The development of SOLID training model aims to address this challenge by adopting an experiential learning approach, which emphasizes hands-on experience-based learning and field practice (Passarelli and Kolb 2023).

The SOLID model was designed with five integrated learning stages, where each stage aims to improve technical skills, scientific literacy, and decision-making abilities in tofu industry waste management. Unlike instructional and one-way conventional training methods, SOLID model encourages active participation from the participants in exploring the potential of waste as a valuable economic resource.

1. Self-Confidence: This stage aims to build participants' self-confidence in managing a sustainable tofu industry. A previous study (Lu et al. 2014) emphasized that project-based learning and field practice can increase students' self-efficacy, which affects the success of field implementation.
2. Opportunity: This stage introduces the economic potential of tofu waste processing, such as for animal feed or biogas as an alternative energy.
3. Learning of Technology: This section focuses on the application of appropriate technology in the tofu industry waste management, such as the use of biofilters for liquid waste or fermentation for organic fertilizer.

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4. Initiative: At this stage, participants are encouraged to innovate and develop environmentally-based solutions according to the principles of problem-based learning (PBL). Compared to traditional methods, PBL is more effective in increasing creativity, problem-solving skills, and innovation in entrepreneurship (Pagoray 2021).
5. Decision: (This final stage helps participants make strategic decisions related to the sustainability of the tofu industry business, including in financial, production, and environmental impact aspects. In previous studies, a business simulation-based approach and decision-making have been shown to improve conceptual understanding and readiness of students to face industry challenges (White et al. 2022).

Training was carried out through a simulation and direct practice approach, with the main material covering liquid waste management, utilization of tofu dregs and whey water, and strategies for using alternative energy to reduce emissions from burning firewood. The evaluation results in various aspects showed that the predetermined objectives in the planning can be achieved. This aligns with the previous statement (Kiss et al. 2022) that community involvement, as a result of environmental education, can be realized by ensuring the community understands the benefits gained from such training. Training programs that emphasize waste management and green accounting can enhance environmental awareness among employees and help them grasp the significance of reducing waste. When workers are capable of managing eco-friendly industries, it not only benefits the environment but also fosters acceptance and strengthens social relationships within the broader community (Pambudi et al. 2022).

Environmental education strategies can be effectively implemented through training, fair trading, and partnerships. During training, industry participants learn to manage solid, liquid, and gas waste. Modules 5, 6, and 7 highlight the economic potential of waste management within a circular economy framework. Module 5 covers using soybean pulp as animal feed, Module 6 explores converting whey water into organic fertilizer, and Module 7 focuses on transforming whey water into biogas for renewable energy. These strategies boost the confidence of both training participants and the surrounding community in managing waste effectively (Salazar et al. 2022).

The partnership aspect of this model is realized through collaboration between industry actors, communities, academics, and the government in creating a more sustainable waste management system. This approach not only supports the creation of valuable waste but also reduces the environmental pollution to avoid social conflicts. By involving various stakeholders, the SOLID model encourages collective awareness and real action in realizing more environmentally friendly tofu industry, which is in line with the SDGs, especially Goal 12 (Responsible Consumption and Production) and Goal 17 (Partnerships to Achieve the Goals).

The effectiveness of this model was tested using the one-group pretest-posttest design method, to determine changes in participants' knowledge, attitudes, and skills after training.

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### Overview of the Tofu Industry in Karang Anyar

The tofu industry in Karang Anyar Sub-Village, Makassar City, is a small-scale industry that applies traditional production methods, where each business unit produced around 400 to 500 kg of soybeans per day and employing four to nine workers. The majority of industry actors have run this business for generations, without the application of modern technology or adequate waste management systems.

Indonesian tofu industry commonly has limitations in access to environmentally-friendly technology (Junaidi et al. 2024), minimal awareness of the waste impacts, and limited practice-based education programs in industrial waste management. This is the main obstacle in implementing a sustainable tofu industry. Therefore, skills-based education and training are important solutions to improve production quality and reduce environmental impacts (Tarrant and Thiele 2016)

### Waste Problems in the Tofu Industry

The tofu industry produces liquid waste, solid waste, and air pollution that can pollute the environment if not managed properly. The main liquid waste comes from the soaking, washing, and coagulation process of soybean extract, which produces whey water with a high organic content. Laboratory test results show that the Chemical Oxygen Demand (COD) of whey water waste reaches 16,250 ppm, far exceeding the standard quality limits set in environmental regulations (Pagoray 2021). If disposed of directly without treatment, this waste can decrease the groundwater quality and water eutrophication, thus is harmful for the ecosystem balance.

The solid waste in the form of tofu dregs (okara) contains high levels of vegetable protein and crude fiber, so can be used as animal feed or organic fertilizer. However, due to limited knowledge about waste utilization, these dregs are often discarded unprocessed, contributing to environmental pollution (Nostia and Kurniawan 2023).

The use of firewood in tofu production results in exhaust emissions containing particulates (PM2.5), carbon monoxide (CO), and polycyclic aromatic hydrocarbons (PAHs). This air pollution causes health risks for workers and the surrounding community (Fleisch et al. 2020). In addition, it also reduces the air quality and causes both long-term respiratory disorders and cardiovascular disease (White et al. 2022).

### Validation, Practicality, and Effectiveness of the Training Model

The training model was validated by environmental and industrial education experts, achieving an average score of 0.84, classified as very valid. Observer assessments during training indicated a practicality score of 81.9 to 85.2 percent, confirming that the model is highly applicable in the tofu industry.

To evaluate the model's effectiveness, pretest and posttest measurements were conducted on training participants. Statistical analysis using the Paired Sample t-Test revealed a significant increase ($p < 0.05$) in participants' knowledge, attitudes, and skills after training. This demonstrates that SOLID-based training effectively enhances tofu industry actors' understanding and skills in sustainable waste management.

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## CONCLUSIONS

This study developed the SOLID training model as an innovative approach in vocational education to enhance sustainable waste management in the tofu industry. Validation results indicated the model is very valid (0.84) and highly practical (81.9–85.2%), making it suitable for small industries. Effectiveness testing with a paired sample t-test showed a significant increase ($p < 0.05$) in participants' knowledge, attitudes, and skills post-training. These results suggest that practice-based and innovative methods are more effective than traditional theoretical training. Therefore, the SOLID model is recommended for integration into vocational education and environmental training curricula to cultivate a competent workforce in resource management and strategic decision-making. Its application is expected to promote environmentally friendly small industries, enhance circular economy competitiveness, and support the sustainability of the micro-industry sector.

### References

1) Adeoye, Moses Adeleke, Kadek Adrian Surya Indra Wirawan, Made Shania Satya Pradnyani, and Nyoman Intan Septiarini. 2024. "Revolutionizing Education: Unleashing the Power of the ADDIE Model for Effective Teaching and Learning." *JPI (Jurnal Pendidikan Indonesia)* 13(1).

2) Anggarini, Sakunda, Nur Hidayat, Nimas Mayang Sabrina Sunyoto, and Putri Siska Wulandari. 2015. "Optimization of Hydraulic Retention Time (HRT) and Inoculums Addition in Wastewater Treatment Using Anaerobic Digestion System." *Agriculture and Agricultural Science Procedia* 3:95–101.

3) Badan Pusat Statistik Indonesia. 2024. "Rata-Rata Konsumsi per Kapita Seminggu Beberapa Macam Bahan Makanan Penting, 2007-2023." *Badan Pusat Statistik Indonesia*. Retrieved (https://www.bps.go.id/id/statistics-table/1/OTUwIzE%3D/rata-rata-konsumsi-per-kapita-seminggu-beberapa-macam-bahan-makanan-penting--2007-2023.html).

4) Chua, Jian-Yong, and Shao-Quan Liu. 2019. "Soy Whey: More than Just Wastewater from Tofu and Soy Protein Isolate Industry." *Trends in Food Science & Technology* 91:24–32.

5) Darmajana, Doddy Andy, Nok Afifah, and Ashri Indriati. 2020. "The Effect of Extraction Method and Types of Coagulants on the Results and Physicochemical Properties of Tofu." *Food Science and Technology (Brazil)* 40(December):677–82. doi: 10.1590/fst.34719.

6) Feng, Hongbo, Linyi Jin, Yongfeng Chen, Junchao Ji, Zhen Gong, Wangxian Hu, Chao Ying, Yifan Liang, and Jun Li. 2024. "Tofu Wastewater as a Carbon Source Flowing into Municipal Wastewater Treatment Plants for Reductions of Costs and Greenhouse Gas Emissions." *Journal of Environmental Management* 370:122550.

7) Fleisch, Abby F., Lisa B. Rokoff, Eric Garshick, Stephanie T. Grady, Jonathan W. Chipman, Emily R. Baker, Petros Koutrakis, and Margaret R. Karagas. 2020. "Residential Wood Stove Use and Indoor Exposure to PM2. 5 and Its Components in Northern New England." *Journal of Exposure Science & Environmental Epidemiology* 30(2):350–61.

8) Gabriella, Diana Ayu, and Agus Sugiarto. 2020. "Kesadaran Dan Perilaku Ramah Lingkungan Mahasiswa Di Kampus." *Jurnal Ilmu Sosial Dan Humaniora* 9(2):260–75.

9) Ginting, Erliana, Dian Adi Anggraeni Elisabeth, Aniswatul Khamidah, Jemmy Rinaldi, Indrie Ambarsari, and Sri Satya Antarlina. 2024. "The Nutritional and Economic Potential of Tofu Dreg (Okara) and Its Utilization for High Protein Food Products in Indonesia." *Journal of Agriculture and Food Research* 101175.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.15194815

10) Hardyanti, Nurandani, Heru Susanto, Mochamad Arief Budihardjo, and Angga Tri Saputra. 2023. "Characteristics of Tofu Wastewater From Different Soybeans and Wastewater at Each Stage of Tofu Production." *Ecological Engineering & Environmental Technology* 24.

11) Hartini, Sri, Faradhina Azzahra, Ratna Purwaningsih, Bimastyaji Surya Ramadan, and Diana Puspita Sari. 2021. "Framework for Increasing Eco-Efficiency in the Tofu Production Process: Circular Economy Approach." *Production Engineering Archives* 29(4):452–60.

12) Hartini, Sri, B. S. Ramadan, R. Purwaningsih, S. Sumiyati, and M. A. A. Kesuma. 2021. "Environmental Impact Assessment of Tofu Production Process: Case Study in SME Sugihmanik, Grobogan." P. 12004 in *IOP Conference Series: Earth and Environmental Science*. Vol. 894. IOP Publishing.

13) Hwang, Yeong-Hyeon, Seong-Il Kim, and Jiann-Min Jeng. 2000. "Examining the Causal Relationships among Selected Antecedents of Responsible Environmental Behavior." *The Journal of Environmental Education* 31(4):19–25.

14) Ji, Xiaowen, Shaojie Zhou, Wenwen Chen, Bin Cao, Yumeng Sun, Qiyang Che, Yinglao Zhang, Jibin Zhang, Ting Ding, and Jiaping Xu. 2025. "Black Soldier Fly and Microbiome Collaborate to Bioconvert the Tofu Whey Water in an Efficient and Environment-Friendly Manner." *Journal of Water Process Engineering* 69:106888.

15) Junaidi, A., A. Mashar, B. Basrowi, D. Muharomah, J. Situmorang, A. Lukas, A. Asgar, L. Herlina, L. Manalu, and L. Payung. 2024. "Enhancing Sustainable Soybean Production in Indonesia: Evaluating the Environmental and Economic Benefits of MIGO Technology for Integrated Supply Chain Sustainability." *Uncertain Supply Chain Management* 12(1):221–34.

16) Karim, Ahasanul, Emmanuel Freddy Osse, and Seddik Khalloufi. 2025. "Innovative Strategies for Valorization of Byproducts from Soybean Industry: A Review on Status, Challenges, and Sustainable Approaches towards Zero-Waste Processing Systems." *Heliyon*.

17) Kiss, Bernadett, Filka Sekulova, Kathrin Hörschelmann, Carl F. Salk, Wakana Takahashi, and Christine Wamsler. 2022. "Citizen Participation in the Governance of Nature-based Solutions." *Environmental Policy and Governance* 32(3):247–72.

18) Lu, Jingyan, Susan Bridges, and Cindy E. Hmelo-Silver. 2014. "Problem-Based Learning." *The Cambridge Handbook of the Learning Sciences* 298–318.

19) Marsden, Emma, and Carole J. Torgerson. 2012. "Single Group, Pre-and Post-Test Research Designs: Some Methodological Concerns." *Oxford Review of Education* 38(5):583–616.

20) Merino-Soto, César. 2023. "Aiken's V Coefficient: Differences in Content Validity Judgments." *MHSalud* 20(1):23–32.

21) Mulder, Martin. 2019. "Competence-Based VET and Implications for Policy and Practice1." *Work-Based Learning as a Pathway to Competence-Based Education* 44.

22) Nostia, Rohima, and Andi Kurniawan. 2023. "Analysis of Solid and Liquid Waste Characteristics of Tofu Industry in Bancar Village, Bungkal District, Ponorogo Regency." *Indonesian Journal of Environment and Sustainable Development* 14(1).

23) Pagoray, Henny. 2021. "Limbah Cair Industri Tahu Dan Dampaknya Terhadap Kualitas Air Dan Biota Perairan." 9(1):53–65.

24) Pambudi, Yonathan Suryo, Cicik Sudaryantiningsih, Elvis Umbu Lolo, Agerippa Yanuranda Krismani, Richardus Indra Gunawan, Maria Yumima Banoet, Virgianto Tara Amah, and John Tunggu Jama. 2022. "Dissemination of Student and Lecturer Research Results to Help the Community Overcome Environmental Pollution Due to Tofu Industry Liquid Waste." *Asian Journal of Community Services* 1(6):345–52.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.15194815

25) Passarelli, Angela M., and David A. Kolb. 2023. "Experiential Learning Theory." *Student Learning Abroad: What Our Students Are Learning. What They're Not, and What We Can Do About It*.

26) Safshekan, Sedigheh, Ali Ozturen, Azar Ghaedi, and Ali Ozturen. 2020. "Residents ' Environmentally Responsible Behavior : An Insight into Sustainable Destination Development." *Asia Pacific Journal of Tourism Research* 25(4):409–23. doi: 10.1080/10941665.2020.1737159.

27) Salazar, Gabby, Kenneth C. Rainer, Lauren A. Watkins, Martha C. Monroe, and Sadie Hundemer. 2022. "2020 to 2040: Visions for the Future of Environmental Education." *Applied Environmental Education & Communication* 21(2):182–203.

28) Singh, P., and K. Krishnaswamy. 2022. "Sustainable Zero-Waste Processing System for Soybeans and Soy by-Product Valorization." *Trends in Food Science & Technology* 128:331–44.

29) Stanojević, Sladjana P., Aleksandar Ž. Kostić, Danijel D. Milinčić, Andjela B. Stanojević, and Mirjana B. Pešić. 2023. "Composition of Proteins in Fresh Whey as Waste in Tofu Processing." *Journal of Environmental Science and Health, Part B* 58(1):10–20.

30) Sudarto, Yudhi, Salundik Salundik, and Moch Sridurеsta Soenarno. 2023. "Biogas Production from Tofu Liquid Waste with Cow Manure Mixture."

31) Sukarelawan, Moh Irma, Toni Kus Indratno, and S. M. Ayu. 2024. "N-Gain vs Stacking." *Yogyakarta: Suryacahya*.

32) Tarrant, Seaton Patrick, and Leslie Paul Thiele. 2016. "Practice Makes Pedagogy–John Dewey and Skills-Based Sustainability Education." *International Journal of Sustainability in Higher Education* 17(1):54–67.

33) White, Julie D., Annah B. Wyss, Thanh T. Hoang, Mikyeong Lee, Marie Richards, Christine G. Parks, Laura E. Beane-Freeman, John L. Hankinson, David M. Umbach, and Stephanie J. London. 2022. "Residential Wood Burning and Pulmonary Function in the Agricultural Lung Health Study." *Environmental Health Perspectives* 130(8):87008.

34) Zhang, Lei, Yang Hu, Xue Wang, Olugbenga Abiola Fakayode, Haile Ma, Cunshan Zhou, Aiming Xia, and Qun Li. 2021. "Improving Soaking Efficiency of Soybeans through Sweeping Frequency Ultrasound Assisted by Parameters Optimization." *Ultrasonics Sonochemistry* 79:105794.

35) Zikargae, Mekonnen Hailemariam, Amanuel Gebru Woldearegay, and Terje Skjerdal. 2022. "Empowering Rural Society through Non-Formal Environmental Education: An Empirical Study of Environment and Forest Development Community Projects in Ethiopia." *Heliyon* 8(3).