STI Focus

SCIENCE, TECHNOLOGY AND INNOVATION

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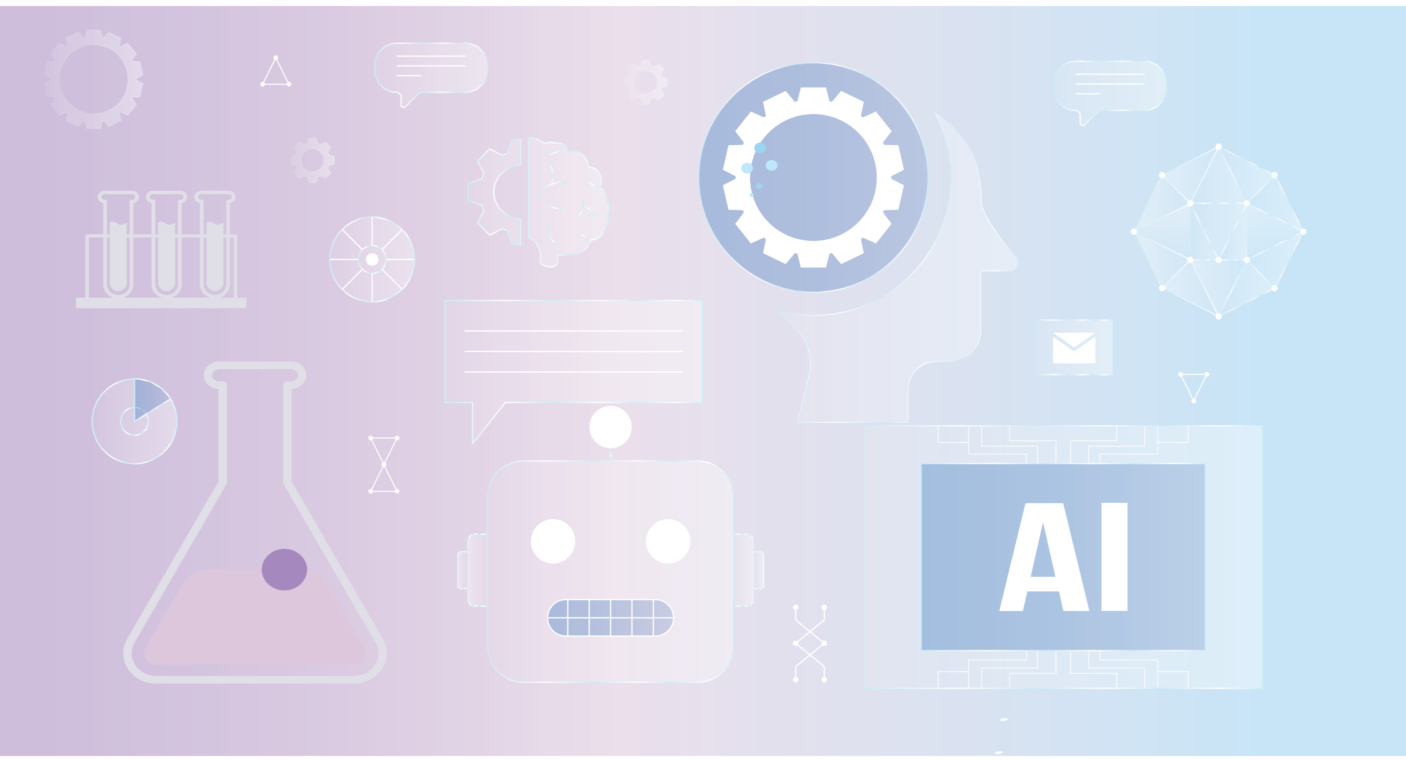

Ministry of Industry, Science, Technology & Innovation

National Institute of Science, Technology and Innovation

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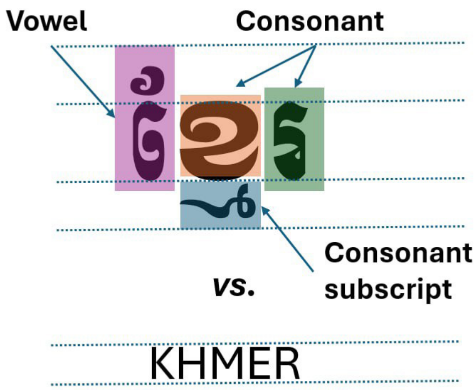

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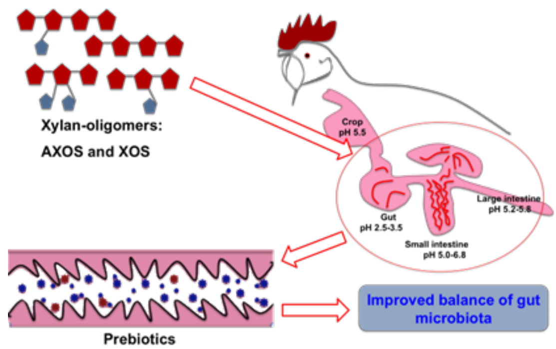

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MANAGED BY

Department of Science, Technology and Innovation Promotion and Development
National Institute of Science, Technology and Innovation (NISTI)
Ministry of Industry, Science, Technology & Innovation (MISTI)

ADDRESS OF NISTI

National Road No2, Sangkat Chak AngRe Leu, Khan Mean Chey, Phnom Penh, Cambodia

FOREWORD

Welcome to the latest issue of our STI Focus Volume 3, Issue 1, where we delve into the exciting world of scientific innovations and advancements. In order to continue our progress in the field of STI, we must persist with our commitment towards open science. STI Focus, which is a biannual publication created by the National Institute of Science, Technology and Innovation (NISTI), helps to make this possible by sharing important research insights and discoveries with people of all ages. This edition explores the captivating topic of research findings, technology trends, and STEM education & careers. The team of expert writers holding master's and PhD degrees, have thoroughly examined these subjects to bring you an educating and engaging collection of articles.

I would like to acknowledge all of the authors on this issue, whose papers I believe will undoubtedly increase public knowledge of science and its potential for benefiting our everyday lives. They are certain to enlighten all decision-makers on the need of STI as a means of advancing industrialization and enabling Cambodia's economy to remain competitive both locally as well as internationally. The industrialization process requires highly qualified STEM labor, which must be encouraged. Thus, for Cambodia to fully realize its goals for socio-economic development, there must be an increase in the number of highly qualified technicians, engineers, and scientists. Whether you are a casual reader or a dedicated enthusiast, I am certain that you will find something of interest in the pages ahead. I hope that this issue will inspire further research and discussions on the related topic and that you will enjoy and learn as much as I did from this publication.

Phnom Penh, 2 July 2024

Minister

HEM Vanndy

EDITORIAL NOTE

In the first issue of 2024, STI Focus continues its mission to foster the advancement of Science, Technology, and Innovation (STI) to the public. This edition unfolds across three pivotal sections "Scientific Findings", "Technology Trends", and "STEM Education & Careers". The first section contains four meticulously crafted manuscripts; The Practical Application of Plant Growth-Promoting Bacteria (PGPB) as Bio-Inoculants for Enhancing Plant Growth, Interactive 3D Virtual Tour and Navigation, State of the Art Khmer Text Recognition, and Abusive Image Classification Using Hybrid Model. The next session contains three manuscripts including Effect of Endo-Xylanase Supplementation in Boiler Chicken Diets, Potential Use of Laccases in Biodegradation and Detoxification Dyes in Textile Wastewater, and A Review on Deep Learning Algorithms for Hand Gesture Recognition in Higher Education. The last section addresses Nurturing Computational Thinking through Education, Why Cambodia Need Edtech Startup for Overseas Scholarship, and A Woman in Science.

Each manuscript highlighted in this issue has undergone rigorous peer review to maintain scholarly integrity and excellence. In conclusion, on behalf of the Editorial Board and the Editor team, we extend our sincere thanks to authors, reviewers, and NISTI officers for your continued support and engagement. Moreover, readers are encouraged to access STI Focus digitally through the Ministry of Industry, Science, Technology & Innovation (MISTI) website or by scanning the QR code provided below.

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SCIENTIFIC FINDINGS

The Practical Application of Plant Growth Promoting Bacteria (PGPB) as Bio-Inoculants for Enhancing Plant Growth

1

Chem Chanchao
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi
Thailand

Tsukasa Ito
Ph.D., Urban and Environmental Engineering
Hokkaido University, Japan

Highlight

- PGPB integration enhances soil fertility and crop productivity sustainably.
- PGPB, as bio-inoculants, offer natural alternatives to chemical fertilizers, reducing ecological impact.
- Isolating and characterizing PGPB strains provides insights into their potential for improving plant growth.
- Research and application of PGPB hold promise for sustainable agriculture and food security.

Figure 1. The role of PGPBs in soil fertility restoration

I. Introduction

Plant growth-promoting bacteria (PGPB) are diverse bacteria that enhance plant growth and development. These beneficial microbes inhabit the soil, particularly within the rhizosphere (the region near plant roots), on plant root surfaces, inside plant tissues, or even on aerial parts of plants (de Andrade et al., 2023; Compant et al., 2010). PGPBs have beneficial effects on plant growth and health through various mechanisms, including but not limited to nitrogen fixation, phosphate/potassium/zinc solubilization, production of phytohormones, biocontrol, induced systemic resistance, enhancement of nutrient uptake, and enhancement of stress tolerance (Nagrale et al., 2023; Hyder et al., 2023) (Figure 1).

PGPBs enhance plant essential nutrient uptake of nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), Calcium (Ca), copper (Cu), or iron (Fe) through various mechanisms. Nitrogen (N), by converting atmospheric N into usable forms for protein and chlorophyll synthesis; Phosphorus (P), through solubilizing insoluble P into accessible forms for root development; Potassium (K), by mobilizing K from soil minerals, aiding osmoregulation and enzyme activity; and Zinc (Zn), increasing its bioavailability essential for enzyme function and growth. These mechanisms collectively boost plant health and offer sustainability by enhancing soil nutrient bioavailability.

The interaction between PGPBs and plants involves the uptake and utilization of essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn), which are crucial for their growth, development, and productivity. PGPBs, particularly those in the genera *Pseudomonas, Bacillus, Rhizobium, Azospirillum,* and *Azotobacter*, can fix atmospheric nitrogen (N_2) into ammonia (NH_3) or related nitrogenous compounds that plants can absorb and utilize (Santhosh et al., 2019). This process occurs through the enzyme nitrogenase, which these bacteria possess. Nitrogen fixation by PGPB provides a direct source of nitrogen for plants, which is crucial for synthesizing amino acids, nucleic acids, and chlorophyll (Tariq et al., 2023).

Additionally, PGPBs, such as species of *Pseudomonas and Bacillus*, secrete organic acids and phosphatases that solubilize and mineralize phosphorus, converting it from insoluble forms (e.g., tricalcium phosphate) into soluble forms ($H_2PO_4^-$ and HPO_4^{2-}) that plants can efficiently uptake (Pan & Cai, 2023; Sati et al., 2020). Enhances phosphorus availability in the soil, promoting root development, energy transfer, and the synthesis of nucleic acids (Vengavasiet al., 2021). PGPBs, including strains of *Bacillus and Pseudomonas*, release organic acids that solubilize potassium from mineral sources, making them available for plant uptake (Etesami & Adl, 2020). These bacteria can mobilize K^+ from silicate minerals by producing acids or chelation. Potassium is essential for osmoregulation, enzyme activation, and photosynthesis. Its improved availability supports overall plant health and stress resistance (Johnson et al., 2022).

Zinc-solubilizing bacteria (e.g., certain strains of *Pseudomonas*) produce organic acids that mobilize zinc from insoluble zinc compounds in the soil (Haroon et al., 2022). This process increases the concentration of bioavailable Zn^{2+} ions near the plant roots. Zinc is vital for enzyme function, protein synthesis, and growth regulation (Solanki, 2021). Mobilization of zinc by PGPB can significantly improve plant growth and crop yields (Ullah et al., 2020). Furthermore, PGPBs synthesize growth-promoting hormones like auxins, cytokinins, and gibberellins, leading to improved root structure and more excellent absorption of soil nutrients. Also, some PGPBs synthesize antimicrobial substances that protect plants from pathogens and against disease (Ajijah et al., 2023). Auxins, primarily indole-3-acetic acid (IAA), are the most prevalent phytohormones produced by PGPBs (Çakmakçı et al., 2020). IAA synthesis can proceed through multiple pathways, notably the indole-3-pyruvate and tryptophan side-chain oxidase pathways, utilizing tryptophan secreted by plant roots as a precursor. IAA enhances root elongation and branching, thus expanding the root surface area for improved water and nutrient uptake (Lobo et al., 2022).

Likewise, PGPBs synthesize cytokinins, which foster cell division and growth, delay leaf senescence, and boost plant nutrient mobilization (Kejela, 2024). Cytokinins are produced from adenine bases through cytokinin synthase enzymes. Another group of hormones, gibberellins, also produced by PGPBs, facilitate stem and leaf growth (Woo et al., 2023). Gibberellins are generated via the terpenoid pathway, transforming geranylgeranyl diphosphate (GGDP) into various gibberellins through enzymatic actions. While ethylene is typically viewed as a stress hormone, certain PGPBs can regulate its levels by producing the enzyme ACC

(1-aminocyclopropane-1-carboxylate) deaminase, which breaks down the ethylene precursor ACC, thereby reducing ethylene levels and mitigating stress effects on plants (Castro-Camba et al., 2022).

In addition to phytohormones, PGPBs synthesize antimicrobial substances such as siderophores, hydrolytic enzymes, or antibiotics (Rumyantsev et al., 2023). Siderophores are produced via a non-ribosomal peptide synthetase (NRPS)-dependent pathway, sequestering iron and indirectly fostering plant growth by restricting pathogen spread. PGPBs secrete enzymes like chitinases, β-1,3-glucanases, and proteases that break down the cell membrane of pathogenic fungi and bacteria (Saeed et al., 2021). Furthermore, PGPBs generate antibiotics, including phenazines, pyrrolnitrin, and hydrogen cyanide (HCN), through intricate biosynthetic pathways involving multiple enzymes that transform precursor molecules into effective antimicrobial agents, thus inhibiting the growth of competing microbes and protecting plants (Olanrewaju et al., 2017).

PGPBs can benefit plants by tolerating various environmental stresses such as drought, salinity, and heavy metal toxicity (Kumar et al., 2023). The mechanisms to enhance plant tolerance to stress can be broadly categorized into direct and indirect effects. Direct mechanisms involve processes such as synthesizing phytohormones and solubilizing and mobilizing nutrients in the soil. Indirect mechanisms operate through the enhancement of stress-related enzymes and antioxidants. PGPBs can enhance the activity of stress-related enzymes and increase the production of antioxidants in plants, thereby helping to mitigate oxidative stress caused by environmental stressors (Abdelaal et al., 2021). A study by Pandita (2022) revealed that PGPBs can immobilize heavy metals or transform them into less toxic forms, thus reducing plant uptake and ameliorating toxicity symptoms. Furthermore, Bhise and Dandge (2019) confirmed that PGPB inoculation has been reported to lessen the effects of salinity stress by improving ion homeostasis, reducing sodium uptake, and enhancing potassium absorption.

PGPBs are beneficial microorganisms that play a crucial role in promoting a healthy soil ecosystem. These bacteria increase the diversity and activity of microorganisms in the soil. On the other hand, chemical fertilizers can be harmful to soil microbial communities, thereby reducing soil fertility (Pahalvi et al., 2021). Additionally, chemical fertilizers can also degrade soil structure, leading to a reduction in organic matter content (Tripathi et al., 2020). Conversely, PGPBs can improve soil structure, which enhances water retention and aeration, making the soil more suitable for plant growth (Lin et al., 2022). Furthermore, PGPBs offer a sustainable and environmentally friendly approach to promoting food safety and security by enhancing soil health, reducing chemical inputs, and improving nutrient management in agricultural systems (Chandran et al., 2021). Therefore, the practical application of PGPBs can be a critical connection in sustainable agriculture, reducing the demand for chemical fertilizers and pesticides, improving soil quality, and helping to increase crop yields.

II. PGPBs as Bio-Inoculants

PGPBs are bacteria that can enhance plant growth and protect plants from disease and abiotic stresses through various mechanisms (Nagrale et al., 2023). The practical application of PGPBs as bio-inoculants represents a sustainable approach to enhancing plant growth. Some of the most popular and commercially successful strains of PGPB belong to the *Bacillus, Pseudomonas, Enterobacter, Burkholderia, Acinetobacter, Alcaligenes, Arthrobacter, Azospirillum, Azotobacter, Beijerinckia, Erwinia, Flavobacterium, Rhizobium,* and *Serratia* genera (Pranaw et al., 2020). *Rhizobium* is a symbiotic bacterium that fixes nitrogen in nodules on the roots of leguminous plants (Masson-Boivin & Sachs, 2018). This process converts atmospheric nitrogen into ammonia, which the plant can use. *Rhizobium* is commonly used as an inoculant for legume crops such as soybeans, peas, lentils, and alfalfa. It helps enhance nitrogen uptake and reduces the need for synthetic nitrogen fertilizers (Morel et al., 2012).

Azospirillum is known for producing phytohormones, such as auxins, which promote root growth and development (Zaheer et al., 2022). It is commonly used for cereals and grasses, improving root structure and nutrient absorption. This leads to enhanced crop growth and yields like wheat, maize, and rice (Raffi & Charyulu, 2021). *Bacillus*, a diverse group of bacteria, includes species like *B. subtilis* and *B. amyloliquefaciens*, which are known for their ability to solubilize phosphate, produce phytohormones, and offer biocontrol against pathogens (Luo et al., 2022). Their applications are utilized across various crops to enhance nutrient uptake, promote growth, and provide disease resistance.

Pseudomonas fluorescens is renowned for its ability to solubilize phosphate, produce siderophores (which sequester iron for plant use), and suppress soil-borne diseases through antibiotic production (Blanco-Vargas et al., 2020). Its applications are used in seed treatment and soil application for various crops to improve growth and health by enhancing nutrient availability and protecting against pathogens. By reducing reliance on chemical fertilizers and pesticides, PGPBs as bio-inoculants promote sustainable agriculture, improve soil health, and contribute to food security while minimizing environmental impact (Ortega Pérez et al., 2023). PGPBs can be applied as bio-inoculants using several techniques, depending on the type of bacteria, crop, and the required effect. Applying PGPBs such as *Pseudomonas* spp. and *Bacillus* spp. as biofertilizers is an innovative approach to sustainable agriculture (Mehmood et al., 2023; Sansinenea, 2019). These microorganisms can enhance plant growth, nutrient uptake, and disease resistance. In case study research tomato plants (*Solanum lycopersicum*) serve as a model species, and several methods exist to introduce these beneficial bacteria, each employing specific techniques. One such method involves immersing the plant's roots in a bacterial suspension with an optical density (OD) at 660 nm of at least 1.0 (Ji et al., 2014). This process facilitates direct contact between the bacteria and the plant roots, promoting immediate colonization of the root surfaces (Figure 2-a) (Andreote et al., 2010). After immersion, the plants are transplanted under controlled environmental conditions to ensure optimal growth and microbial activity. The ideal growth conditions for *S. lycopersicum* include a temperature range of 21-29 °C, relative humidity of 60-70%, at least 6 to 8 hours of direct sunlight per day, and a soil pH range of 6.0 to 6.8.

Another method of introducing PGPBs to *S. lycopersicum* is by microbial seed coating (Figure 2-b) (Paravar et al., 2023). This method involves applying PGPBs onto the seeds of *S. lycopersicum* before planting. It is typically done using a slurry that adheres to the seeds, ensuring immediate microbial contact upon seed germination. Watering *S. lycopersicum* with a bacterial suspension is also an effective method (Figure 2-c) (Chaín et al., 2020). This technique involves using a liquid solution containing PGPBs to irrigate *S. lycopersicum*. The bacteria penetrate the soil and colonize the root zone regularly. The bacterial suspension is distributed through watering systems to achieve even coverage around the plant's root zone. Spraying the tomato plants with bacterial suspensions is another method (Figure 2-d) (Fu et al., 2020). A solution of PGPBs is directly applied to the tomato plants. Although this method is less direct than root applications, spraying can significantly enhance the colonization of the leaf surface by PGPBs, which can directly benefit

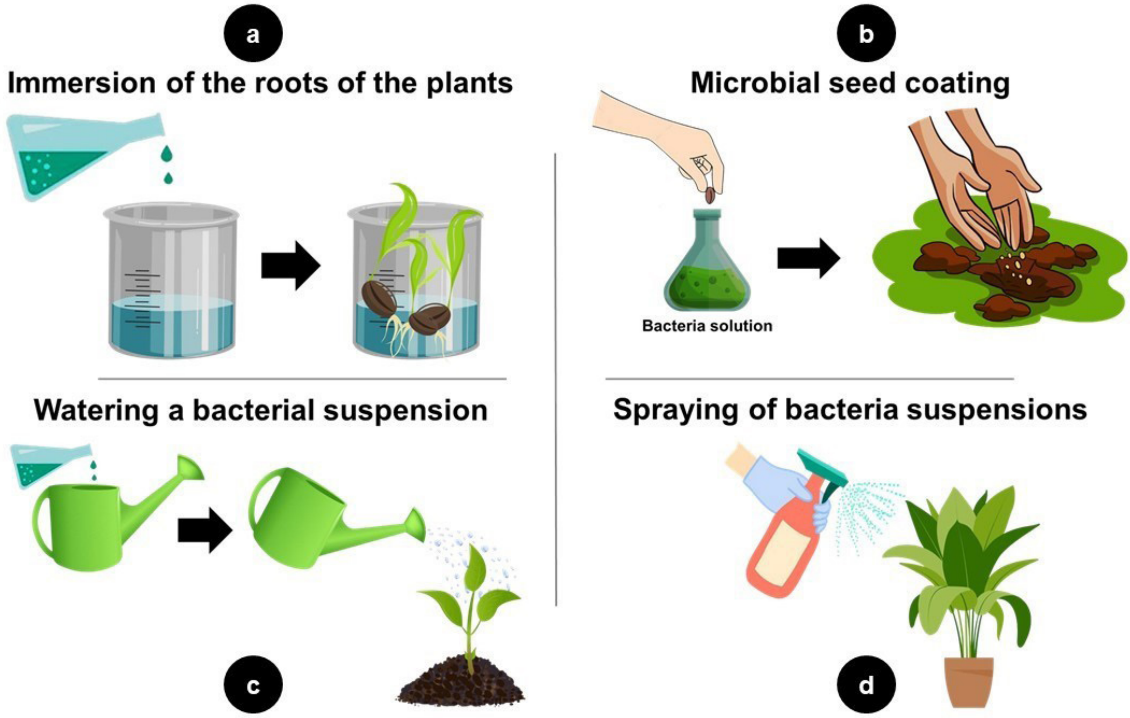

Figure 2. The methods of using PGPBs as bio-inoculants. (a) immersion of the roots of the plants, (b) microbial seed coating, (c) watering a bacterial suspension, and (d) spraying of bacteria suspensions.

plant health, including providing insecticidal activity.

III. Isolation and Characterization of PGPBs

Isolating and characterizing PGPBs are crucial for sustainable agriculture. This process allows researchers and practitioners to select the most suitable strains for specific applications, ensuring safety, efficiency, and environmental sustainability. Consequently, isolating and characterizing the potential PGPBs are necessary. PGPBs can be sampled at three levels (Figure 3-1): the rhizosphere, the phyllosphere, and the endosphere.

The rhizosphere refers to the soil surrounding the roots, where a rich community of microorganisms, including PGPBs, interacts directly with the plant root system, influencing nutrient uptake and plant health. The phyllosphere includes the plant's above-ground parts, such as leaves and stems, which provide a habitat for various microorganisms that can affect plant growth and disease resistance. Lastly, the endosphere consists of the internal tissues of the plant, where certain bacteria can reside, often providing benefits to the plant by enhancing growth, stress tolerance, or disease resistance from within.

Potential PGPBs are isolated using nutrient-rich culture media such as Luria broth (LB) or Nutrient broth (NB). This step allows for the growth of a diverse microbial population from environmental samples (as shown in Figure 3-2). To obtain pure cultures, each strain is purified through repeated sub-culturing, ensuring that only a single bacterial type remains in the culture (Figure 3-3). The next step involves morphological characterization, wherein cell morphology is examined under a microscope to note the bacteria's shape, size, and Gram-staining pattern, providing preliminary identification information (Figure 3-4). Further identification and characterization involve several biochemical tests to understand the metabolic characteristics of the isolates. Standard procedures such as tests for catalase and oxidase activity, indole production, and sugar fermentation profiles offer insights into the functional capabilities of the bacteria (Figure 3-5). For definitive PGPB identification, DNA is extracted from pure cultures, and PCR is performed using 16S rRNA gene-specific primers. The obtained sequences are then compared to those in NCBI databases to accurately identify the genus and species of the bacteria (Figure 3-6). Functional characterization of the isolates includes assays to evaluate plant growth-promoting traits. These assays test for abilities such as phosphorus, potassium, and zinc solubilization, nitrogen fixation, and the production of plant growth regulators like indole-3-acetic acid (IAA), siderophores, and hydrogen cyanide (HCN). Additionally, the potential of the isolates to inhibit plant pathogens (showing antagonistic activity) and to produce natural toxins with insecticidal activity is assessed (Figure 3-7).

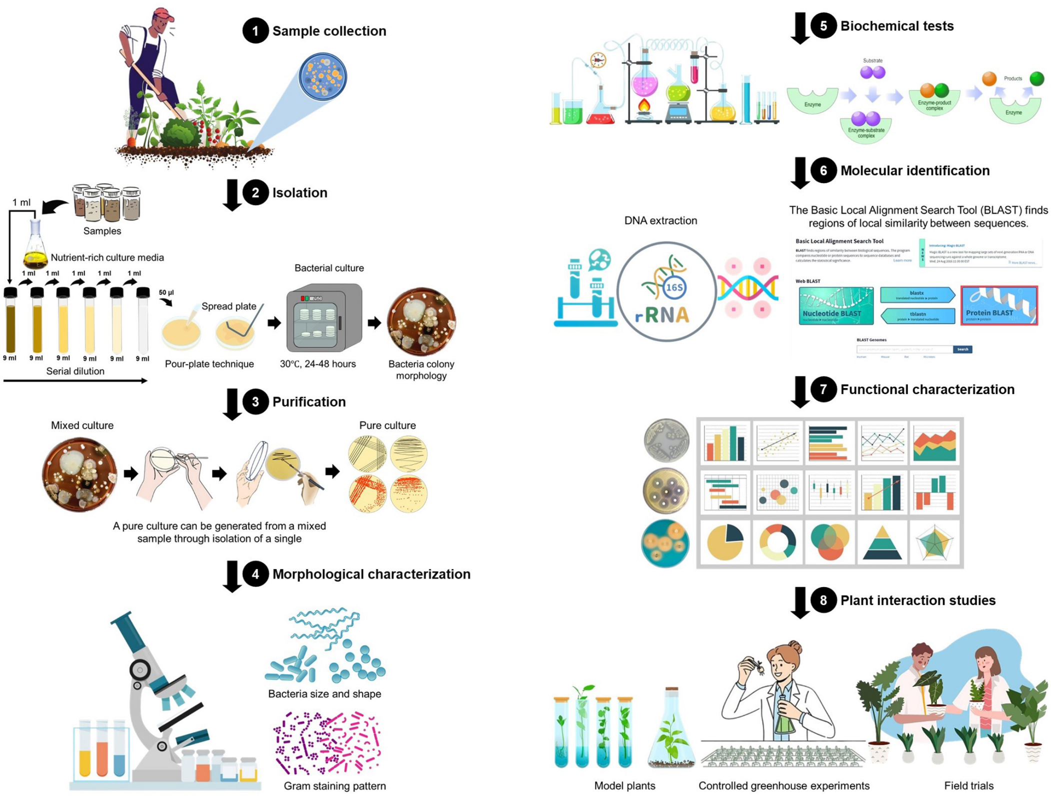

Figure 3. The diagram presents the process of isolating and characterizing PGPBs (Adapted from Majeed et al., 2015)

The process involves eight steps: (1) Sample collection: PGPBs can be obtained from the rhizosphere, phyllosphere, and endosphere. (2) Isolation: the PGPBs can be isolated using nutrient-rich culture media such as LB or NB. (3) Purification: to obtain pure cultures, each strain should be purified through repeated sub-culturing. (4) Morphological characterization: the cell morphology is examined under a microscope to note the bacteria's shape, size, and gram-staining pattern. (5) Biochemical tests: the metabolic characteristics of the PGPBs are determined through various tests such as catalase and oxidase activity, indole production, and sugar fermentation profiles. (6) Molecular identification: the genomic DNA is extracted, and PCR is performed. The obtained sequences are compared to NCBI databases to identify the PGPBs accurately. (7)

Functional characterization: to evaluate the plant growth-promoting traits of each strain, PGPBs are tested for abilities such as P, K, and Zn solubilization, N fixation, and the production of plant growth regulators like IAA, siderophores, and HCN. (8) Plant interaction studies: the selected PGPB strains are verified through inoculation on model plants in controlled greenhouse experiments. Successful strains are then tested at the field scale to evaluate the effectiveness and consistency of the isolated PGPBs in enhancing plant growth under natural conditions.

The practical application of selected PGPB strains is verified through inoculation on model plants in controlled greenhouse experiments. Parameters such as root and shoot length, biomass, and overall plant health are analyzed to confirm the growth-promoting effects of the bacteria (Figure 3-8). Subsequently, successful strains are tested at the field scale to evaluate the effectiveness and consistency of the isolated PGPBs in enhancing plant growth under natural conditions. This comprehensive approach from isolation to field application ensures the identification and utilization of effective PGPBs for sustainable agriculture.

IV. Challenges and Limitations

Although PGPBs substantially benefit agricultural productivity and sustainability, their widespread implementation faces several challenges and limitations. The effectiveness of PGPBs can vary considerably depending on environmental factors, soil types, and crop species. What works in controlled conditions or laboratory settings may yield different results in the field due to the complexity and variability of natural ecosystems. Furthermore, the interaction between PGPBs and plants is influenced by various factors such as soil pH, temperature, moisture, and other biotic and abiotic stressors. This context-dependency can lead to inconsistent outcomes across different agricultural settings. Competition with native microflora is also a challenge for PGPBs. Introduced PGPBs must compete with the resident soil microorganisms for resources and niches.

The ability of PGPBs to effectively colonize the plant rhizosphere and exert their beneficial effects can be hindered by native microbial communities. The introduction of PGPBs, particularly genetically modified strains, into agricultural systems is subject to strict regulatory oversight to ensure they are safe for the environment, humans, and animals. This can be a lengthy and costly process. The practical applications of PGPBs are still being optimized. While significant progress has been made in understanding how PGPBs promote plant growth, the detailed mechanisms, especially in complex field conditions, are still being elucidated. Therefore, the complex interactions between PGPBs, plants, and other soil organisms still need to be fully understood. More research is needed to optimize the use of PGPBs in diverse agricultural ecosystems.

V. Current Research Context in Cambodia

PGPBs as bio-inoculants are receiving significant attention in environmental biotechnology. However, the application of PGPBs as bio-inoculants in Cambodian agriculture is still in limitation, as most Cambodian farmers rely on synthetic chemical fertilizers and pesticides (Phat et al., 2022; Wang et al., 2011). In developing countries like Cambodia, integrating PGPBs into agriculture could lead to a significant shift towards more sustainable farming practices. Given Cambodia’s reliance on agriculture, this could have broad economic and environmental benefits, including improved food security, reduced environmental impact from chemical inputs, and increased sustainability of farming practices. Although research on PGPBs in Cambodia is still in its early stages, continued investment in research, field trials, and farmer education will be essential to unlocking the full potential of these bio-inoculants.

VI. Concluding Remarks

Using PGPB shows excellent potential in enhancing agricultural sustainability, soil fertility, and crop productivity. These beneficial microorganisms offer a natural and eco-friendly alternative to traditional chemical fertilizers and pesticides through nitrogen fixation, nutrient solubilization, hormone production, biocontrol, and stress tolerance enhancement. Incorporating PGPBs as bio-inoculants can promote sustainable agriculture, reduce reliance on synthetic inputs, and minimize environmental impact. Additionally, isolating and characterizing PGPB strains from natural habitats can provide valuable insights into how we can improve plant growth and soil health. Implementing PGPBs in agricultural practices can improve food security and help combat the ecological challenges of conventional farming methods. Continued research on PGPBs offers exciting opportunities for advancing sustainable agriculture and addressing global food security challenges.

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Mr. Chem Chanchao is currently a PhD student supported by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT Scholarship) at the Laboratory of Water and Environmental Microbiology, Department of Environmental Engineering Science, Graduate School of Science and Technology, Gunma University, Japan. He earned a Master of Science in Biochemical Technology and a Bachelor of Science in Biology from the Excellent Center of Enzyme Technology and Microbial Utilization, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand (2020), and the Royal University of Phnom Penh (2017), respectively. His research focuses on the 4 R's of sustainability: Reduce, Reuse, Recycle, and Rethink. These concepts aim to eliminate waste, give new phenomenon to discarded items, repurpose materials, and encourage us to consider the environmental impact of our consumption decisions. For instance, he has applied these principles in his research by developing methods to reduce chemical fertilizers in agriculture and repurposing agricultural waste for bioproduction. In his current research, he works on synthetic microbial communities (SynComs) applications for sustainable farming practices, including plant growth-promoting bacteria and biological control.

State-of-the-Art Khmer Text Recognition

2

Buoy Rina
Ph.D. Student, Informatics
Osaka Metropolitan University, Japan

Chenda Sovisal
Master's Degree, Advanced Computing Systems
Lucian Blaga University of Sibiu, Romania

Taing Nguonly
Ph.D., Computer Science
Dresden University of Technology, Germany

Kong Marry
Ph.D., Telecommunications Technology and
Information Technology, Waseda University, Japan

Highlight

- Detailed two-dimensional (2D) visual features are required for accurate Khmer text recognition due to the complex Khmer writing system.
- Our proposed 2D-based approach can capture local 2D feature dependencies and reduce model complexity by using chunking a long textline image into a sequence of overlapping smaller chunks over which 2D features are extracted and modelled.
- The experimental results show that our proposed models outperform the baseline models and the existing state-of-the-art models on multiple real benchmark datasets.

I. Introduction

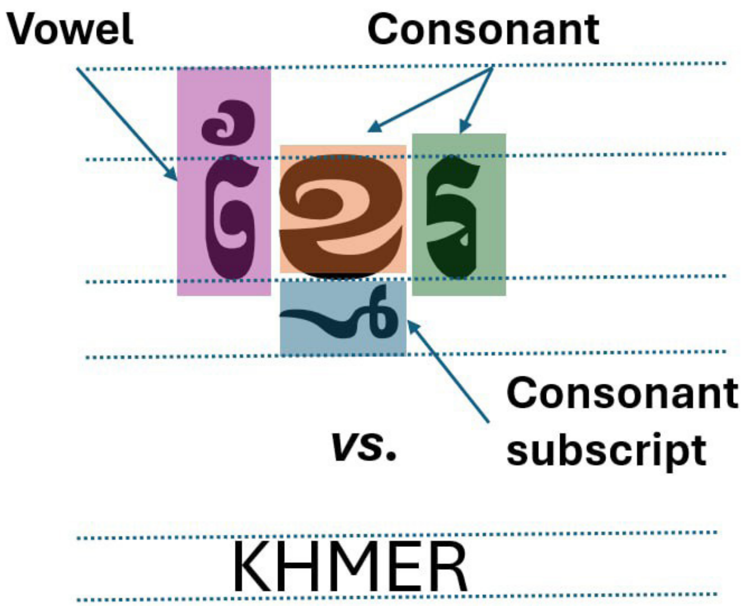
Recognizing Khmer text accurately remains a challenging task because of the intrinsic complexity of Khmer script. The Khmer script has the largest inventory of characters (Valy et al., 2019), and it is recognized as one of the most intricate writing systems (Valy et al. 2020). Unlike the Latin script, the Khmer script has more complex structure and features. These features include diacritics, character stacking, and ligatures. In addition, Khmer does not employ any visible word delimiters, resulting in implicit word boundaries. Because of character stacking, Khmer characters are spatially distributed and thus, 2D feature modelling is required. Moreover, since there is no word boundary, Khmer textline images can be significantly longer than word-level Latin scene text images. In addition, the self-attention mechanism, introduced by Vaswani et al. (2017), proves to be a potent architecture for capturing 2D feature dependencies, as noted by Diaz et al. (2021). Because of its flexibility and ability to capture long-range dependencies via pair-wise feature-to-feature dot products, a self-attention layer poses a time and memory complexity scaling, which is quadratically with the size of 2D feature maps. Long textline images, coupled with 2D feature modeling, impose a substantial computational constraint, especially in a low-resource environment.

In this paper, we introduce a hybrid convolutional Khmer textline recognition method that is also based on Transformer networks. The proposed approach extracts 2D spatial feature maps and models feature dependencies at the local chunk level. This is done by chunking a long textline image into a sequence of overlapping smaller chunks. The extracted 2D local contextual features are merged for downstream steps and character decoding. Such image chunking and merging approach reduces the training complexity, induced by long input images (arbitrarily wide because of no visible word boundaries), to a linear relationship with respect to textline width.

II. Methodology

Like TrOCR (Li et al., 2023) and SATRN (Lee et al., 2020), the proposed Khmer text recognition architecture employed in this paper comprises both an encoder and a decoder, as illustrated in Figure 1. When dealing with 2D feature maps, the CNN-based feature extractor of the encoder side extracts 2D feature maps, which are four times smaller than the input textline image. In the case of 1D feature maps, the height of the resulting feature maps is one. On the other hand, the decoder module comprises Transformer decoder units. Unlike a standard Transformer decoder, static position encoding is used to allow arbitrarily long textline recognition. The decoder module receives T (as shown in Figure 1) as input and predicts character distributions over 131 labels, which include Khmer characters, and commonly used foreign symbols, along with three special tokens for padding, ending of text, and beginning of text.

As illustrated in Figure 1, the image chunking technique is integrated into the proposed Khmer textline recognition system, utilizing 2D feature maps and Transformer networks. By chunking a long textline image into a sequence of overlapping smaller chunks, the model complexity can be drastically reduced. This model complexity reduction results in a linear relation with respect to the textline width, as opposed to a quadratic relation when the image chunking technique is not used.



Intelligent Informatics

As depicted in Figure 2, the model complexity of the entire textline image is $O(5^2C)$. However, by chunking into smaller segments to extract 2D local features and subsequently, merging the extracted 2D features together, the overall model complexity is reduced to O(5C), which is around five times lower.

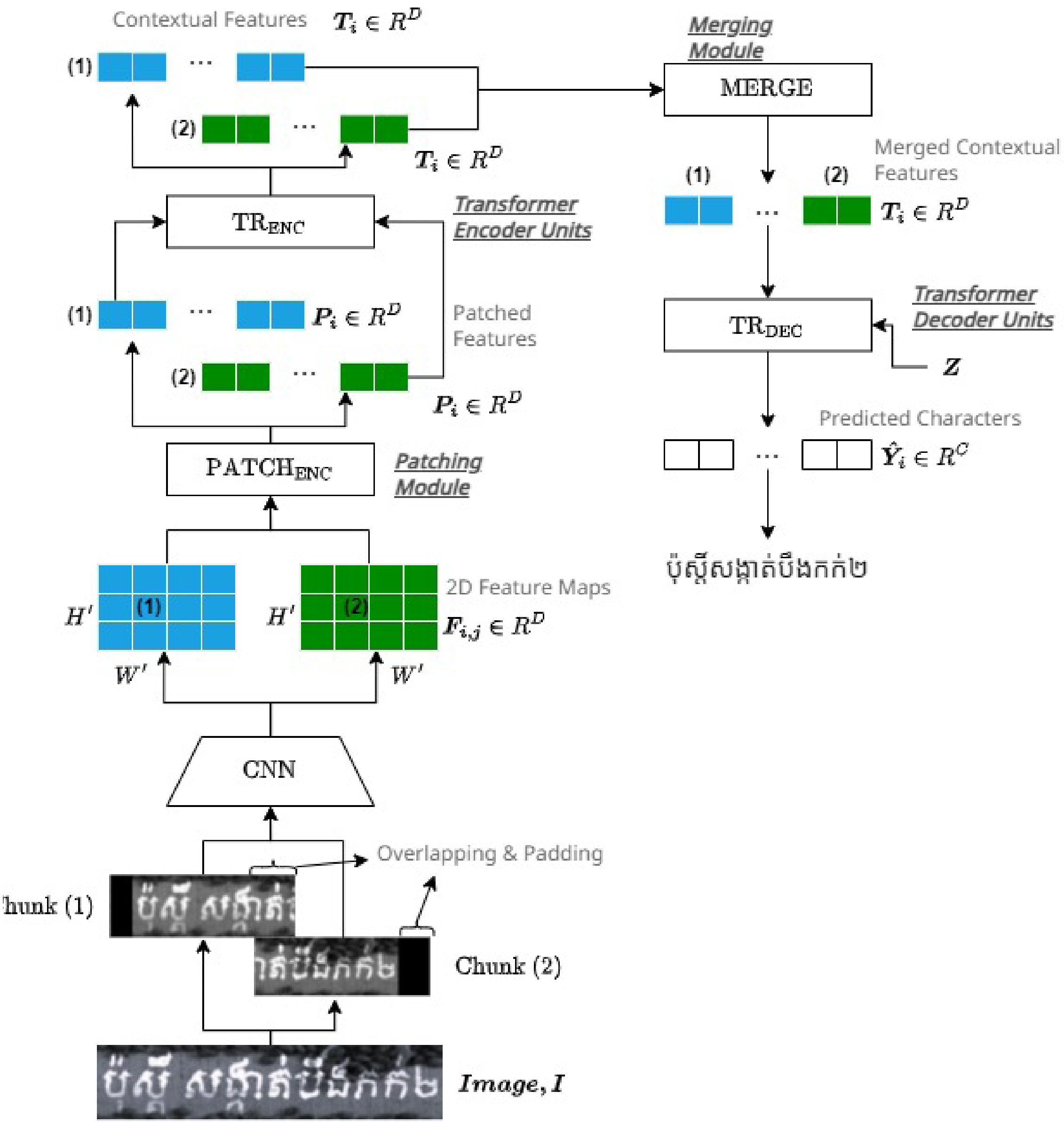


Figure 1. The proposed 2D Transformer-based encoder-decoder architecture, incorporating the chunking and merging technique.

III. Datasets

We created synthetic training datasets by transforming the original textline data into synthetic images. We utilized the same Khmer corpus and the same commonly-used fonts as those of Tesseract for Khmer script. For performance evaluation, we utilized two real datasets. Firstly, we employed the proprietary Khmer identity card dataset, containing 1.5K images taken with smartphone cameras in natural scenes. Secondly, we assessed the effectiveness of our proposed models, using 2D feature maps, on the KHOB dataset. The KHOB dataset is based on the cropped textline images extracted from PDF documents of various sources, which are different from the first dataset. However, the images in this dataset feature cleaner backgrounds

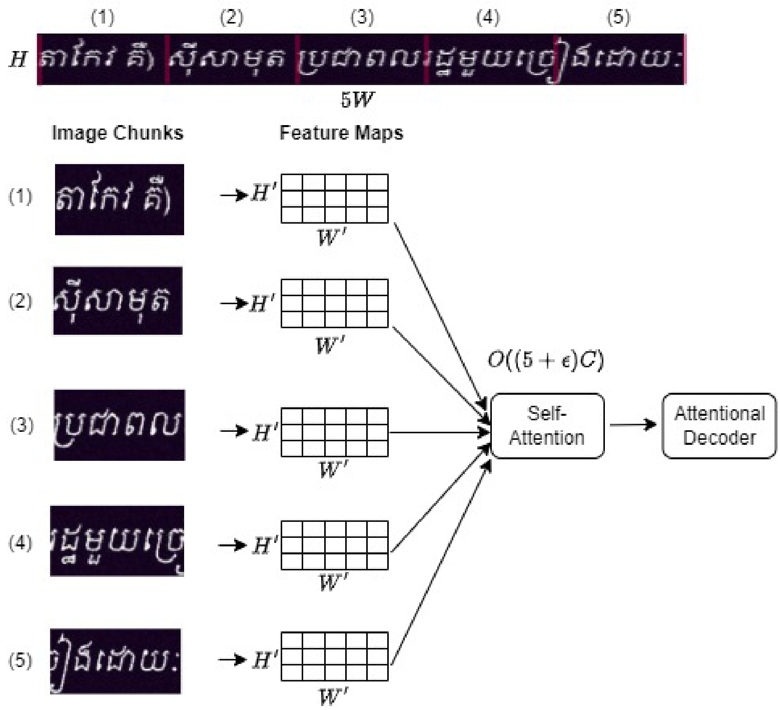


Figure 2. Self-attention complexity reduction by the image chunking technique.

but have lower resolution because of compression. As a result, the resolution of smaller characters (i.e., subscripts and diacritics) is significantly affected. The curated collection includes 336 textline images.

In addition, to evaluate the adaptability of our proposed method to different input types, we further trained our 2D models on another real dataset by transfer learning. We utilized the Sleuk Rith dataset, which is based on historical handwritten palm leaf manuscripts. The character error rate (CER) is compared with the performance of the published model developed by Valy et al. (2020).

IV. Experiments and Results

To compare the performance of 1D versus 2D feature maps, we established 1D models, which serve as the baseline models. Two CNN feature extraction architectures, which are VGG and ResNet as listed in Table 1, were experimented with. When the input image has a height of 42 and 48 pixels, respectively, both extractors produce feature maps that have 12 units in the height direction. For our proposed models, utilizing 2D feature maps, a patching kernel (3,1) was used and it downsampled the feature maps extracted by the CNNs by a factor of three and one in the height and width directions, respectively. The decoder module consists of three Transformer decoder units, each with a model dimension of 512 and eight attention heads. For image chunking, we utilized a chunk width of and an overlapping margin of 100 and 16 pixels, respectively. For the ResNet cases, input images were resized to 48 pixels in height while preserving the original aspect ratio. Thus, the resized images can be arbitrarily long. Similarly, for the VGG cases, a common height of 42 pixels was used.

In addition, we also created three additional baseline models, which are CRNN (convolutional recurrent neural

Table 1. Detailed specifications of VGG and ResNet backbones

Layer	Configuration	Output (H'×W'×C)
Input	grayscale	48×132×1
Conv1	c:64 k:3×3 s:1×1 p:1×1	48×132×64
Pool1	k:2×2 s:2×2	24×66×64
Conv2	c:128 k:3×3 s:1×1 p:1×1	48×132×128
Pool2	k:2×2 s:2×2	12×33×128
Conv3	c:256 k:3×3 s:1×1 p:1×1	12×33×256
Conv4	c:256 k:3×3 s:1×1 p:1×1	12×33×256
Pool3	k:1×2 s:1×2	6×33×256
Conv5	c:512 k:3×3 s:1×1 p:1×1	6×33×512
BatchNorm1	-	12×33×512
Conv6	c:512 k:3×3 s:1×1 p:1×1	6×33×512
BatchNorm2	-	12×33×512
Pool4	k:1×2 s:1×2	3×33×512
Conv7	c:512 k:3×3 s:1×1 p:1×1	2×32×512

(a) VGG

Layer	Configuration	Output (H'×W'×C)
Input	grayscale	48×132×1
Conv1	c:32 k:3×3 s:1×1 p:1×1	48×132×32
Conv2	c:64 k:3×3 s:1×1 p:1×1	48×132×64
Pool1	k:2×2 s:2×2	24×66×64
Block1	[c:128 k:3×3 s:1 × 1 p:1 × 1; c:128 k:3 × 3 s:1 × 1 p:1 × 1] × 1	24×66×128
Conv3	c:128 k:3×3 s:1×1 p:1×1	24×66×128
Pool2	k:2×2 s:2×2	12×33×128
Block2	[c:256 k:3 × 3 s:1 × 1 p:1 × 1; c:256 k:3 ×3 s:1 × 1 p:1 × 1] × 2	12×33×256
Conv4	c:256 k:3×3 s:1×1 p:1×1	12×33×256
Pool3	k:2×2 s:1×2 p:1×0	6×34×256
Block3	[c:512 k:3 × 3 s:1 × 1 p:1 × 1; c:512 k:3 × 3 s:1 × 1 p:1 × 1] × 5	6×34×512
Conv5	c:512 k:3×3 s:1×1 p:1×1	6×34×512
Block4	[c:512 k:3 × 3 s:1 × 1 p:1 × 1; c:512 k:3 × 3 s:1 × 1 p:1 × 1] × 3	6×34×512
Conv6	c:512 k:2×2 s:1×2 p:1×0	3×35×512
Conv7	c:512 k:2×2 s:1×1 p:1×1	2×34×512

(b) ResNet

Table 2. Character error rate (CER in %) results on the Khmer ID card, KHOB, and Sleuk Rith datasets. Bold: lowest. Italic: second lowest.

Model	Khmer ID Card		KHOB	Sleuk Rith[1]
	Name	Number		
Valy et al.[2]				6.16
Tesseract OCR (Baseline)	27.78	5.64	11.37	94.88
CRNN (Shi et al.; Baseline)	7.34	2.36	6.17	4.81
TRBC (Baek et al.; Baseline)	6.80	0.76	5.42	3.26
TRBA (Baek et al.; Baseline)	7.23	3.53	7.77	3.80
1D-VGG Baseline	4.31	1.61	3.32	2.92
1D-ResNet Baseline	4.24	**0.57**	**2.55**	**2.46**
Our Proposed 2D-VGG	*3.47*	1.27	*3.03*	*2.66*
Our Proposed 2D-ResNet	**3.00**	*0.62*	3.41	**2.46**

[1] Fine-tuning from the respective Khmer script model.
[2] SOTA model on the Sleuk Rith dataset.

network) (Shi et al., 2017), TRBA (using an attentional decoder), and TRBC (using a connectionist temporal classification decoder) as proposed by Baek et al. (2019). However, thin-plate spline (TPS) transformation was omitted from these baseline models as TPS requires a fixed image size and thus, the input image cannot be arbitrarily long. Image chunking was not utilized in these baseline models. It should be noted that both the CRNN and TRBC models are based on a connectionist temporal classification decoder (CTC), which generates all characters in parallel, while the TRBA model is based on an attentional decoder (i.e., using an attention mechanism for decoding), which generates all characters sequentially.

We begin by analyzing the recognition performance on the proprietary Khmer identity card dataset, our proposed models, utilizing 2D features, obtained CERs that were two times lower than those of the baseline models for both name and number fields, as illustrated in Table 2. To be specific, these baseline models include Tesseract OCR, CRNN, TRBC, and TRBA. We observed significant differences in CERs between the identity card full name in Khmer and the identity card number in Latin. These drastic differences highlight that the Khmer script has a more complex structure than the Latin script. The improvements in CERs achieved by our models compared to the 1D baseline models and other baseline models validate the proposed method that uses 2D local feature maps.

On the KHOB dataset, our models showcased similar CER improvements compared to the baseline models, as evidenced in Table 2. Specifically, our proposed 2D model using a VGG feature extractor demonstrated superior performance in terms of CER when compared to the equivalent baseline model.

Both the proprietary Khmer identity card and KHOB datasets contain printed text modality. In this part, we focus our attention on the handwritten, historical text modality. As for the Sleuk Rith dataset, we finetuned the baseline models (excluding Tesseract) and our models, using 2D feature maps, on a small training set, followed by an evaluation on the test set. As shown in Table 2, both the baseline models and our models, using 2D feature maps, achieved lower error rates compared to the model by Valy et al. (2020). These results highlight that our 2D approach can be applied to the historical, handwritten text, even with a limited labeled dataset.

V. Conclusion

We introduce a method for Khmer text recognition by using a hybrid convolutional Transformer architecture. Together with the image chunking and merging technique, our approach can handle long textline images while also reducing the model complexity and capture 2D feature maps at the local chunk level. Our models, using 2D feature maps, demonstrated superior performance compared to the baseline models on multiple benchmark datasets. To further validate the proposed method, future work should be concerned with experimenting with other low-resource scripts, such as Thai, Vietnamese, and Burmese, which share similar features with the Khmer script. Other feature extractors, such as vision Transformers (ViT), should be also experimented with. In addition, more benchmark datasets should be constructed for rigorous evaluation and to contribute to the community of low-resource Khmer language.

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Mr. Buoy Rina received the B.S. and M.S. degrees in petroleum engineering from Universiti Teknologi PETRONAS, Malaysia, in 2012 and 2022, and the M.S. degree in IT engineering from Royal University of Phnom Penh, Cambodia in 2022. From 2012 to 2019, he was a petroleum engineer and R&D team lead at Three60 Energy Asia (formerly, LEAP Energy), Kualar Lumpur, Malaysia. Since 2020, he has been a machine learning engineer at Techo Startup Center of the Ministry of Economy and Finance, Cambodia. Currently, he is a PhD student at Osaka Metropolitan University, Osaka, Japan. His research interests include numerical simulation, stochastic optimization, document recognition and analysis, natural language processing, and machine learning in production. He has published multiple peer-reviewed papers in Elsevier, IEEE, and MDPI. He was a recipient of the Vice-Chancellor Award in 2012, the Convocation Award in 2022 from Universiti Teknologi PETRONAS, Cambodia Digital Award 2022 (R&D), and a winner of the Oxford Machine Learning Summer School 2023 competition (OxML23).

Interactive 3D Virtual Tour and Navigation

3

Kor Sokchea
Master's Degree, Applied Computer Science,
Heidelberg University, Germany

Chhay Lyhong
Bachelor's Degree, Architect
Limkokwing University of Creative Technology,
Cambodia

Eong Koungmeng
Bachelor's Degree, Information Technology
Engineering, Royal University of Phnom Penh,
Cambodia

Highlight

- Virtual tour technology revolutionizes our interaction with the environment by providing more convenient and accessible alternatives to physical tour.
- Different types of virtual tour are studied to identify their strengths and weaknesses.
- We present our unique 3D virtual tour of the Institute of Digital Technology (IDT) building at Cambodia Academy of Digital Technology and the STEM building at Royal University of Phnom Penh.
- This virtual tour was built using Unity engine, prioritizing an enhanced user experience with improved interaction and navigation.

I. Introduction

A 3D virtual tour is a digital simulation of a real or imaginary place that allows users to explore the environment interactively. Unlike traditional static images or videos, 3D virtual tours provide immersive and engaging experiences without the need to be physically present. The covid-19 pandemic accelerated the adoption of virtual and remote technologies, further popularizing the use of 3D virtual tours (Vargo et al., 2021).

3D virtual tours are revolutionizing a wide range of industries, including education, tourism, and real estate. 3D Virtual tours enable students and parents to experience the school layout and facilities from anywhere, at any time. Beyond enhancing school exploration, 3D virtual tours offer immersive experiences including virtually exploring historical landmarks, diving into the ocean, or even journeying inside the human body compared to traditional learning materials such as textbooks and videos (Suwarno & Murnaka, 2020). Virtual field trips present an innovative and interactive learning method that leads to enhanced knowledge retention among students (Mead et al., 2019). In the tourism sector, 3D virtual tours provide a more convenient, time-saving, and cost-effective alternative to traditional tours while offering additional information (Lenzen et al., 2018). Museums, art exhibitions, and world heritage sites that incorporate 3D virtual tour technology offer a novel way to engage and draw users from across the globe (Styliani et al., 2009). Lastly, in real estate, virtual tours simplify the process for clients to visualize their desired spaces, ultimately improving the efficiency of buying and selling properties (Leimontaitė & Naimavičienė, 2023).

II. Type of Virtual Tours

Virtual tours can be classified into two types, panoramic image-based virtual tour and 3D mesh-based virtual tour. Each of them has its own strength and weakness with different interactivity and complexity.

2.1. Panoramic Image-Based Virtual Tour

Panoramic image-based virtual tour or 360 degrees virtual tour allows users to look around and view any angle around them. This type of virtual is created by first capturing images of the desired environment. These images are then stitched together to form 360 degrees panorama images. Finally, multiple panoramas can be combined to form an interactive visit path.

360-degree virtual tour offers several advantages compared to other methods because of its relative ease of creation, requiring no 3D modeling expertise, and ability to deliver a heightened sense of realism by preserving the natural state of environment. While 360-degree panoramic tours require fewer resources due to their use of 2D images, they offer limited interactivity. Users cannot freely explore the environment or interact with objects. Additionally, achieving optimal results is dependent on good lighting and modifying the virtual environment post-creation is challenging.

This method is applicable in various contexts, including the 3D virtual tour of the Santa Maria della Scala Museum Complex in Siena, Italy (Fineschi et al., 2015). They utilized two GoPro cameras to capture the rooms, PTGui to merge the images, and Unity3D for final implementation. The panoramas were used as internal textures on spheres, each projected onto the lenses of Oculus Rift Head-mounted Displays (HMDs). Another example is the web-based campus virtual tour for Telkom University, developed by Perdana et al. (2019). This virtual tour employs panoramic images, utilizing the 3Dvista application to streamline the creation process and establish tour paths. Furthermore, it incorporates narration to provide explanations, information, and guidance for users.

2.2. Three-dimension (3D) Mesh-Based Virtual Tour

Another approach to creating virtual tours involves using 3D mesh. This method utilizes computer-aided design software or photogrammetry 3D reconstruction technique to generate 3D models of the environment.

Virtual tours employing 3D mesh techniques offer heightened interactivity compared to those using 360-degree panoramic images. This heightened interactivity enables users to directly interact with each 3D object, resulting in a more immersive experience than interacting with panoramic images. Users can freely explore the environment, with the ability to make changes as they interact. However, capturing precise details and running this tour is more time-consuming and resource-intensive than with panoramic virtual tours. Nevertheless, advancements in hardware and new 3D reconstruction techniques such as Neural Radiance Fields (NeRF) (Mildenhall et al., 2021) and Gaussian Splatting (Kerbl et al., 2023) promise to simplify both creation and use of 3D mesh-based virtual tours.

The mesh-based method has found applications in various contexts. For instance, Skamantzari & Georgopoulos (2016) utilized photogrammetry to reconstruct 3D models of exhibits for a virtual museum. Subsequently, these models were employed to create the museum's environment, with additional features such as camera control systems, mini-maps, and user interfaces enhancing the interactive virtual museum experience. Moloo et al. (2016) proposed a 3D virtual tour of the University of Mauritius, utilizing 3D models and WebGL to enable web-based tours. Another application is the virtual tour guide training system developed by Want et al. (2019), where new tour guides are trained using VR software built with Unity and 3D models from 3ds Max.

III. Methodology

The development of our 3D virtual tour consists of 4 main stages. The first stage involves information gathering, where we collect detailed information about the building and environment. In the second stage, 3D modeling was created by using 3D modeling tools like Blender and Unity's ProBuilder to create the 3D environment and objects. Then, in the third and fourth stage, we incrementally added and tested features such as the movement system, mini-map, information tap, automated tour, priority tour, dialogue system, interaction system, sound, and user interface (UI), as shown in figure 1.

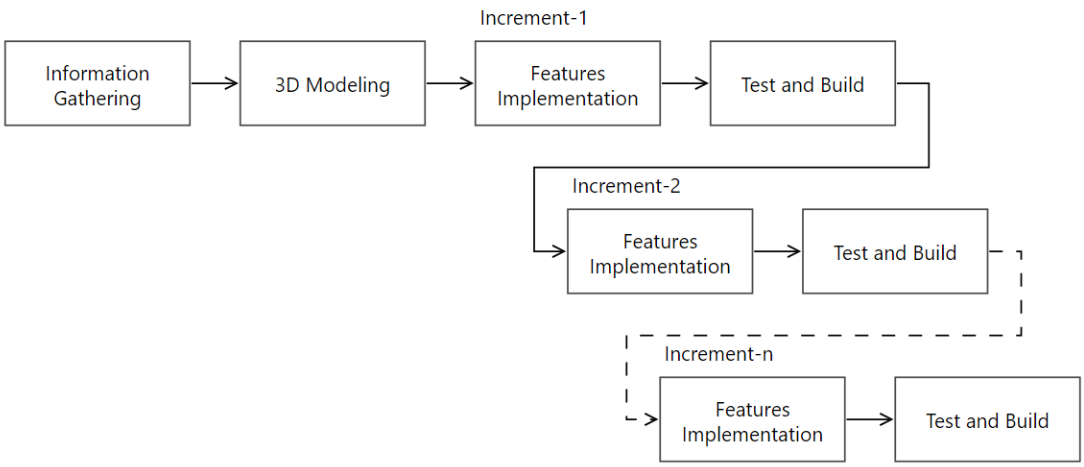

Figure 1. Development Process

Table 1. Devices Specifications and Performance Results

Device	Avg CPU Load	Avg GPU Load	Avg. RAM Usage	Avg FPS
Desktop	32.77%	53.37%	4.6% (1400 MB)	102.7
Laptop	21%	85%	32% (2600 MB)	38
Android Phone	50%	98%	13% (1100 MB)	31

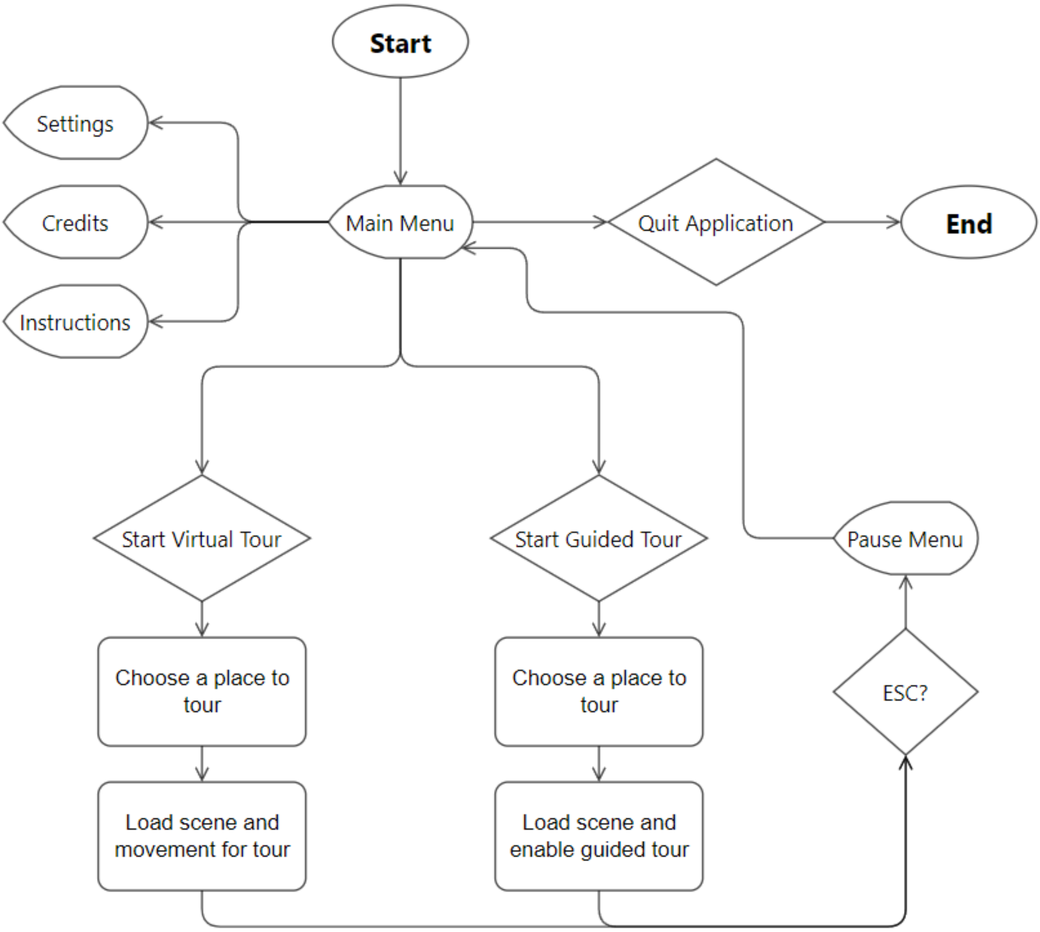

Figure 2. User Flow Diagram

Figure 2. illustrates the user flow diagram of our 3D virtual tour. The user is first greeted with our main menu, which offers access to the virtual tour, settings, instructions, credits, and the option to quit the application. Upon selecting the virtual tour button, users can choose their desired location and tour types (manual or automatic). Our latest features like the priority tour, dialogue system, and interaction system aim to enhance user experience, interaction, and navigation.

IV. Result

The application was built for Android and Standalone Windows. It was tested on 3 different devices including a desktop (Core i7-12700F CPU, RTX 3060 Ti GPU, 32GB RAM), a laptop (Lenovo IdeaPad3, Core i5-1135G7 Processor, 8GB RAM), and an android device (Samsung Galaxy S21 Ultra, Octa-core CPU, Mali-G78 MP14 GPU, 8GB RAM).

The result from Table 1 shows the program's performance across various devices and hardware configurations. Higher specifications, especially increased GPU processing power, result in higher FPS (Frame Per Second).

The followings are screenshots of our 3D virtual tour program:

Figure 3. Main Menu

Figure 4. IDT Tour

Figure 5. STEM Tour

Figure 6. Mini-map and Information Tab

Figure 7. Dialogue System

Figure 8. Priority Tour

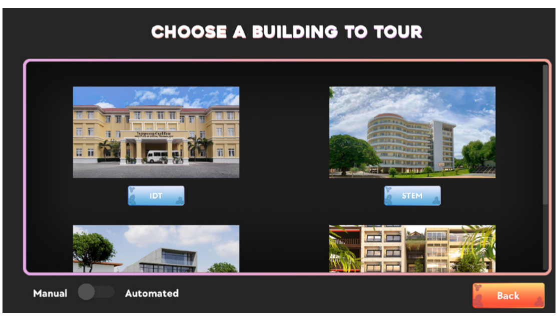

Figure 10. Tour Options Menu

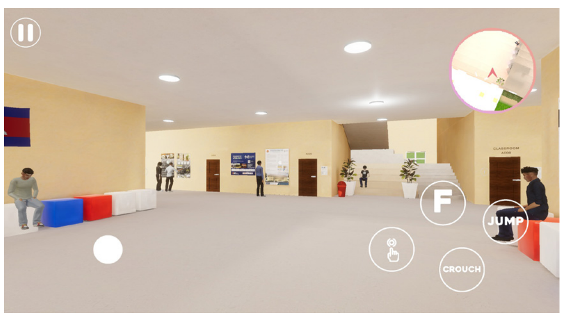

Figure 9. Android UI

V. Conclusion and Future Work

In short, this paper has presented a mesh-based 3D virtual tour technique that revolutionizes user experience compared to existing university virtual tours. Unlike conventional virtual tours that rely on panoramic images, our approach offers higher immersion and interactive experiences. The authors hope this work will serve as a valuable resource and inspiration, sparking a significant interest in Computer Graphics among students, particularly within Cambodia.

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Mr. Kor Sokchea is a deputy director general at Institute of Digital Technology, Cambodia Academy of Digital Technology (CADT). He holds master's degree in applied computer science from Heidelberg University in Germany in 2014 under Erasmus Mundus scholarship, and a Bachelor of Computer Science from RUPP in 2007. After graduation, he joined a newly established Faculty of Engineering at RUPP, where he served as lecturer and researcher at Department of Information Technology Engineering until February 2022. His research interests span from 3D Computer Graphics, Document Image Analysis and Recognition, to Image Processing.

Abusive Image Classification Using Hybrid Model

4

Kor Sokchea
Master's Degree, Applied Computer Science, Heidelberg University, Germany

Soy Vitou
Bachelor's Degree, Information Technology Engineering, Royal University of Phnom Penh, Cambodia

Lany Malis
Bachelor's Degree, Information Technology Engineering, Royal University of Phnom Penh, Cambodia

Y Kimly
Bachelor's Degree, Information Technology Engineering, Royal University of Phnom Penh, Cambodia

Highlight

- Image Classification is the task of classifying images into different labels. In this work, we will classify image into only two labels: abusive and non-abusive.
- We proposed a Hybrid model of Convolutional Neural Network (CNN) and XG-Boost to efficiently classify abusive images for low resource dataset.
- With the Hybrid model, we achieved an impressive 92% accuracy on unseen data with a dataset of 562 images. This demonstrates efficiency in handling low-resource and complex patterns of abusive images.

I. Introduction

Image classification, a fundamental task in image recognition, involves assigning labels to images based on specific rules. This research focuses on abusive image classification, a crucial aspect of recognizing harmful content within images. Abusive images are categorized by various forms of abusive content in the images including emoji and filter abuse, figure transformation, silly makeup on the face, and animal masking, as you can see in Figure 3. Classification is necessary to protect users, ensure legal compliance, and preserve individual reputation on internet. Availability of abusive images can cause psychological harm, normalize harmful behaviours, facilitate criminal activities, and undermine trust and safety online environments.

Recent successful studies (Çetin et al., 2022) achieved 99.39% accuracy in classifying COVID-19 chest X-ray data on specific dataset which contains 12 000 images including original images and augmented images. Similarly (Ramaneswaran et al., 2021), demonstrate the effectiveness of a Hybrid Inception v3 XG-Boost classifier improved outcomes for acute lymphoblastic leukemia images. Building on these achievements, we proposed a hybrid model by combining CNN and XG-Boost (Extreme Gradient Boosting) to enhance accuracy and efficiency on low resource dataset and complex patterns of abusive images.

II. Methodology

2.1. Dataset

We compiled a dataset of approximately 112 non-abusive images and 140 abusive images, sourced from diverse platforms on the internet and social media. Due to insufficient dataset, we manually created more images by using Adobe Photoshop and Canvas. Our dataset consists of 562 images, containing 112 non-abusive and 450 abusive images, divided into six labels- non-abusive, nice emoji edited, Makeup abuse, Transform abuse, Emoji abuse, and Filter abuse for training and testing. We grouped all the images into multiple labels because the four labels of abusive images exhibit extremely different abusive patterns. This makes directly applying binary classification on abusive and non-abusive images less accuracy.

2.2. Data Preprocessing

• Normalization: Digital images are commonly encoded in a three-dimensional representation known as RGB, where the three channels correspond to red, green, and blue colours. Each channel's pixel values range from 0 to 255. This wide range can create computational challenges, especially for large datasets. To address this, we employ a normalization process that scales these pixel values to a narrow range, typically between 0 to 1. This normalization offers efficient computation and facilitates the learning process for deep learning models when working with images.

• Feature Extraction: Feature extraction refers to the transformation of raw data into numerical features suitable for deep learning algorithms. This process aims to capture the most meaningful and relevant information from images. To accomplish this, we leverage the capabilities of the pre-trained VGG16 model, which has been trained on a massive dataset, enabling it to inherently discern and extract essential features from images. VGG16 architecture is shown in Figure 1.

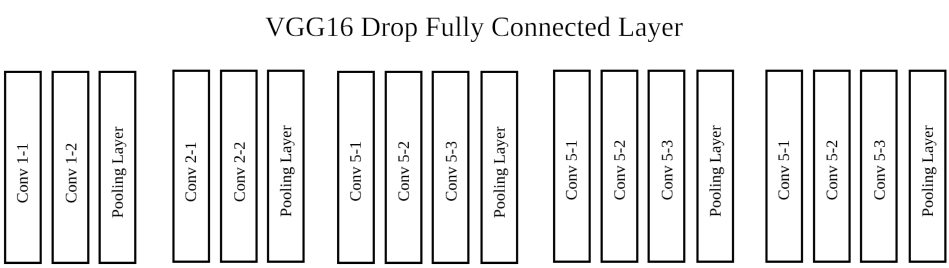

Figure 1. Feature extraction layer is a crucial role in machine learning

2.3. Proposed Architecture

As illustrated in Figure 2, our proposed architecture begins with normalizing the input image to a range of 0 to 1. This preprocessing step ensures computational efficiency and consistent data for the subsequent feature extraction layer, which is responsible for capturing the most significant information from the image. Initially, we explored a binary classification approach because of the presence of two labels. However, due to the complexity of identifying various types of abusive content led us to adopt a multiclassification approach using XGBoost. The VGG16 model extracts features from the image, resulting in tabular data. This format aligns well with XGBoost, emerging as the most suitable choice for this type of data because of its ability to deal with tabular data effectively. After the XGBoost classifier, we implemented a matching algorithm as you can see in Figure 2 and Figure 3. This matching algorithm is commonly used in programming. This step aims to enhance the model's understanding of abusive content for binary classification. As mentioned earlier, our goal is to classify images as either abusive or non-abusive, not to identify specific content types. This technique focuses on extracting features of abusive content to achieve high accuracy and robustness.

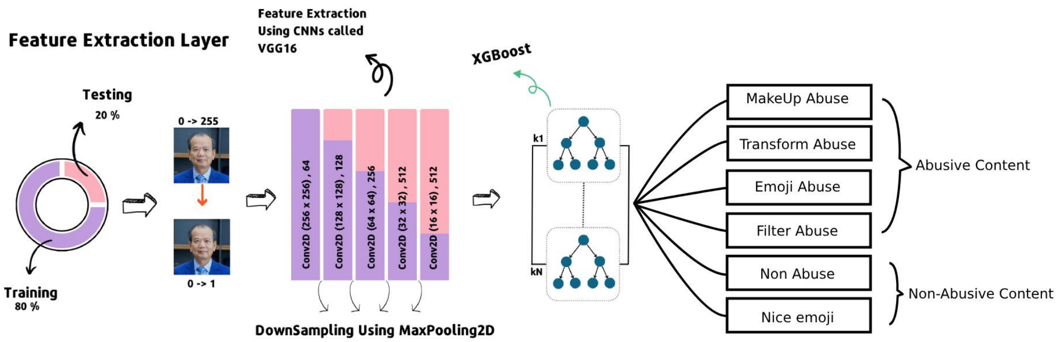

Figure 2. Proposed architecture combination of VGG16 and XGBoost Classifier

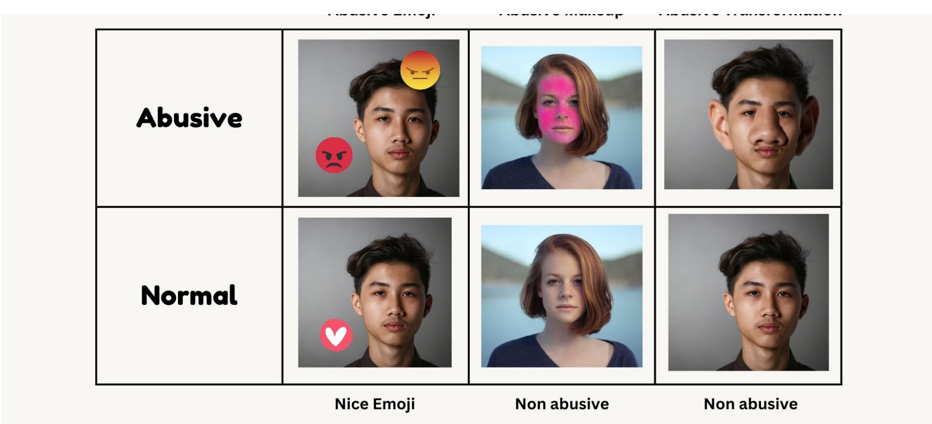

Figure 3. Sample of abusive and non-abusive content

2.4. Regularization

XG-Boost is specifically designed for handling tabular data efficiently and operates on the basis of decision-making trees as its fundamental building blocks, with 'K' representing the total number of trees in this context. Since the XG-Boost algorithm relies on decision trees, it can lead to overfitting. To prevent this issue, we apply regularization, as indicated in (Samat et al., 2020)

$$\hat{y}_i = \emptyset(x_i) = \sum_{k=1}^{K} f_k(x_i)$$

$J(f_k)$ is the regularization term for the k-th tree, incorporating both L1 and L2 regularization as well as tree complexity regularization.

$$\hat{y}_i = \emptyset(x_i) = \sum_{k=1}^{n} f_k(x_i) + \sum_{k=1}^{n} J(f_k)$$

2.5. Hyperparameter

In machine learning, hyperparameters are external configuration settings that dictate a model's behaviour. They govern how the model learns from and generalizes to data. Improper selection can lead to suboptimal results, such as lower accuracy or ineffective confusion matrices. Therefore, careful selection of hyperparameters is crucial for achieving optimal model performance. Our experiment record for defining model behaviour illustrates in Figure 4.

Hyperparameter	Value
k_estimator	130
learning_rate	0.1
subsample	1
reg_lambda	1
early_stopping_rounds	15

Figure 4. Parameters that are set for experiment

III. Result

The performance of the model has been assessed with four various metrics: accuracy 91.66 %, precision 91.91%, Recall 91.66% and F1-Score 91.65 %, as you can see in the table below. Based on the table, our model achieved over 90% across all metrics on unseen data, even though it was trained on a small dataset of only 562 images, consisting of both abusive and non-abusive examples. The reason for this result is that our model was trained on a small and unbalanced dataset compared to previous research, without using any methods to increase its size or balance out its content. However, this demonstrates the model's effectiveness in spite of limited and unbalanced training data. Moreover, the combination of CNNs and XG-Boost model represents a dynamic solution. The model can adapt and improve over time through regular find-tuning and updates. This ensures the model remains effective against evolving abuse tactics, allowing it to keep pace in the face of the ever-changing nature of online content.

Metrics	***Accuracy***	***Precision***	***Recall***	***F1-Score***
XGBClassifier	***0.9166***	***0.9191***	***0.9166***	***0.9165***

IV. Conclusion

The proposed hybrid model achieved a promising result in classifying abusive and non-abusive images despite being trained on a small dataset of only 562 images and the nature of complexity pattern in abusive images. With this result, we can conclude that the model effectively learned the distinguishing features between different categories within the data. The authors hope that this paper this work will serve as a valuable resource and inspiration, sparking a significant interest in abusive image classification application, which can safeguard the dignity of our leaders and create safer and healthier digital environments in our country.

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TECHNOLOGY TRENDS

Effect of Endo-Xylanase Supplementation in Broiler Chicken Diets: A Prebiotics Approach to Improve Digestibility, Gut Microbiota and Growth Performance

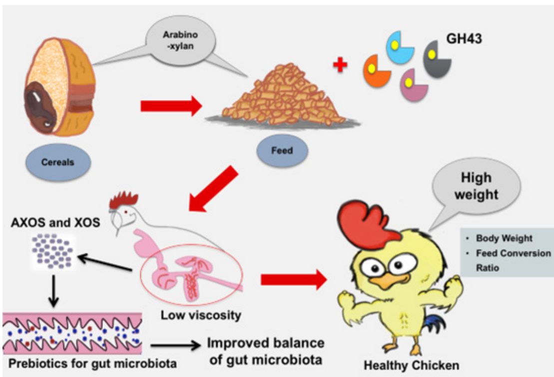
5

Sorn Virak
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi (KMUTT), Thailand

San Techly
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi (KMUTT), Thailand

Highlight

- Enzyme endo-xylanases are shown to reduce intestinal viscosity.
- The addition of endo-xylanases in the animal feed improves overall digestibility rates of digesta.
- Supplementation of endo-xylanase leads to balance in gut microbiota manifesting as healthy broiler chickens.
- The activities of endo-xylanases improved the growth performance of broiler chicken.



Graphical Abstract. Effects of enzyme supplementation on chicken health.

I. Introduction

Several dietary components are the predisposing factors when regulating broiler performance, digestive, microbial, and health outcomes (Gangadoo et al., 2016). Feed ingredients are selected overall for nutrient delivery but also provide the absence of anti-nutritional or toxic factors, palatability, feed intake effect, and cost. Poultry requires amino acids from proteins, vitamins, and minerals for primary nutrients, while also requiring energy from lipids, proteins, and starches (Ravindran et al., 2016). Nutritional balance and quality are crucial for broiler chickens, as nutritional changes can lead to diseases like hepatic steatosis and spike mortality syndrome (Kumari et al., 2016). However, previous research indicates extensive interactions between poultry hosts and their gut microbiome, involving nutrient exchange, gut morphology, physiology, and immunity (Pan & Yu, 2014). Therefore, in this article, we will discuss the potential benefits of supplementing endo-xylanase in broiler diets, focusing on its impact on digestibility, gut health, and broiler chicken performance by decreased viscosity of digesta.

II. Cereal Grain and Arabinoxylans

Cereals are the most important food crops in the world, and cereal products are the most important of these food sources. Cereal grains (rice, barley, oats, millet, sorghum, and maize) constitute major sources of dietary energy and protein for humans and livestock (Guerrieri & Cavaletto, 2018). Cereal fibers, composed of carbohydrate polymers resistant to digestion in monogastric animals' small intestines, are believed to stimulate gut health by being fermented in the distal gut (Mendis et al., 2016). The main fraction of cereal fiber is composed of arabinoxylans (AX), pectins, resistant starch, cellulose, β-glucans, ash (mineral), and high levels of enzymes, vitamins, and globulin storage proteins (Figure 1).

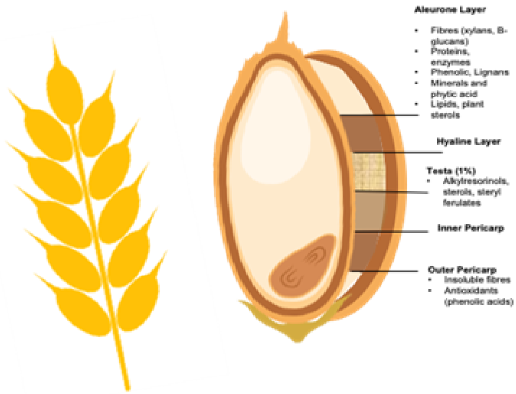


Figure 1. Schematic to show the structure of a cereal seed. The hairs of the brush contain pentose (hemicellulose) and hexose (cellulose). Endosperm, rich in starch, oils, and protein, is a crucial component of animal diets due to its nutritional value.

AX from different sources differs in its substitution along the xylan backbone. AX consists of a backbone of β-(1,4)-linked xylose residues, which are substituted with arabinose residues on the C(O)-2 or C(O)-3 positions in general structure. The structure of AX polymer and enzymes involved in its degradation are shown in Figure 2. Therefore, cereals offer a high abundance and an inexpensive source of proteins, which are critical nutritional and functional ingredients in food if the broiler is subjected to this type of nutrition (Zou et al., 2019). The improvement of the water-solubility properties of the cereal protein in the digestive system of broiler chicken is the most important need for enzymes involved in this process (Zhang et al., 2015). While we are focused on broiler chickens, the ratio of AX:Xylose has also been shown to affect retention times of digesta in pigs, thereby regulating and promoting a healthy digestive system (Zou et al., 2019).

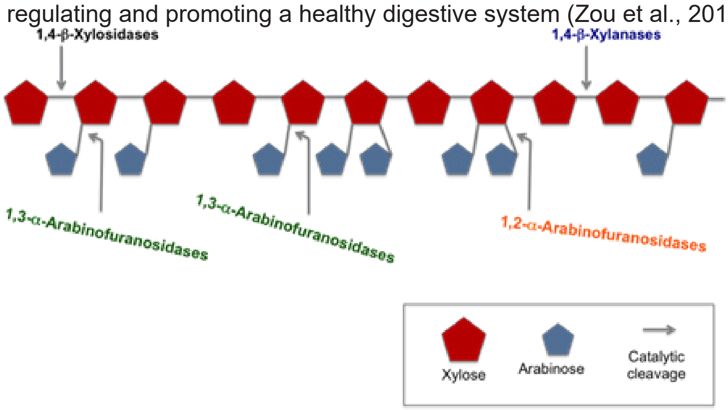


Figure 2. Schematic to show the structure of wheat arabinoxylan; adapted from (Mechelke et al., 2017)

III. Digesta Viscosity

Viscosity refers to the internal fluid resistance of a substance, conceptualized as being glutinous, thick, syrupy, or sticky. In poultry, particularly with broiler chickens, viscosity is a significant concern. AX polymers in cereals can increase digesta viscosity, thereby reducing nutrient digestibility and feed efficiency. Enzyme xylanases play a crucial role in decreasing intestinal viscosity by hydrolyzing wheat non-starch polysaccharides (NSPs), leading to improved nutrient uptake and growth performance (Lei et al., 2016). The supplementation of xylanase in wheat-based diets has shown positive effects on immunity, reduced bacterial species, and alleviated intestinal mucosal barrier impairment in broiler chickens (Liu et al., 2012). Notably, enzyme xylanase activity is inhibited by viscous digesta compared to NSP in the upper digestive tract system. Consequently, this inhibition results in a decrease in digesta viscosity in the small intestine, eliminating the nutrient-encapsulating effect on cell wall polysaccharides, which are known to release the enclosed nutrients (Lei et al., 2016). It was found that supplementation of xylanases and debranching enzymes of glycoside hydrolases family 43 (GH43) in a wheat-based diet showed a significant reduction in viscosity between 30-70% (Figure 3), respectively.

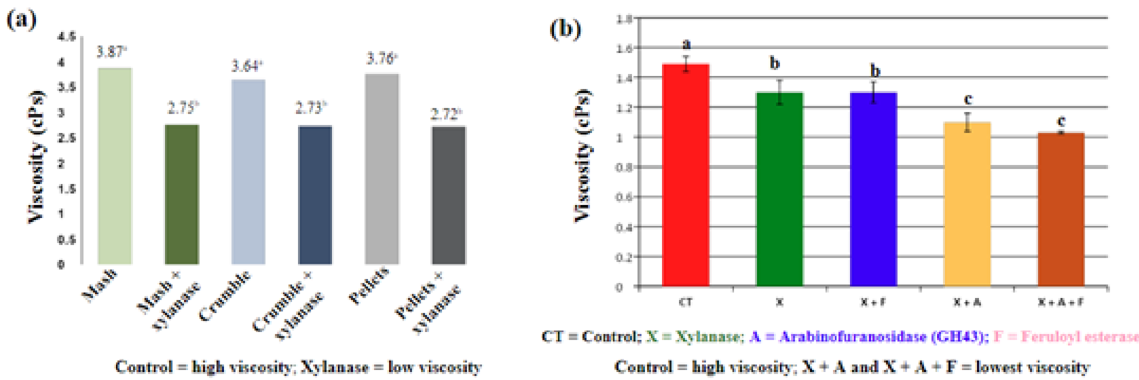


Figure 3. (a) Effects of xylanase enzyme on viscosity of jejunal digesta of broilers (42 days of age), adopted from (Hosseini & Afshar, 2016), (b) Effects of enzymes on gut viscosity of broilers on (36 days of age), adopted from (Lei et al., 2016).

IV. Xylanases

Xylanases and arabinofuranosidases are enzymes involved in the degradation of plant cell wall components, specifically xylan and AX. They cleave AXs by hydrolyzing the 1,4-β-d-xylosidic linkage. The degradation pattern varies, resulting in various products. Endo-β-1,4-xylanases GH10 degrade AX with high substitution, while GH11 xylanases cleave unsubstituted regions. GH43 hydrolyzes the 1,3 or 1,2-β-d-xylosidic linkage between arabinose residues in the xylan backbone. Additionally, 1,3 or 1,2-β-d-arabinofuranosidases help reduce the substitution degree of AX polymer to the smallest structure, which functions as a prebiotic (Goncalves et al., 2015).

V. Xylan Hydrolysis Product as Prebiotics

Enzymatic hydrolysis of AX results in the production of xylooligosaccharides (XOS) and arabinoxylan-oligosaccharides (AXOS) (Figure 4). AXOS and XOS exert prebiotic effects in the colons of humans and animals through the selective stimulation of beneficial intestinal microbiota. Prebiotics are non-digestible food ingredients that stimulate the growth and activity of specific intestinal bacteria (Singh et al., 2021). They must be non-aggressive to gastric acidity and mammalian enzymes, susceptible to fermentation by the gut microbiota, and able to restore beneficial bacteria. Prebiotics increase the composition of intestinal bacterial populations, leading to improved immune responses and lower feed conversion ratios. The fermentation of prebiotics by colonic bacteria produces short-chain fatty acids (SCFA), which lower pH, improve calcium and magnesium bioavailability, and inhibit harmful bacteria (Singh et al., 2021; Yacoubi et al., 2018).

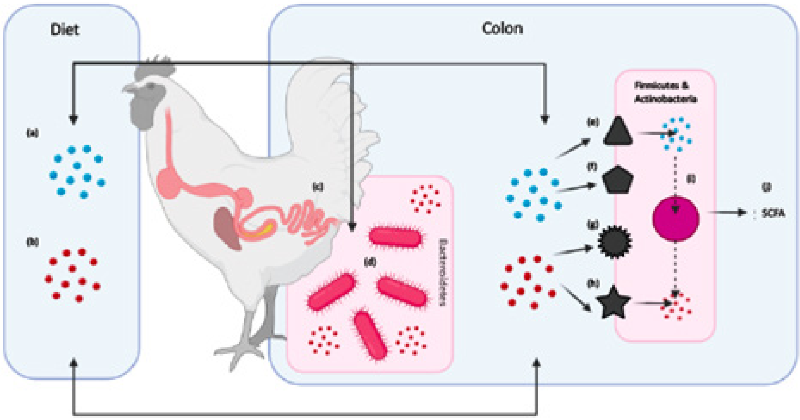


Figure 4. Concept of AX and the hydrolysis to AXOS to produce SCFAs

whereas

(a) AX intake in the diet, (b) AXOS intake through diet, (c) starch utilization encoded by polysaccharide utilization loci, (d) depolymerization pathway using bacteroidetes, (e) ATP-binding cassette transporters, (f) cation transporters, (g) major transporters, (h) PEP-phosphotransferase transporters, (i) arabinofuranosidase and xylosidase, and (j) SCFA – short chain fatty acids.

VI. Gut Microbiota and Chicken Health

Gut microbiota plays a critical role in broiler health, influencing gastrointestinal development, biochemistry, immunology, and infection resistance. In poultry, gut microbiota forms a synergistic relationship with the host, impacting energy and nutrient utilization. Inadequate gut microbiota can lead to immune regulation loss, pathogenic overgrowth, and inflammation, resulting in dysbiosis. Lactobacilli and probiotic bacteria can reduce inflammatory responses, highlighting the importance of gut microbiota in health (Lei et al., 2016; Singh et al., 2021). In broiler chickens, feed additives, including prebiotics from enzymatic hydrolysis, are widely used to improve gut health and stimulate performance (Figure 5).

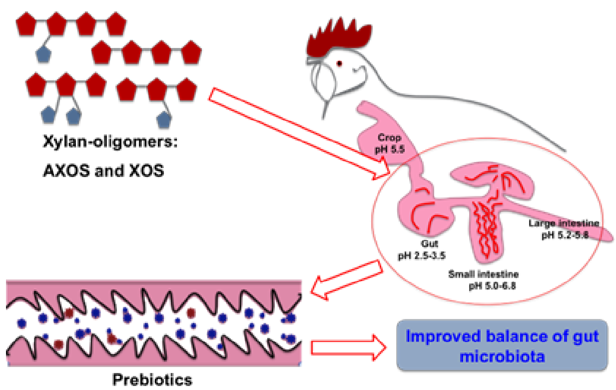


Figure 5. Effect of prebiotics on the gut microbiota of broiler chickens.

The previous findings indicate that GH43 leads to a lower viscosity, which increases substrate availability, therefore increasing the prebiotic effects and the resultant gut microbiota proliferation (Yacoubi et al., 2018). Quantification of SCFAs in the ceca of the broiler gut fed with GH43 xylanases showed an increased concentration of butyrate (Table 1), which might be responsible for improved immune health and therefore may explain better feed intake and feed conversion ratio (FCR) (Table 2, Figure 6).

Table 1. Effects of enzymes on lactic, acetic and butyric acids concentrations (μM) in the ileal and cecal (14 days of age), adopted from (Yacoubi et al., 2018).

Gastrointestinal Tract	Parameters	Wheat Control	Wheat + Enzymes
Ileum	**Total SCFA**	$21.1^{a} \pm 2.3$	$21.4^{a} \pm 1.9$
	Acetate	$1.6^{b} \pm 0.4$	$1.8^{a} \pm 0.3$
	Lactate	$19.5^{a} \pm 2.2$	$19.7^{a} \pm 2.0$
	Butyrate	$< 0.1^{a}$	$< 0.1^{a}$
Cecum	**Total SCFA**	$39.4^{b} \pm 2.5$	$65.6^{a} \pm 5.6$
	Acetate	$30.6^{b} \pm 2.1$	$49.7^{a} \pm 4.9$
	Lactate	$2.5^{b} \pm 0.3$	$3.7^{a} \pm 0.5$
	Butyrate	$5.3^{b} \pm 0.6$	$10.2^{a} \pm 1.0$

Note: Wheat with enzymes has a high amount of SCFA, lactic, butyric and acetic acids.

Table 2. Effects of xylanase on growth performance of broilers, adopted from (Zhang et al., 2014).

Description		Control	Xylanase	SEM	p-value
Initial body weight (g/bird)		122.3	**122.5**	0.74	0.982
7 to 21 days	Body weight gain (g/bird)	498.9	**528.4**	4.91	0.029
	Feed intake (g/bird)	798.2	**803.2**	12.95	0.953
	Feed conversion ratio	1.60	**1.52**	0.03	0.048

Note: The supplementation of enzyme xylanase caused increased body weight gain by 5.9% and improved FCR by 5.3%, respectively.

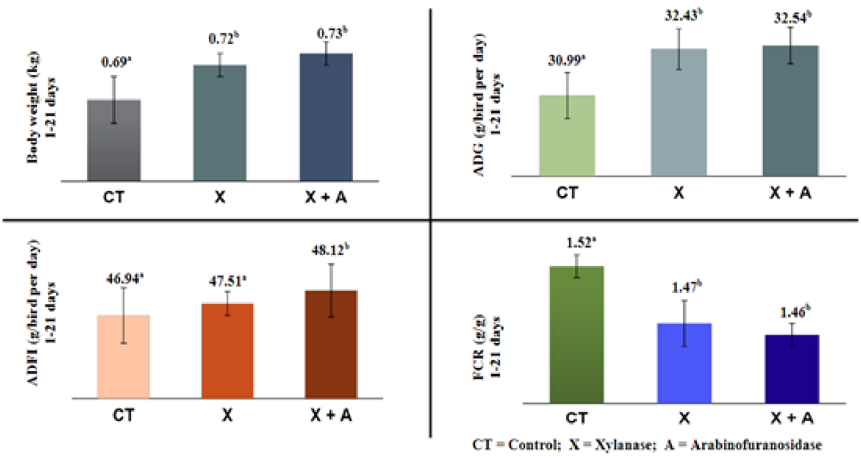


Figure 6. Effects of GH43 enzymes on the growth performance of broilers, adopted from (Lei et al., 2016).

VII Conclusion

In conclusion, the supplementation of endo-xylanase emerges as a promising strategy for improving the gut health of broiler chickens. This is attributed to its ability to promote colonization, protect the intestinal barrier, and reduce the growth of pathogenic bacteria. Endo-xylanase contributes to overall broiler performance through its prebiotic effects on gut microbiota, decreased digesta viscosity, enhanced nutrient uptake, and improved average daily growth.

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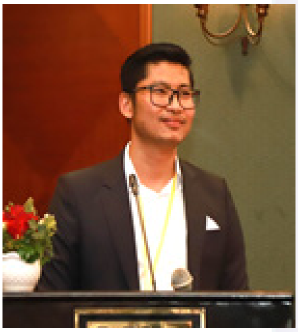


Mr. Sorn Virak currently serves as a Foundation Year Program Coordinator and researcher at the Department of Foundation Year, Faculty of Health Science and Biotechnology, University of Puthisastra (UP). He earned his M.Sc. in Biochemical Technology from King Mongkut's University of Technology Thonburi in Thailand in 2019 and holds a B.Sc. in Biology from the Royal University of Phnom Penh in Cambodia in 2016. His research focuses on the application of enzymes in food technology, pretreatment technology of agricultural residue for bioproducts and renewable energy production, as well as science and health science education at higher education levels. His work also addresses key issues and challenges to improving Cambodia's research culture. He has published several research articles on pretreatment, enzyme technology, and science and health science education in Cambodia. Additionally, he serves as an associate editor for the Cambodian Journal of Education Research and Cambodian Education Forum in Cambodia.

Potential Use of Laccases in Biodegradation and Detoxification Dyes in Textile Wastewater: A Green Approach for Wastewater Treatment in Cambodia

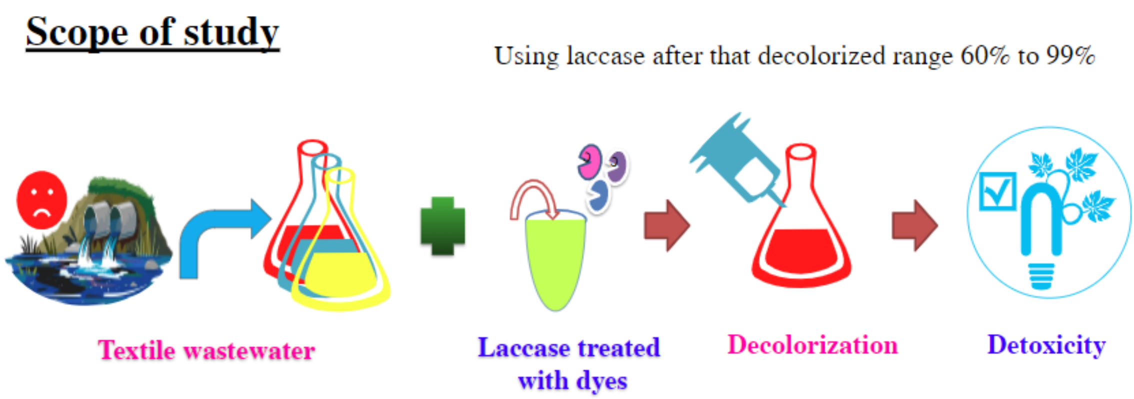
6

San Techly
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi
(KMUTT), Thailand

Sorn Virak
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi
(KMUTT), Thailand

Highlight

- Laccases can effectively decolorize textile synthetic dye effluent.
- The use of laccases as a green biocatalyst shows promise for decolorization and detoxification of textile effluent.
- Laccase-catalyzed degradation mechanisms of the synthetic dyes have the potential to degrade the toxicity of wastewater.
- Highlights the potential use of laccases as a green approach to treat textile wastewater in an environmentally friendly manner in Cambodia.



Graphical Abstract: Effect of laccases application for wastewater treatment and dye decolorization.

I. Introduction

The textile industry is vital to Cambodia's economic landscape. At the same time, wastewater disposal from textile production processes poses serious environmental concerns. Synthetic dyes are widely used in various industries, such as textiles, food, cosmetics, and pharmaceuticals (Figure 1) (Forootanfar et al., 2016). Dye wastewater from the textile industry is estimated at 2,800,000 tons per year (Yang et al., 2017), affecting human health, aquatic ecosystems, and environment (Abd El-Rahim et al., 2017). Traditional treatment methods are often associated with drawbacks. Laccases can be found in fungi, plants, insects, and bacteria; they belong to the blue multicopper oxidases (Figure 2) (Liang et al., 2017). Laccases, with their unique characteristic of degrading phenolic and polyphenolic aromatic compounds (Sharma et al., 2015), offer a promising alternative for the biodegradation and detoxification of dyes in textile wastewater. Therefore, this review aims to provide a better understanding of the effects of laccases used in wastewater treatment containing synthetic dyes.

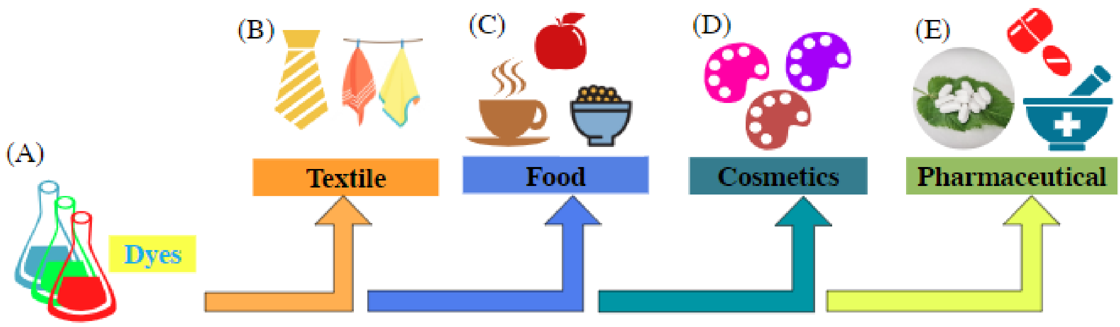


Figure 1. Use of dyes in various industries. (A) dyes; (B) textiles; (C) food; (D) cosmetics; and (E) pharmaceuticals.

II. Laccases

what are laccases and their applications in wastewater treatment?

Laccases are copper-containing enzymes widely distributed in nature (Figure 2), known for their ability to oxidize a variety of organic compounds. They are capable of transferring four electrons from four reducing substrate molecules to one oxygen molecule, which is their unique characteristic for degrading phenolic and polyphenolic aromatic compounds, including synthetic dyes, with no requirement for cofactors, producing water as the only byproduct (Liang et al., 2017).

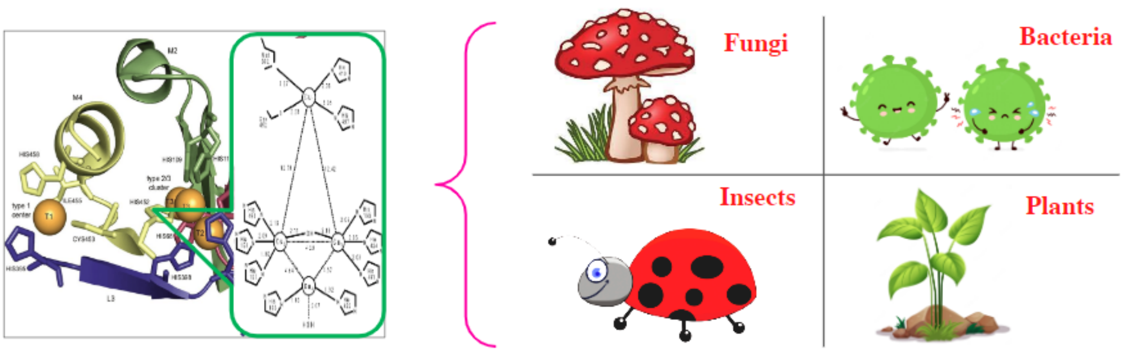


Figure 2. The molecular arrangement of the copper atoms in the active site of laccase (Liang et al., 2017; Rivera-Hoyos et al., 2013).

Synthetic dyes are complex aromatic compounds used in textiles that were classified into 4 groups, including azo dye, anthraquinone, triphenylmethane, and indigo dyes. Nowadays, more than 100,000 different dyes are used in textiles (Yang et al., 2017). However, the azo dye residues found in textile industry wastewater have a detrimental effect on the majority of environmental systems due to its making up the majority of synthetic dyes; more than 60% of all dyes are in this class (Ayed et al., 2011). Using laccase-based wastewater treatment emphasizes reducing chemical usage, energy consumption, and overall environmental impact in Cambodia (Abd El-Rahim et al., 2017; Chen et al., 2018; Liang et al., 2017). There is also a discussion of the possibility of financial rewards from sustainable activities.

III. Mechanisms of Laccase-Mediated Synthetic Dye Degradation

Laccases catalyze the oxidation of dyes, breaking down complex structures into simpler ones, resulting in less harmful components. The involvement of free radicals and the role of mediators in enhancing laccase efficiency are also explored. However, mechanisms of malachite green (MG) dye: the first pathway starts with demethylation of MG followed by degradation or polymerization of MG for chromophore destruction. In the second pathway, MG is first hydroxylated to its carbinol form, which is quickly broken down (Fisher et al., 2011). Azo dye degradation by laccase cleavage of the azo bond (-N=N-) is oxidative (Figure 3) (Forootanfar et al., 2016).

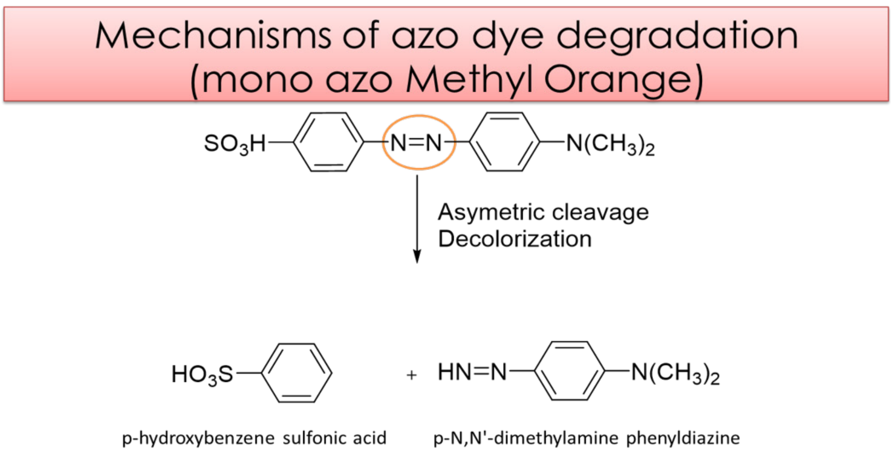


Figure 3. Example of decolorization of dyes by laccases; adopted from (Forootanfar et al., 2016).

However, without a redox mediator, the degradation of MG by laccase is still toxic (Figure 4). In the presence of a redox mediator, the mechanism of action of laccase on a dye such as malachite green (MG) began with the demethylation of MG, followed by degradation or polymerization of MG, resulting in chromophore destruction.

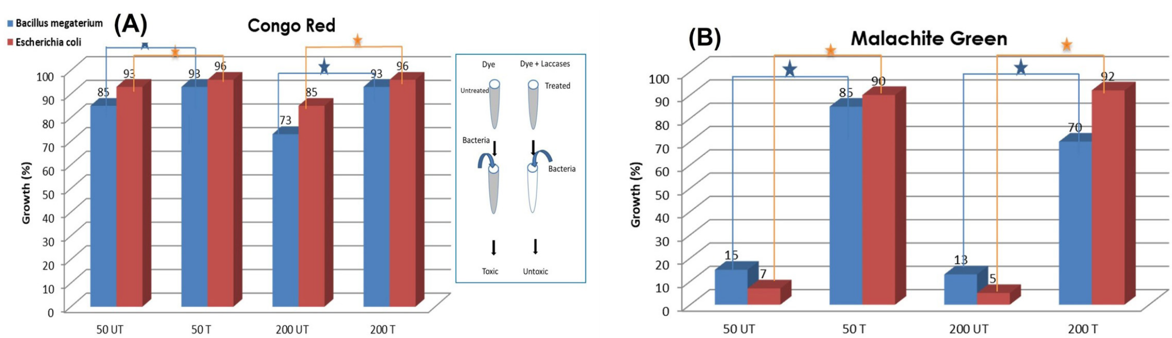


Figure 4. Microtoxicity test by determining bacterial growth (A) Congo Red, and (B) Malachite Green; adopted from (Forootanfar et al., 2016).

Alternatively, in the presence of different mediators, MG was first hydroxylated to its carbinol form and then rapidly broken down (Figure 5). Laccases in the presence of mediators efficiently decolorize dyes such as MG (87.8%), bromocresol purple (71.6%), and methyl violet (68.1%) (Chen et al., 2018; Chmelová & Ondrejovič, 2016; Sharma et al., 2015).

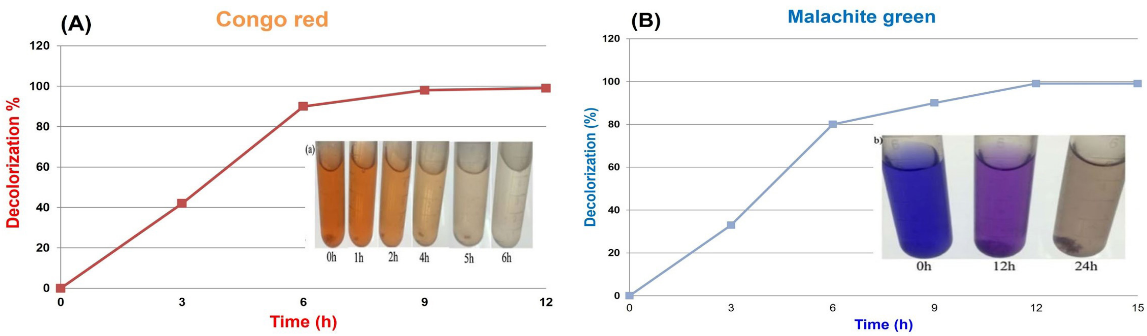
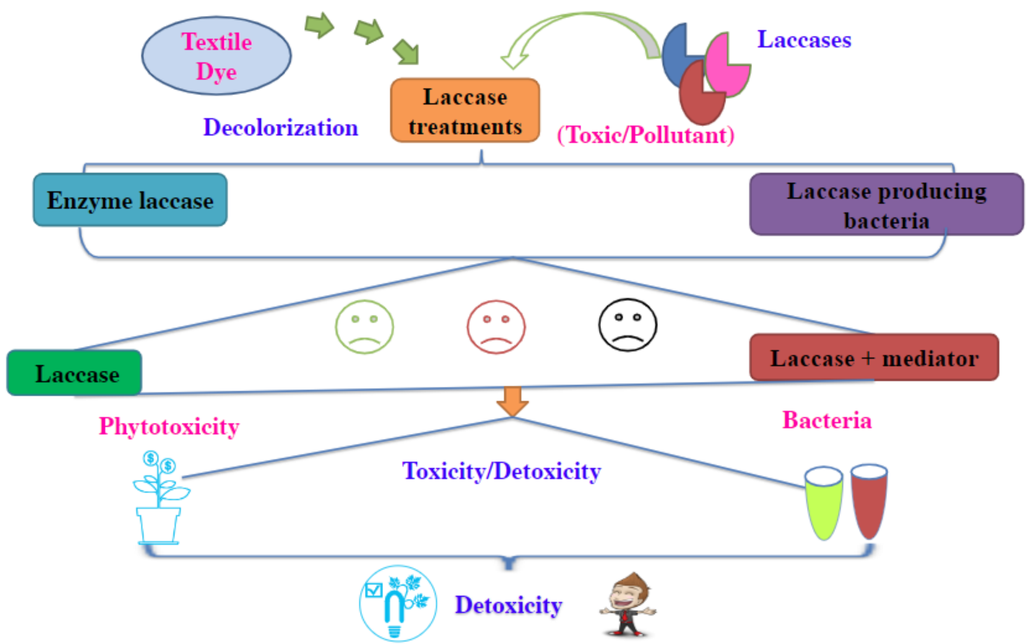


Figure 5. Decolorization of synthetic dyes (A) Congo red and (B) Malachite green; adopted from (Ma et al., 2017).

IV. Conclusion

In conclusion, laccases can effectively decolorize textile synthetic dye effluent. Using laccases as a green biocatalyst shows promise for the decolorization and detoxification of textiles into lower-toxicity metabolites. Overall, laccase-catalyzed degradation mechanisms of the synthetic dyes have the potential to degrade the toxicity of wastewater. This highlights laccases as a green approach for treating textile wastewater in an environmentally friendly manner in Cambodia.



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Mr. San Techly is currently a full-time foundation year lecturer and researcher at the Department of Foundation Year, Faculty of Health Science and Biotechnology at the University of Puthisastra (UP). He holds a Master of Science in the field of Biochemical Technology (International Program) under the research title "Characterization of a putative endo-1,4-β-glucanase from *Clostridium* sp. Z-7026" in Enzyme Technology Laboratory, Division of Biochemical Technology, School of Bioresources and Technology, from King Mongkut's University of Technology Thonburi in Thailand in 2019 and a Bachelor of Science in the field of Biology from the Royal University of Phnom Penh (RUPP) in Cambodia in 2016. His research focuses on the characterization of enzymes from plants, bacteria, fungi, and insects and the application of those enzymes in wastewater treatment and food technology. He has published several research articles in national and international journals related to his interest in enzyme technology.

A Review on Deep Learning Algorithms for Hand Gesture Recognition in Higher Education

7

Long Pakrigna
PhD Candidate
Electrical and Electronic Engineering
Universiti Kuala Lumpur, Malaysia

Samok Ponloeu
Master of Science
Computer Science
University of East London, United Kingdom

Toch Ensophea
Dual Major: Bachelor of Science
Computer Science & Data Science,
ACLEDA Institute of Business & TUX Global Institute,
Cambodia

Highlight

- Hand gesture recognition has emerged as a prominent area of research in higher education, driven by the potential to revolutionize learning experiences.
- This paper delves into deep learning algorithms for hand gesture recognition and their applications in educational settings.
- It aims to provide a critical analysis of existing literature, while also offering fresh perspectives on this evolving field.


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I. Historical Context

Overview of Hand Gesture Recognition in Higher Education:

Traditionally, higher education relied on conventional teaching methods, such as lectures and textbooks. However, advancements in technology have paved the way for more interactive and engaging learning experiences. Hand gesture recognition systems have emerged as a promising technology to facilitate natural and intuitive human-computer interaction in educational environments.

Introduction of Deep Learning Algorithms:

Deep learning algorithms have revolutionized the field of hand gesture recognition by enabling the development of highly accurate and robust models. With the advent of deep neural networks, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), researchers have achieved significant advancements in recognizing and interpreting hand gestures with high precision.

II. Current Landscape of Deep Learning Algorithms for Hand Gestures in Higher Education

Deep Learning Techniques for Hand Gesture Recognition:

• Convolutional Neural Networks (CNNs): These algorithms excel at automatically extracting features from hand images or videos, making them well-suited for gesture recognition. CNNs typically consist of convolutional layers that learn these features and pooling layers that downsample the data for improved efficiency. (Zhang et al., 2020) (https://www.mdpi.com/1424-8220/23/1/2)

• Recurrent Neural Networks (RNNs): RNNs are particularly effective in recognizing dynamic gestures involving sequences of hand movements. A specific type of RNN, Long Short-Term Memory (LSTM) networks, are well-suited for this task due to their ability to learn long-term dependencies within gesture sequences. (Xu & Yang, 2023) (https://www.mdpi.com/2504-2289/7/2/102)

Applications in Higher Education:

• Virtual Reality (VR) and Augmented Reality (AR): VR and AR applications can leverage hand gestures for enhanced learning experiences. Imagine virtual labs where students manipulate objects using hand gestures or interactive simulations where students interact with virtual environments through hand movements.

• Smart Classrooms: Smart classrooms can integrate hand gesture recognition for various purposes. Students could use gestures to interact with interactive whiteboards, participate in response systems by raising virtual hands, or control presentations through hand movements.

• Online Learning Platforms: Online learning platforms have the potential to incorporate hand gestures for navigating learning materials, participating in discussions through virtual hand raising or hand gestures signifying agreement/disagreement, or providing feedback through specific hand gestures.

III. Factors Driving the Adoption of Deep Learning Algorithms in Higher Education

Advancements in Deep Learning: The advancements in deep learning algorithms, particularly CNNs and RNNs, have played a crucial role in driving the adoption of hand gesture recognition in higher education. These algorithms have demonstrated remarkable accuracy and robustness, making them suitable for complex gesture analysis and interpretation.

Demand for Interactive Learning Experiences: The increasing demand for interactive and immersive learning experiences among students has fueled the adoption of deep learning algorithms for hand gesture recognition. These algorithms enable students to interact with educational content in a natural and intuitive manner, enhancing their engagement and understanding.

IV. Challenges and Opportunities

Dataset Availability and Annotation: One of the major challenges in the development of deep learning algorithms for hand gesture recognition in higher education is the availability of annotated datasets. Collecting and annotating large-scale datasets with diverse hand gestures can be time-consuming and resource-intensive.

Real-Time Performance: Real-time performance is another significant challenge in deploying deep learning algorithms for hand gesture recognition in educational settings. Achieving low-latency and high-speed processing is crucial to ensure seamless interaction and responsiveness in real-time applications.

Ethical Considerations: When using hand gesture recognition systems in educational settings, potential concerns regarding data privacy and collection practices should be addressed. Ensuring informed consent and responsible data handling is crucial. (Romero et al., 2021) (https://link.springer.com/10.1007/978-3-319-17727-4_193-2)

Bias in Algorithms: Deep learning algorithms can inherit biases from the data they are trained on. This raises concerns about the accuracy of gesture recognition for diverse student populations. Mitigating bias through careful data selection and algorithm design is critical.

Opportunities:

• Enhanced Interactive Learning Experiences: Deep learning algorithms for hand gesture recognition present exciting opportunities to create more interactive learning experiences in higher education. By leveraging these algorithms, educators can develop immersive virtual reality (VR) and augmented reality (AR) applications that enable students to interact with virtual objects and simulations using natural hand gestures. This ability to interact with the learning environment in a more intuitive way can lead to a more engaging and ultimately more effective learning experience for students.

• Personalized Learning: The utilization of deep learning algorithms for hand gesture recognition opens up possibilities for personalized learning experiences. These algorithms can be used to analyze and interpret individual students' gestures, allowing for tailored feedback, adaptive learning paths, and personalized educational content. For instance, hand gesture recognition could be used to identify students who are struggling with a concept and provide them with additional support or resources.

V. Benefits for Students with Disabilities

Hand gesture recognition technology has the potential to offer significant benefits for students with disabilities. For students who may have difficulty using traditional input methods like keyboards or mice, hand gesture recognition can provide an alternative and potentially more accessible way to interact with educational technology. This can promote greater inclusion and participation in the learning process for students with disabilities.

VI. Comparison with Traditional Methods

Traditional human-computer interaction methods, such as keyboards and mice, have served education well for many years. However, hand gesture recognition technology offers several potential advantages:

• Natural and Intuitive: Hand gestures can be a more natural and intuitive way to interact with computers, especially for complex tasks that require multiple clicks or keystrokes.

• Increased Engagement: The ability to interact with educational content using hand gestures can lead to increased student engagement and motivation.

• Accessibility: As mentioned earlier, hand gesture recognition can provide an alternative input method for students with disabilities.

However, it is important to acknowledge that traditional methods also have some advantages:

•Universality: Keyboards and mice are universally recognized and understood, while hand gesture recognition systems may require some learning.

• Accuracy: Traditional input methods can be very accurate, especially for tasks like typing text. While hand gesture recognition accuracy is improving, it may not yet be suitable for all situations.

Ultimately, the best approach may be a combination of traditional methods and hand gesture recognition, depending on the specific educational context and learning goals.

VII. Conclusion and Future Outlook

This paper has provided a comprehensive review of deep learning algorithms for hand gesture recognition in higher education. It has explored the historical context, current applications, driving factors, challenges, and opportunities associated with this technology. The paper also highlighted the potential benefits for students with disabilities and compared hand gesture recognition with traditional input methods. Finally, it discussed future research directions and emphasized the importance of ethical considerations.

Deep learning algorithms hold immense potential to revolutionize the way students interact with learning materials and educators in higher education. By addressing the existing challenges and ensuring responsible development, hand gesture recognition technology can contribute to creating a more engaging, interactive, and personalized learning experience for all students.

Future Research Directions

Several exciting avenues exist for future research in this field:

• Deep Learning Architectures: Exploring new deep learning architectures specifically designed for hand gesture recognition tasks.

• Sensor Technologies: Investigating new sensor technologies that can capture hand gestures with greater accuracy and detail.

• Personalization Techniques: Focusing on developing personalization techniques to adapt gesture recognition to individual student needs and learning styles.

Ethical Considerations

As this technology continues to evolve, it is crucial to consider the ethical implications of its use in educational settings. Data privacy, informed consent, and responsible data handling practices must be prioritized to ensure the ethical and responsible development and deployment of hand gesture recognition systems.

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Mr. Long Pakrigna is a passionate technology lecturer in Phnom Penh. He holds a Master of Engineering in Computing Engineering Systems from King Mongkut's Institute of Technology Ladkrabang, Thailand. He has a dual bachelor's degree; in Computer Science from National Polytechnic Institute of Cambodia and Informatics Engineering from STMIK IKMI Cirebon, Indonesia. Currently, he is a PhD candidate at the Universiti Kuala Lumpur, majoring in Electrical and Electronic Engineering. In addition to his qualification and current position, he used to be an IT officer, IT Programmer, IT Supervisor in Phnom Penh, and a data analyst in Kuala Lumpur. His research and development interests are Natural Language Processing, Data Science, Robotics, IoT and Renewable Energy.

EDUCATION & CAREERS

Nurturing Computational Thinking through Education: A Fusion of Coding and STEM as a 21st Century Skill

8

Chan Raksmey
Master's Degree
Social and Solidarity Economy
Lumière Lyon 2, France

Chey Nalin
Postgraduate Diploma
Economics and Finance, Royal School of Administration, Cambodia

Highlight

- "The Changing Winds and Shifting Sands" can be referred to the shift of learning curriculum in the 21st century to a four-interdisciplinary focus —Science, Tech, Engineering, Mathematics — known as STEM.
- STEM empowers students to make sense of the real world and enhances creativity, critical thinking, and metacognitive whereas coding encourages innovative, analytical thinking, and problem-solving skills.
- A fusion of coding and STEM education nurtures computational thinking of learners, enables them to practically hands-on STEM disciplines through project-based learning, and paves way for STEM career paths.

I. Introduction

You are awakened in the morning to the sound of an alarm clock from your smartphone, followed by a glance at your wristband to check last night's sleep cycle. On the way to school, you book a rickshaw from the mobile app and pay the fee seamlessly via a QR code. What you may not realize is most of your daily activities are powered by technology and programming. Without it, the routine would regress to difficulties in many last decades.

Therefore, learning curriculum has shifted its focus due to technological development in the 21st century that can be put as "The Changing Winds and Shifting Sands". Cambodia has transitioned from traditional learning and teaching approaches to a four-interdisciplinary focus — Science, Tech, Engineering and Mathematics — known as STEM, enabling students to make sense of the real world and enhancing creativity, critical thinking, metacognitive, and problem-solving skills (MoEYS, 2019). This development responds to the mass demand of the industrialized economy and job market, where scientific and technological skills are essential. Additionally, coding is becoming increasingly important in the digital world, as it helps nurturing learners' hard skills and cognitive skills. Hence, this paper will delve into the benefits of the synthesis of STEM education and coding, followed by exploring Cambodia's progress, and a way forward.

II. Methodology

The paper employed qualitative research methods by using exploratory and interpretivist approaches aiming to shed more light on the fusion of STEM education and coding. Hence, secondary data on coding, STEM learning curriculum, and recent reports on employability skills and NGS were selected for perusal and analysis.

III. Roles of the Fusion of Coding and STEM Education

1. Nurturing Students' Computational Thinking

Coding, a vital subject in STEM, allows students to practice and familiarize with software building and application. Through coding, students acquire a set of skills including problem-solving, communication, and teamwork. Learners also have full freedom to experience, iterate, refine projects, and break down problems, which becomes a tool of expression bringing their creativity into life.

Integrating coding into STEM curriculum goes beyond simply enhancing students' abilities in science subjects; it also stimulates a concentralization known as Computational Thinking — a skill that learners develop through their imagination and application-building processes. Coding cultivates this thinking for students as they approach problems in chunks, and then break down large tasks into smaller solvable pieces. Throughout the process, students cannot rely solely on click-and-drag methods; instead, they must scrutinize their instructions, correcting syntax errors as part of debugging. Learners are encouraged to identify patterns among problems, dealing with tasks such as reduction, embedding, transformation, and simulation until reaching the final desired outcomes (Flórez et al., 2017). These repetitive processes of identifying problems and finding solutions ultimately nurture the computational thinking of learners to advance in the real world.

2. Foster Experiential Learning of STEM Disciplines

STEM education emphasizes on boosting students' interests and engagement in scientific disciplines while coding encourages innovative, analytical thinking, and problem-solving skills. With STEM-based coding education, students learn coding and apply it into STEM disciplines through engineering design, mathematical modeling, data analysis, and simulations in practical project topics (Güleryüz, 2023; Texas Education Agency, 2023). For instance, Automation and Robotic education is a combination of STEM disciplines including mathematics and engineering with coding. Students use coding to program robots and automated systems to create simulations to perform tasks in projects related to healthcare, manufacturing, agriculture, etc., (Curaoglu & Konyaoglu, 2023; Goh & Ali, 2014). Educational robotics include Ozobot (age 5-18), Photon robot (age 5-12), Edison robot (age 4-16), and Lego Mindstorms Education EV3 (age 10-16) (Moraiti et al., 2022). Through these, students can start engaging practically in color coding from an early age to initiate practical STEM-based coding projects to explore and solve problems in their interested fields which can further spark their curiosity and interest in STEM careers.

3. Career Prospects for Learners through STEM-based Coding Education

The future work is changing at a fast pace with the adoption of 21st century cutting-edge technologies. Important skills needed for future jobs include both technology skills, and analytical and creative thinking (Figure 1&2). Technology skills in big data, AI, encryption, and cybersecurity are necessary whereby over 75% of companies are expecting to adopt them in the next five years. Noticeably, AI and Machine Learning specialists are projected to be one among the fastest growing jobs from 2023 to 2027 (Figure 3). Analytical and creative thinking remain indispensable skills needed in 2023 and continue to be top skills required in approximately next five years (WEF, 2023). Due to increasing demands in technology and cognitive skills to fit the future job trend, nurturing learners through integration of STEM and coding is increasingly significant. The synthesis of both enables students to hands-on practice of STEM disciplines through project-based learning and; therefore, cultivates computational thinking, creative and innovative thinking which are essential in STEM career pathways. Notably, students have career prospects in bioinformatics from coding in science education; in AI, Machine Learning, Web development, and prototyping through coding in technology and engineering education; and in cryptography including secure encryption and decryption from coding in mathematics education (Texas Education Agency, 2023).

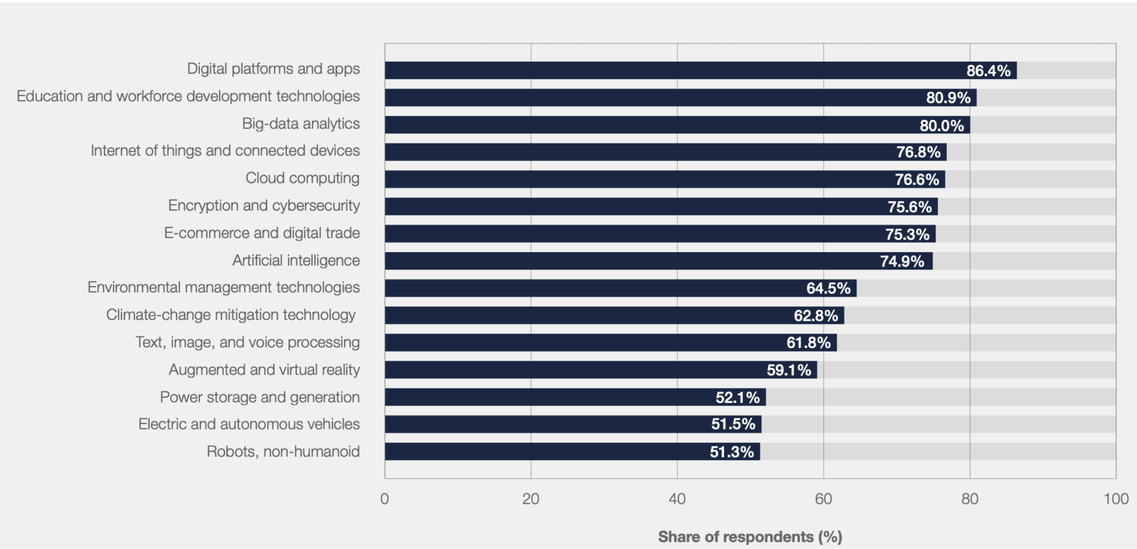

Figure 1. Technology Adoption in 2023-2027 (WEF, 2023)

IV. Cambodia's Pathway to Coding and STEM Education Fusion

STEM education and coding have been well-considered by MoEYS to develop 21st century skills for learners to be well-equipped for the future of work. In 2022, the New Generation School (NGS) system in partnership with mangoSTEEMS, a company specializing in Robotics, Coding, and AI software, piloted an academic programme in coding and AI, whereby software licenses including Robotify (a coding program), and Build Something Different (an application development program) were discounted and provided to students in fifth to seventh grade with a total of 195 students (KAPE, 2023). Moreover, KAPE received grant from Meta-Facebook through Khmer Digital Literacy Programme, one of WeThinkDigital initiatives by Meta, to systemize NGS's new digital curriculum by combining existing ICT curriculum with WeThinkDigital curriculum (KAPE, 2019, 2023). This has been a great progress from MoEYS and NGS with partners in incorporating coding in STEM education while giving students the taste of experiential learning. Curriculum content; however, is still under progress. Hence, a few programming languages, adopted by European countries, including Scratch Jr (for fifth and sixth grade), and Python, C/C++ (for seventh and higher grades) as well as mathematical topics needed for the fusion shall be taken into consideration (Corrienna et al., 2021; Vasylieva & Hodovaniuk, 2022).

Figure 2. Skills on the Rise (WEF, 2023)

Fastest growing vs. fastest declining jobs

WORLD ECONOMIC FORUM

Top 10 fastest growing jobs

1.	AI and Machine Learning Specialists
2.	Sustainability Specialists
3.	Business Intelligence Analysts
4.	Information Security Analysts
5.	Fintech Engineers
6.	Data Analysts and Scientists
7.	Robotics Engineers
8.	Electrotechnology Engineers
9.	Agricultural Equipment Operators
10.	Digital Transformation Specialists

Top 10 fastest declining jobs

1.	Bank Tellers and Related Clerks
2.	Postal Service Clerks
3.	Cashiers and ticket Clerks
4.	Data Entry Clerks
5.	Administrative and Executive Secretaries
6.	Material-Recording and Stock-Keeping Clerks
7.	Accounting, Bookkeeping and Payroll Clerks
8.	Legislators and Officials
9.	Statistical, Finance and Insurance Clerks
10.	Door-To-Door Sales Workers, News and Street Vendors, and Related Workers

Source
World Economic Forum, Future of Jobs Report 2023.

Note
The jobs which survey respondents expect to grow most quickly from 2023 to 2027 as a fraction of present employment figures

Figure 3. Fastest growing vs Fastest declining jobs (WEF, 2023)

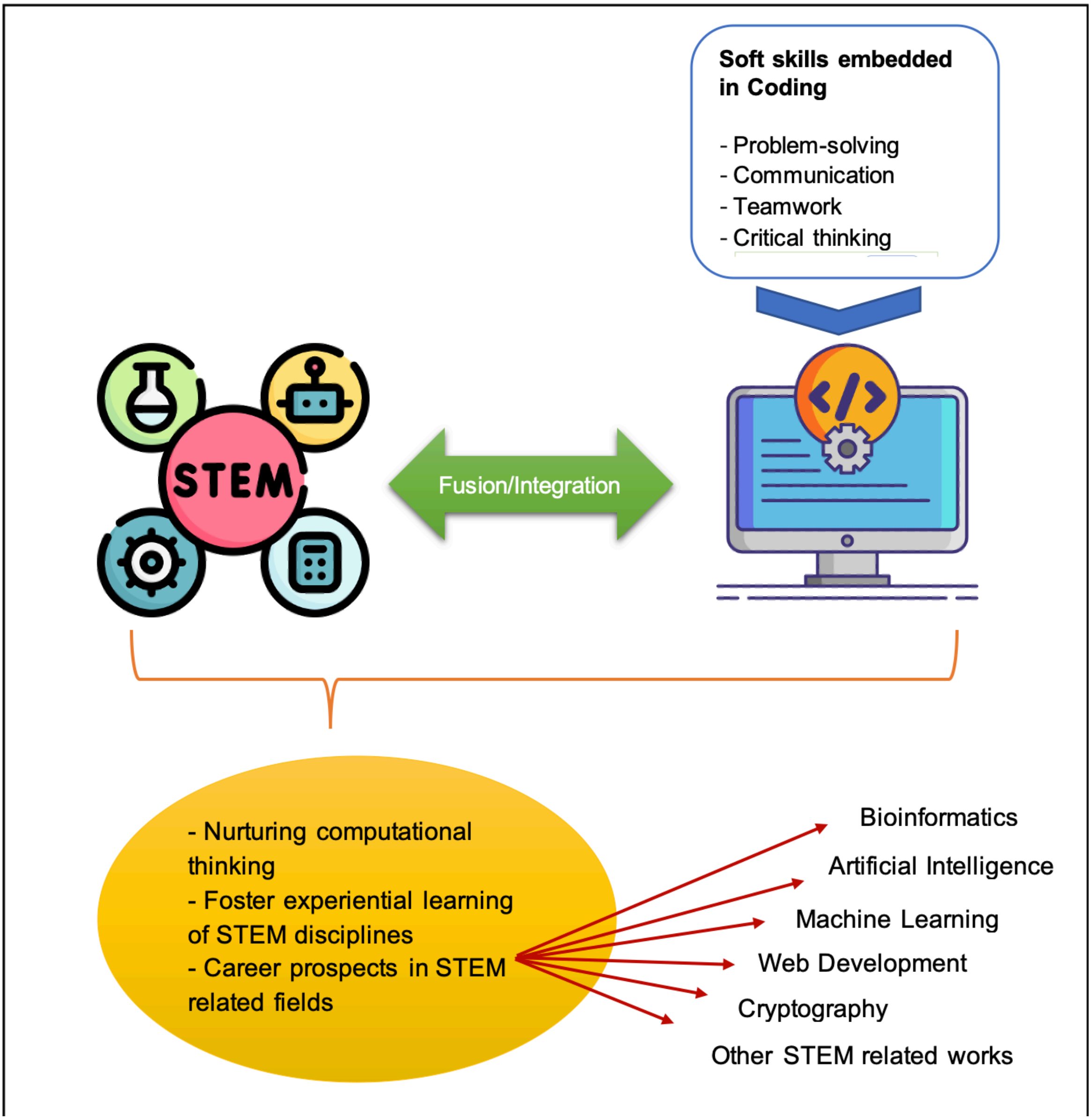

Figure 4. Conceptualization of STEM Education and Coding (Source: Authors)

V. Conclusion and A Way Forward

The integration of coding into STEM education is no longer an option but rather an obligation to meet market demand. From the above analysis, this digest found that the evolution in curriculum offers tremendous benefits and equips learners with essential scientific knowledge, cognitive skills — notably computational thinking, and 21st century competencies including creative thinking and problem-solving. Consequently, a myriad of employment opportunities emerges, ranging from bioinformatics and AI to web development and cryptography. As a way forward, fostering partnerships between private enterprises and schools is a promising strategy to not only provide students with practical hands-on coding experiences but also enable private firms to identify and nurture potential talents for future employment opportunities.

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Mr. Chan Raksmey is currently pursuing a high-official Diploma at the Royal School of Administration (ERA). He obtained his bachelor degrees in Education (TEFL) and International Studies from the Royal University of Phnom Penh, and a master degree in Social and Solidarity Economy from Lumière Lyon 2. Raksmey used to work on a research project in change management for online learning in Cambodia and has published research articles and opinion pieces in many renown journals in different disciplines, namely change management and education.

Why Cambodia Needs EdTech Startup for Overseas Scholarship?

9

Y Phoura
Ph.D., Agricultural and Environmental Biology
The University of Tokyo, Japan

Phou Sothearoth
Ph.D., Regional Development Studies
Toyo University, Japan

Highlight

- Problems: More than 50% of applicants faced challenges when applying for overseas scholarships: didn't know how to apply (66.4%), didn't know the detailed scholarship information (63.0%), couldn't decide which scholarship matches their qualifications (40.3%), lack of consultation and mentorship (65.5%), and lack of qualifications like IELTS or TOEFL language proficiency (59.7%).
- Solutions: EdTech startups using digital platforms could help solve the abovementioned problems.
- Scholarar: The under-development Scholarar App will solve the problems by matching overseas scholarship information with the applicant's qualifications, degrees, and majors without laborious searching online.

I. Introduction

Cambodia aims to become an upper-middle-income country by 2030 and a high-income country by 2050 (RGC, 2019). Educational and digital transformation, especially Cambodian human resources in STEM (Science, Technology, Engineering, Mathematics), is significant in achieving this goal (RGC, 2021). However, most of the STEM majors can only be acquired from overseas education. In fact, there are two main ways to get an overseas education: scholarship-funded or self-funded, but the latter is available only to a small group of high-class individuals with costly tuition and living expenses (Figure 1). According to its sources, overseas scholarships can be divided into three main types: government scholarships (government-to-government cooperation), university scholarships, and others from organizations like the World Bank, Asian Development Bank, or Gate Cambridge Scholarships (Figure 1).

Problems faced by Cambodians when applying for overseas scholarship

Scholarship is a type of financial package (i.e., money) that is challenging and requires applicants with enough qualifications and preparations due to the nature of the scholarships, which mainly have lengthy, complicated, and manual processes. According to the results of the online survey questionnaire using Google Forms from 119 respondents, with 52.9% female and 95.8% aged 15-30, the challenges faced by the respondents were: didn't know how to apply (66.4%), didn't know the detailed scholarship information (63.0%), couldn't decide which scholarship matches their qualifications (40.3%), lack of consultation and mentorship (65.5%), and lack of qualifications like IELTS or TOEFL language proficiency (59.7%) (Figure. 2) (Scholarar, 2024 (unpublished data)).

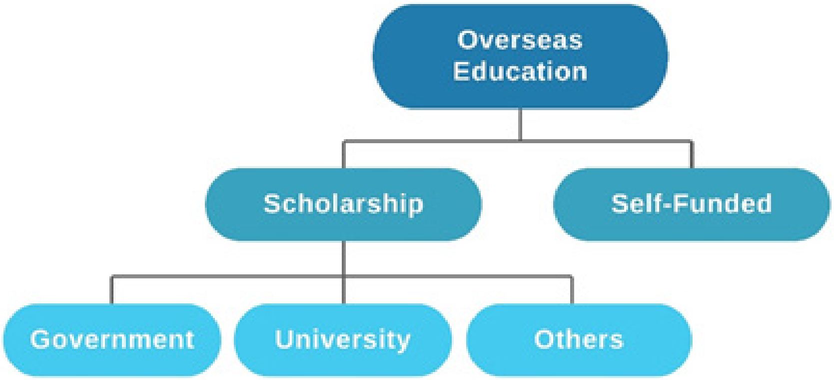


Figure 1: Types of Scholarship

Solutions through EdTech Startup: Case Study of Scholarar

Cambodia, on average, spends around $80M, with a 10% increase per year on overseas education (US DOC, 2019; UNESCO, 2024). Thus, the need for educational technology (EdTech) startups using digital technology to match Cambodian talents with overseas scholarships has never been more critical, but so far, there is no such EdTech startup working on overseas scholarships (Startup Cambodia, 2024). This article delves into a startup called Scholarar, an EdTech platform with a vision "to maximize Cambodian talents with overseas education through scholarships." This digital startup's mission is to bridge the gap between Cambodian talents and the global educational opportunity to enhance the country's human capital and contribute to its socio-economic development, which is perfectly aligned with the Pentagonal Strategy-Phase I (Pentagon 1 & 5) of Royal Government of Cambodia (RGC, 2023).

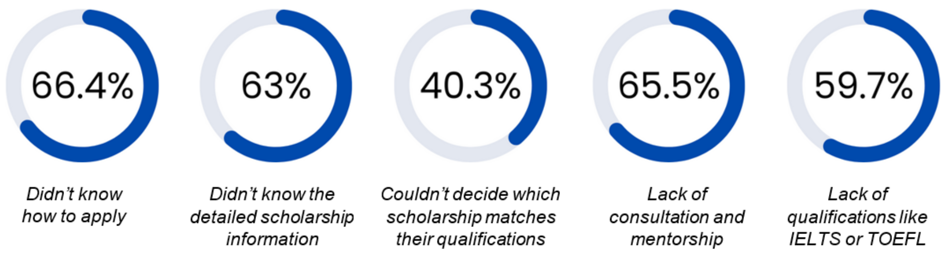


Figure 2: Problems faced by Cambodian students when applying overseas scholarships

Scholarar will solve the abovementioned scholarship problems through an under-development Scholarar App by matching overseas scholarship information with the applicant's qualifications, degrees, and majors without laborious searching online, as seen in the app prototype (Figure 3). Then, the app will recommend the applicant to take the necessary preparation course and language training as well as the scholarship application review. If the applicant has any questions, he/she could get support from Scholarar's AI and scholarship experts. The app also has a bookstore with various books for users, from science (Math) exams to scholarships to self-development to language exams like TOEFL, IELTS, and SAT, ensuring users have enough resources to succeed in their dream education.

From the market validation on the three key app features, including Scholarship Feature, Course Feature, and Chat Feature, from the 119 respondents from the online survey, more than 91% indicated “all three features are excellent and good for their scholarship hunting.” In comparison, among the three features, 55% said “like the Scholarship Feature,” 29% “like the Course Feature,” and 16% “like the Chat Feature.” Moreover, 77.3% said they would download the app, 20.2% would consider downloading it and 2.5% would not download it

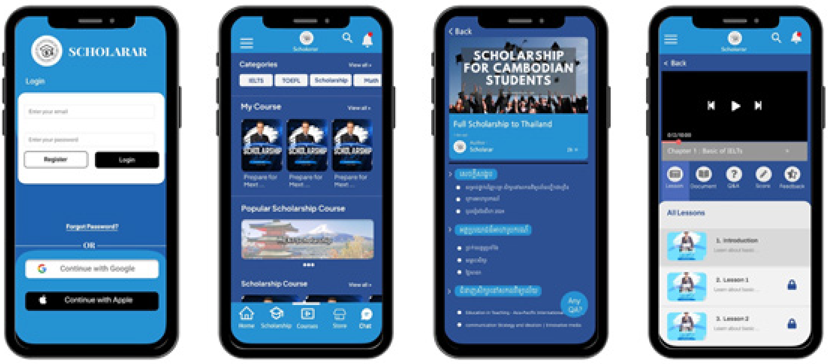


Figure 3: Features of Scholarar App Prototype

Concluding Remarks

Cambodia’s need for EdTech startups to facilitate overseas scholarships is evident. EdTech startups like Scholarar can play a transformative role in enabling Cambodian students to pursue higher education abroad by providing access to information, preparation resources, and digital support. This, in turn, can contribute to the country’s socio-economic development, fostering a generation of globally educated leaders and innovators. However, for these efforts to be successful, they must be supported by a robust and vibrant startup ecosystem, with legal registration, taxation, and investment facilitation. From our viewpoint, the journeys ahead are challenging, but with strategic investment and innovation, the EdTech startup can help Cambodian students achieve their dreams of studying abroad, enriching lives and the fabric of Cambodian society.

Scholarar, an EdTech startup that matches Cambodian talents with overseas scholarships, was founded by Dr. Y Phoura and Dr. Phou Sothearoth on December 1, 2023. Dr. Y Phoura holds a master’s and PhD in Agricultural and Environmental Biology from The University of Tokyo, Japan, in 2023, and has lots of experience mentoring Cambodian scholars in scholarship and IELTS/TOEFL since 2010. Likewise, Dr. Phou Sothearoth holds a master’s and PhD in Regional Development Studies from Toyo University, Japan, in 2023, with more experience helping students secure Japanese scholarships and education while she was in Japan.

A Woman in Science

10

I. Brief Self-Introduction

I have always dreamed of being a food scientist and I was courageous to leave home at a young age to pursue my dream. Where I came from, for a woman to leave her family and hometown and move to the city is considered unsafe and to pursue a career in engineering is even more uncommon plus science and engineering are traditionally for men. In 2016. with determination, I managed to obtain a five-year scholarship from the Cambodian government to study degree in Chemical Engineering and Food Science from the Institute of Technology of Cambodia. I also received a scholarship from the European Commission for two years of study in three different European countries. By 2018, I obtained 3 Master's degree in Sustainable Management of Food Quality (EDAMUS of ERASMUS). Today, I have founded and established two start-ups; Harvest The Sun Co,. Ltd (HTS) which focuses on renewable energy technologies and Cam Agro-Food (CAF) Enterprise aims to be one of sustainable Cambodia's spice wholesalers and exporters. Both enterprises are still at an early stage, I am also managing the day-to-day operations, sales, and marketing.

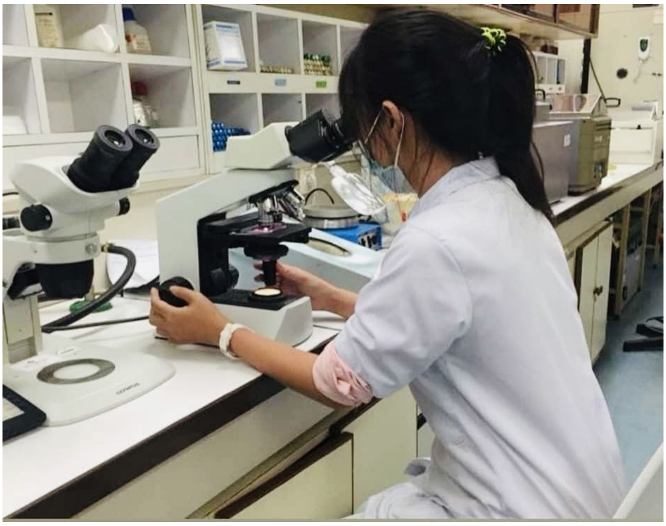
II. Brief Education Life

Why do you think education is important, especially STI education? and what motivate you to choose STI education?

In the past, Science, Technology, and Innovation (STI) can be a very uncommon among educational options. Our parents will encourage children to take up business, medical, engineering or accounting, those that would provide job security. The recent years, especially post pandemic, technology and innovation became such an important topic.

STI can be very challenging, but it serves as essential preparation for people to achieve their goals. Life is about being realistic and studying STI subjects fosters critical thinking, making people more intelligent.

I chose STI because, in high school, I developed a deep interest in Mathematics, Physics, and Chemistry. These subjects fascinated me; every time I learned a new formula and solved a problem, I felt a surge of excitement. This passion led me to pursue an engineering and science major, knowing there would be even more thrilling things to learn.



Moreover, I enjoy solving problems, not just in textbooks but also in daily life and society. STI education has made me more intelligent, creative, and strategic in tackling the challenges I encounter. Take food science for example, previously farmers had to dry their seafood or spices in the sun and risk contamination, with technology we could reduce such risk as well as reduce food waste by prolonging longevity and value. I believe the world needs more innovation and productive solutions, especially since we are living in a climate-challenged world.

What is your oversea education experience?

I pursued master's degrees in three different countries: France, Italy, and Spain.

In France, my major was Nutrition and Food Science. I deepened my knowledge in food science, improved my French language skills, and gained insights into French culture and lifestyle. This major has been crucial to my career, enabling me to solve many of my clients' problems.

In Italy, I specialized in Machinery and Plant of Mediterranean Food and Organic Standards. This major greatly influenced my business ideas. I was exposed to advanced technology in laboratories and food manufacturing. However, upon returning to Cambodia, I noticed many farmers struggling with post-harvest losses and processors lacking market competitiveness. This inspired me to develop the idea of selling solar dryers as a sustainable post-harvest solution and to provide consulting on the right drying techniques for their products.

In Spain, I studied Agro-Food Marketing, which quickly became my favorite major. I have a keen interest in psychology, and marketing is one of my hobbies. I enjoy understanding how people think and how they prefer to learn about new things. As a business owner, it is essential for me to understand my prospects' demands and use my scientific knowledge to offer tailored solutions to each client.

In short, this 19-year education journey and living experience across different schools and countries have allowed me to grow personally and professionally. To me, it was not just an educational journey but a path of self-discovery.

How does your education advance your career?

My education has opened up numerous career opportunities for me. With a strong background in food science, I have the flexibility to choose between working for small or large companies, as this skill is in high demand in the kingdom. Moreover, my education has equipped me with the knowledge and confidence to run my own companies. My education had provided a holistic view in my career; the knowledge and experience allowed me to solve most of the problems of my clients. In short, these 19 years-education journeys and living experience in different schools and countries, allow me to grow personally and professionally. This is not just an education phase but it was self-discovery journey for me as well. Instead of being an employee, I decided to venture out to create solutions to help solve challenges faced by Cambodian farmers.

Beyond technical skills, proficiency in foreign languages has been crucial. It allows me to communicate effectively with a diverse range of people, which is essential in business. Building a broad network is vital for success, and knowing foreign languages expands my circle, enabling me to connect with more professionals and potential partners.

III. Experiences & Achievement

What inspire you to become who you are now?

The opportunity to study my Master, travel, live, and experience made me who I am today. While studying and living overseas for a while, I met with experts, experienced local culture and learned best practices that I could potentially adopt to apply in Cambodia.

As a Cambodian, I often wonder why my country is resource rich but poor in our economic growth. The more I interact with farmers, food producers and consumers, I realized there was a huge gap in technologies, nutrition awareness and having an affordable one stop agriculture service for food producers and farmers.

IV. Personal Development

How did you start your personal development?

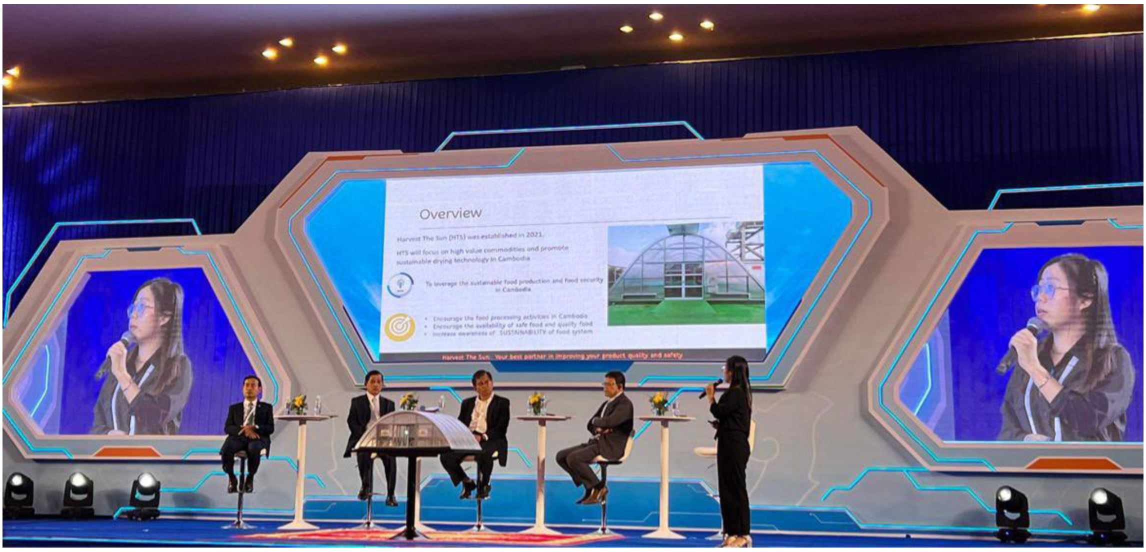
For personal growth, I love to read, travel, listen, and take risks. My favorite topics are business, marketing, and psychology. By the age of 30, I had traveled to 17 countries. I enjoy getting lost and discovering myself during these travels. I spend time listening to people share their life experiences and journeys, and learning from them. In life, opportunities abound. Though I sometimes hesitate or feel scared to try something new, I convince myself to give it a go. Each attempt either teaches me a lesson or boosts my confidence.

How to cope with fear of failure?

Everyone experiences fear of failure. In my experience, coping with this fear starts with acknowledging and accepting it as a natural human response. By accepting it as part of human nature, the pressure becomes more manageable. I convince myself to try things that scare me. Often, I find that the fear was in my mind, not in reality. By continuously facing my fears, I expand my comfort zone. Life is tough and scary when we lack experience, but with each challenge, we grow stronger.

What is your life mission?

My life mission is to be a changemaker. As a food scientist, I've seen many problems and opportunities in Cambodia's food system. I want to use my knowledge and experience to drive positive change. My goals include helping farmers increase their income, creating more jobs, and seeing more authentic Cambodian products exported to contribute to our economic growth.



IV. Advices to Next Generation

What is your message to the next generation about STI education and career opportunities?

As a woman in science who pursued her dream despite early opposition, my message to the younger generation is: follow your passion and learn to enjoy the journey rather than focusing solely on the destination. Education and career paths are journeys, not destinations. Embrace the process and the growth it brings

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National Institute of Science, Technology and Innovation
National Road 2, Sangkat Chak-AngRe Leu,
Khan Mean Chey, Phnom Penh, Cambodia