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Enhancing Agricultural TVET through Technology and Industry Synergy: Next-Generation Workforce Development in Penang

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***Abstract*—** Penang has seen an increasing focus on transforming its agricultural sector to align with modern technological advancements and sustainability goals. This transformation is critical as Penang seeks to reduce its dependence on other states for food and to create a sustainable local food system. Technical and Vocational Education and Training (TVET) offers a unique platform to prepare a skilled workforce capable of supporting agricultural innovation. This study aims to critically assess and advance the integration of agricultural content within TVET programs in Penang. Given agriculture's essential role in regional food security and economic sustainability, there exists a significant misalignment between current TVET curriculum and the sector's evolving needs. Employing a qualitative research approach, including in-depth interviews with TVET educators, industry practitioners, government officials, students, and agricultural entrepreneurs, this study elucidates key challenges and opportunities in embedding contemporary agricultural practices into TVET programs. Findings reveal substantial gaps in curriculum relevance, industry engagement, and technological integration. The study proposes targeted reforms, such as curriculum modernization to include advanced farming techniques, sustainable practices, and technological innovations. Recommendations include fostering robust industry-education partnerships, enhancing public perceptions of agricultural careers through strategic awareness campaigns, implementing targeted financial and non-financial incentives, and investing in advanced technological infrastructure. The study also emphasizes the necessity of supportive policy frameworks and continuous program evaluation to ensure alignment with sectoral demands. This research provides a comprehensive framework for stakeholders to enhance TVET programs, thereby equipping graduates with the requisite skills for the evolving agricultural sector in Penang.
Keywords— "Agriculture, Industry, Technology, TVET, Workforce Development**"**

I. INTRODUCTION

Agriculture has traditionally been an important element of Malaysia's economy, yet in Penang, it has been overshadowed by the manufacturing and technological industries. However, the increasing demand for food security and sustainable farming methods has brought back interest in the industry, making it important to provide future generations with the appropriate abilities and knowledge [17]. Issues such as an ageing farming population, poor technological adoption, and labor shortages highlight the need for fresh ideas to rejuvenate the industry [12]; [17]. In this regard, TVET may play an important role by providing practical, hands-on training that prepares students for the agricultural workforce. TVET is designed to fill skill gaps by emphasising practical knowledge and technological ability. Integrating agriculture into TVET programs has the potential to boost the sector by generating professionals who are skilled about current farming practices, precision agriculture, and sustainability [25]. This study examines the interaction between TVET and agriculture in Penang, evaluating the current landscape, prospective impacts, and strategic recommendations.

Malaysia's agricultural sector, including in Penang, is confronting issues such as ageing farmers, low technological adoption, and a declining labour population [17]. The average age of farmers in Malaysia is increasing, with many nearing retirement, and younger generations are less inclined to pursue careers in farming. The problem becomes more severe by urbanisation and industrial expansion, which restrict accessible agricultural land. Despite these problems, there is a rising awareness of agriculture's importance in food security, rural development, and economic diversification. TVET provides a pathway to addressing these concerns by providing students with skills in contemporary farming, agro-technologies, and environmental protection [25]. Students in TVET programs acquire practical experience that prepares them for direct entry into the workforce, hence addressing labour market job openings. Furthermore, TVET's emphasis on innovation aligns with the demand for sustainable agricultural practices such as precision farming, organic agriculture, and resource-efficient farming techniques [7].

Despite agriculture's crucial relevance to food security and economic stability, there is a rising skills gap limiting the sector's expansion and modernisation. TVET has the ability to close this gap by providing hands-on, industry-relevant education, yet agriculture has a small presence in existing TVET curriculum. The lack of structured agricultural training in Penang's TVET programs contributes to the worker shortfall while also limiting chances for innovation and sustainability in the sector. Furthermore, negative perceptions of agriculture as a low-status job, as well as a lack of coordination among educational institutions, government, and business, provide substantial obstacle to agriculture's successful integration into TVET.

This study aims to address these difficulties by investigating the role of TVET in agricultural education, identifying the challenges, and recommending strategic interventions to improve TVET's effectiveness in supporting the future of Penang's agricultural sector. By addressing these concerns, the study hopes to help create a competent agricultural workforce capable of driving the sector's long-term growth and innovation. The research objectives are to examine the role of TVET in enhancing agricultural education in Penang, to propose strategies for fostering collaboration between TVET institutions, government, and industry as well as to assess the potential impact of agriculture-focused TVET programs on Penang's agricultural sector and workforce. With the objectives, it is hoped to provide an understanding of how TVET can help to produce a skilled agricultural workforce through practical and technical education by suggesting ways in which various stakeholders can work together to support the success of agriculture-focused TVET programs. At the same time, to further understand the wider implications when integrating agriculture into TVET, can influence workforce development and economic growth in the region.

II. LITERATURE REVIEW

Agriculture's integration into TVET is critical for bridging the skills gap and boosting long term development. This literature review addresses at key issues related to the integration of agriculture into TVET programs, such as curriculum development, industry collaboration, public perception, and the role of technology.

A. Curriculum Development

Effective curriculum development is critical for integrating TVET programs with industry requirements. Research emphasises the significance of modernising agricultural curriculum to reflect new practices and technologies. [6] for example, argued that curriculum should embrace developments such as precision farming and sustainable practices in order to remain relevant in the fast-changing agricultural sector. Similarly, [27] suggested that combining hands-on training with academic understanding is critical for preparing students for real-world agricultural challenges. The importance of updating agricultural TVET curriculum on a regular basis to ensure their relevance was emphasized by [3], who claimed that curriculum frequently fall behind industry requirements, especially in areas where agriculture is becoming more tech-driven.

[23] show that partnership between the agriculture industry and TVET institutions is critical for giving students practical, real-world experience. They suggest that internships, apprenticeships, and industry-driven workshops should be part of the curriculum. Despite the widely recognised need to modernise TVET curriculum, a number of problems hinder the progress. According to [26], common barriers include insufficient finance, old infrastructure, and a lack of access to contemporary technologies. These difficulties are particularly prominent in locations with minimal government and

industry backing. TVET programs frequently fail to integrate developing technologies like drones, IoT, and data analytics into their training modules.

Government support is critical for modernising TVET curriculum. [28] emphasises that policy frameworks can stimulate innovation in TVET curriculum by providing financial support for technological improvements and encouraging business partnerships. Governments can also help align TVET courses with national development objectives and evolving industrial needs. Policy assistance is especially vital in Penang to ensure the viability of agricultural TVET programs. Government policies should foster the integration of sophisticated technology and industry partnerships in order to build a workforce capable of addressing the needs of modern agriculture [20].

B. Industry Collaboration

Partnerships between TVET institutions and industry stakeholders are critical for matching educational programs to real-world agricultural demands. These collaborations allow students to obtain practical experience while ensuring that training fits the needs of the workforce market. Internships, apprenticeships, and field training allow students to apply their academic knowledge in real-world contexts. Local agribusinesses have partnered with TVET institutions to provide internship opportunities centred on the implementation of sophisticated agricultural technologies such as IoT and AI-based farming systems [4]. Industry stakeholders play an important role in co-developing TVET curriculum to ensure that it meets current market requirements. Coordinated efforts between educational institutions and agribusinesses have resulted in specialised programs that include training in smart farming technology and sustainable agricultural practices [18]. These programs ensure that graduates are both technically adept and industry ready. Successful TVET programs work closely with industry stakeholders to ensure that the skills taught are relevant to current technologies, practices, and industry expectations. In agricultural TVET, this entails working directly with farms, agribusinesses, and technology providers to stay current on developing trends like precision farming, automation, and digital agriculture. Collaboration between TVET institutions and the agricultural industry is critical to ensuring that educational programs fulfil industry requirements. [10] found that partnerships help students gain practical experience and exposure to current industry practices. Furthermore, [24] highlighted how such collaborations might increase the relevance of TVET programs by connecting them with emerging agricultural technology and practices.

Small-scale farmers and agribusinesses may be hesitant to collaborate with educational institutions due to limited resources, a lack of awareness of the potential benefits, or a lack of formal partnership frameworks [2]. While [11] stressed that industry interaction increases the quality of teaching and learning by bringing industry experts into the classroom, giving students practical insights and up-to-date understanding of the area.

C. Public Perceptions of Agriculture

Agriculture's projected low status when compared to other technological professions makes it less appealing to younger generations. Public perceptions of agriculture have a substantial impact on student enrolment in agriculture-related TVET programs. [14] found that negative perceptions of agriculture as a low-status profession can discourage students from pursuing agricultural education. To address this, the authors suggest that public awareness campaigns emphasising the modern and creative parts of agriculture are critical for attracting students.

Agriculture can be regarded as an unappealing professional path, especially among younger generations. Several studies have found a growing indifference in farming due to beliefs that it is labour-intensive, low-paying, and lacking in status. According to a survey conducted by [9], many young people in Malaysia regard agriculture as a "last resort" job option, connecting it with hard labour and limited professional advancement. Seconded by [1] found that public attitudes towards agriculture differ significantly across rural and urban populations. Agriculture is perceived more positively in rural areas as an essential component of the local economy, whereas urban residents regard it as outdated and distant from their lives.

The public's perception of agriculture as a low-income sector with high levels of economic instability continues to deter newer generations from entering the industry. Despite technological developments, there remains a persisting assumption that farming provides minimal financial benefits [22]. [5] found that the general public is typically unaware of modern farming practices, particularly in urban areas. This information gap can result in misconceptions about modern farming realities and agricultural potential.

D. Role of Technology

Precision farming, artificial intelligence (AI), and automation are all examples of technological developments that are transforming the agriculture sector. Integrating these technologies into agricultural TVET programs is essential for ensuring that students have skills applicable to modern farming techniques. The use of GPS-guided tractors, drones for crop monitoring, and automated irrigation systems has transformed agricultural methods. Agricultural TVET programs can use these technologies to provide students with hands-on experience, better preparing them for the future workforce [30]. Similarly, Virtual reality (VR) and augmented reality (AR) technologies are rapidly being utilised in TVET to imitate farming conditions, giving students a safe space to practise complicated activities like operating machinery or managing pest control. According to [13], immersive learning using virtual reality has a considerable positive influence on student involvement and knowledge. While digital education platforms provide greater access to agriculture education. E-learning systems such as Malaysia's *"e-LATIH"* provide TVET students online courses on modern agriculture technology and methods. These platforms are especially useful for expanding access to students in remote areas who would otherwise struggle to access traditional educational materials [19]. The use of smart farming technologies helps to bridge the gap between traditional agricultural and modern, technology-driven techniques [8].

The integration of modern technology into agriculture training is becoming increasingly significant. Studies by [31] and [15] emphasise the importance of incorporating technology like drones, IoT, and data analytics into TVET programs to educate students for modern agricultural techniques. These technologies improve the learning experience and provide students with skills that are directly relevant to the agriculture sector. In addition, creating agriculture-focused TVET programs necessitates major investment in infrastructure, including training farms, labs, and technological tools. New technologies have a transformative impact on agriculture, addressing difficulties and pave the way for a more sustainable and efficient future [21]. Artificial intelligence, the Internet of Things, computer vision, and machine learning are examples of modern agricultural technology that improve efficiency, resource management, and sustainability [29].

The study emphasises the importance of taking a multifaceted approach to improving agricultural integration in TVET programs. Curriculum development, industry collaborations, public perception and the role of technology are all critical areas. Addressing these issues can help TVET programs better match with industry needs, recruit a new generation of students, and contribute to the agriculture sector's long-term workforce development.

III. METHODOLOGY

This study uses a qualitative research methodology to gather in-depth insights regarding the integration of agriculture into TVET programs in Penang. The goal was to understand the perspectives of various stakeholders, identify issues, and investigate viable solutions. The following methodological steps were adopted.

A. Research Design

A qualitative, exploratory study design has been used to gain a better understanding of the experiences and perspectives of stakeholders involved in both agricultural and TVET. This approach is appropriate for exploring complex topics that require numerous perspectives and interpretations.

B. Data Collection Methods

In-depth interviews were conducted with key stakeholders, including TVET administrators, students, agriculture industry professionals, and government representatives from agriculture agencies. These interviews enabled open-ended discussions concerning the problems, opportunities, and strategies for integrating agriculture into TVET. The interviews were done online via the Google Meet platform. Interviews lasted 45 minutes and were recorded digitally. The following Table 1 shows the details of participants' profiles and Table 2 shows the semi-structured interview questions.

TABLE I
DETAILS OF PARTICIPANTS' PROFILES

Participant ID	**Gender**	**Designation**	**Experience/ Expertise**
Participant 1	Female	Curriculum Developer	Involved in developing and updating curricula for TVET programs, including those related to agriculture.
Participant 2	Male	Founder	Engaged in modern farming techniques, such as hydroponics and organic farming, and experienced in agribusiness management.
Participant 3	Male	Senior Officer	Involved in formulating agricultural policies and supporting agricultural development programs.
Participant 4	Male	Final Year Student (Diploma in Agricultural Technology)	Engaged in hands-on training and internships related to agriculture.
Participant 5	Female	Recent Graduate (Certificate in Sustainable Agriculture)	Recently completed vocational training and is currently seeking opportunities in the agricultural sector.

TABLE 2
SEMI-STRUCTURED INTERVIEW QUESTIONS

Themes	**Main Questions**	**Probing Questions**
Curriculum Development	• "In your opinion, what specific skills and knowledge should be included in agriculture-focused TVET curriculum to ensure that students are well-prepared for the modern agricultural	• Can you give examples of the most important technologies or techniques that students should learn? • How can traditional farming practices be balanced with modern innovations in the curriculum? • What role do you think entrepreneurship should play in the curriculum for agriculture students?
Industry Collaboration	• "How integration between TVET institutions and agricultural industry be strengthened to provide students with more practical, hands-on experiences in the industry?"	• What types of collaborations do you think are most effective, such as internships or joint research projects? • What challenges do you foresee in creating this collaboration, and how might they be overcome?
Public Perceptions on Agriculture	• "What do you think can be done to change the public perception of agriculture as a low-status career and make it more attractive to younger generations?"	• Why do you think agriculture has this perception, especially among youth? • How do you think showcasing new technologies in agriculture could change public perceptions? • What role could successful farmers or agri-preneurs play in changing these perceptions?
Roles of Technology	• "How important is the integration of modern technologies and sustainable practices in agriculture training, and how can TVET institutions ensure that students are well-versed in these areas?"	• Which specific technologies (like drones, IoT, or AI) do you think should be prioritized in TVET training? • How can TVET institutions better collaborate with tech companies or environmental organizations to include sustainability in their programs? • What are the biggest barriers TVET institutions face in adopting these technologies, and how can they be addressed?

The first segment (Curriculum Development) intended to explore how TVET curriculum can be updated to reflect modern agricultural needs, such as precision farming, sustainability, and technological advancements. The second component (Industry Collaboration) was designed to gather insights on potential collaboration strategies, such as internships, apprenticeships, and joint research projects, between the agricultural industry and TVET programs. The third part (Public Perceptions on Agriculture) to examines and identify the ways to promote agriculture as a viable and appealing career path, particularly for youth interested in TVET education. The fourth element (Roles of Technology) focusses on understanding the importance of modern agricultural technologies and sustainability in TVET programs and how institutions can integrate these into the training process.

C. Sample Strategy

A purposive sampling approach was used ensuring that participants represent various key groups involved in or affected by the integration of agriculture into TVET.

D. Data Analysis

Thematic analysis was used to examine the data collected. The processes in this analysis included reading and re-reading interview transcripts to become familiarised with the subject. The essential phrases, ideas, and themes were then determined using a coding technique. This entailed meticulously labelling areas of data that corresponded to the research objectives and questions. Related codes were organised into larger categories that highlight common trends or key challenges concerning the integration of agriculture into TVET curriculum. The final step was to evaluate the data, generate the findings, and relate them to the research objectives.

E. Validity and Reliability

To guarantee the validity and reliability of the findings, inputs were cross-checked, where the authors collected the inputs from interviews and checked the consistency to increase comprehension. The transcripts were then again cross-checked with interview participants to ensure that their perspectives were appropriately conveyed.

F. Ethical Considerations

The study adheres to ethical guidelines, which include collecting informed consent from all participants, maintaining confidentiality, and giving participants the option to withdraw from the study at any time.

This qualitative methodology will provide valuable insights into the problems, opportunities, and solutions for integrating agriculture into Penang's TVET programs. The research will provide a complete knowledge of the present landscape and practical strategies for improving agricultural education through TVET by gathering viewpoints from a variety of stakeholders.

IV. FINDINGS AND ANALYSIS

A. Curriculum Gaps and Needs

Current agriculture curriculum in TVET programs frequently lacks integration of contemporary technologies and sustainable practices. There is a gap between the skills taught and those needed in the sector, such as precision farming, digital agriculture, and sophisticated crop management.

> *"…We recognize the need for modern technologies and sustainable practices in our curriculum. However, updating the curriculum is a gradual process, and we are working on aligning it with industry needs." [participant 1]*
>
> *"…The industry is willing to collaborate with TVET institutions to provide internships, hands-on training, and knowledge sharing. We need to work together to bridge this gap by ensuring that the curriculum keeps pace with technological advancements." [participant 2]*
>
> *"…We feel like the skills we're learning aren't keeping up with the real-world demands. We hear a lot about precision farming and digital agriculture, but we don't get enough hands-on experience with these technologies." [participant 4]*

Based on feedback, we discovered that comparing existing curriculum to industry standards and technological improvements shows out-of-date content and approaches. Interviews with industry professionals emphasise the necessity for up-to-date training that involves practical, hands-on experience with current technologies and sustainable practices. The lack of connection between educational content and industrial requirements indicates that curriculum should be significantly revised to accommodate modern agricultural methods and technologies.

B. Industry Collaboration

There is insufficient coordination between TVET institutions and the agriculture industry, which reduces the relevance of training programs. Existing relationships are frequently not fully executed to provide students with real-world experiences or insights into current industry practices.

> *"…One of the key challenges we face is finding industry partners willing to invest time and resources into collaboration. Many companies are focused on their operations and are hesitant to engage in long-term training partnerships." [participant 1]*
>
> *"…The industry is open to collaboration, but it's difficult to find a mutually beneficial way to engage. We would like to see more tailored programs that meet our specific skill needs, but that requires a closer working relationship with TVET institutions." [participant 2]*
>
> *"…We are aware that there is a gap between TVET institutions and the agricultural industry. Part of our mandate is to facilitate this collaboration by providing incentives for industries to participate in educational programs." [participant 3]*

A review of present industry-education collaboration suggests that stronger, more organised collaborations could improve the practical usefulness of TVET programs. Feedback from both academia and industry professionals emphasises the importance of more effective partnerships to match training with industry needs and technical improvements, as well as with some financial support from the government and stakeholders.

C. Public Perceptions on Agricultural Career

Public perceptions of agriculture as a career are often negative, with agriculture seen as a low-status or less appealing field. This perception impacts student enrolment in agriculture-focused TVET programs.

> *"...We are working hard to shift this perception by showcasing the innovative side of agriculture, such as precision farming, digital agriculture, and sustainability. However, changing deeply rooted societal views takes time and requires coordinated efforts across various stakeholders." [participant 1]*
>
> *"...The negative perception makes it hard for us to attract talent, particularly among younger generations. As a result, we often struggle to find skilled workers who are passionate about agriculture. Changing public opinion is critical to ensuring we have a future workforce." [participant 2]*
>
> *"...Many of us see agriculture as a less prestigious or unattractive field, which makes it less appealing. It's often associated with hard, manual labor, and people don't talk about the technological or business opportunities in agriculture." [participant 4]*
>
> *"...If agriculture programs were marketed as more technology-focused or innovative, more students would be interested. We want to be part of something cutting-edge, and if agriculture is presented that way, it would attract more people." [participant 5]*

Changing the public's perception is viewed as essential to increasing enrolment and securing the future workforce in agriculture-focused TVET programs. TVET institutions recognise the negative perception and are attempting to showcase the modern, creative aspects of agriculture in order to recruit students. The agriculture industry is frustrated by the public's inappropriate perceptions and emphasises the importance of better communication about the diversified and high-tech occupations accessible. Students frequently perceive agriculture as low-status and labour-intensive, but they are willing to study it if it is marketed as a tech-driven and forward-thinking subject with a variety of job opportunities.

D. Technology Integration

TVET programs in agriculture lack modern technologies such as drones, IoT, and data analytics. To facilitate technological integration, upgraded infrastructure and training tools are required.

> *"…One of the major barriers is the lack of infrastructure and funding to acquire these new technologies. Our current facilities are outdated, and without significant investment, it's difficult to provide students with hands-on experience using cutting-edge tools." [participant 1]*
>
> *"...We are working on initiatives to provide funding and resources to help TVET institutions modernize their infrastructure. This includes grants for technology upgrades and partnerships with industry leaders to ensure that students are trained in the latest agricultural technologies." [participant 3]*

> *"…We're excited about the possibilities of integrating technology into agriculture, and we want our programs to reflect the reality of the industry. We hope that our institutions will invest in the necessary infrastructure so that we can gain the skills needed to succeed in this field." [participant 5]*

Authorities see the importance of modernisation and are trying to provide financial support and establish business collaborations to assist TVET colleges in incorporating sophisticated technology into their curricula. Investing in new technology and infrastructure to improve the learning experience and keep students up to date on the latest agricultural breakthroughs. With hands-on experience utilising cutting-edge instruments like as drones and IoT, students will be more enthusiastic about taking the course and looking for better opportunities in the agriculture sector as a career path.

The findings and analysis show that agricultural TVET programs in Penang require immediate upgrading to better line with industry needs and technological improvements. Addressing curricular gaps, strengthening industry collaborations, changing the public's perception of agricultural careers, and incorporating innovative technologies are all key steps towards increasing the effectiveness of agricultural training. Implementing these recommendations would assist ensure that TVET programs develop a qualified and knowledgeable workforce capable of promoting long-term growth in the agriculture sector.

V. RECOMMENDATIONS

To overcome these issues and effectively integrate agriculture into Penang's TVET programs, numerous techniques might be adopted

A. Industry Collaboration

To bridge the education-industry gap, TVET institutions, the agricultural industry, and government agencies should work closely together. These partnerships can promote collaboration through internships and apprenticeship programs that provide hands-on training for students in real-world agricultural settings, as well as joint projects and research initiatives that encourage collaboration between TVET educators and industry experts on innovative agricultural practices and technologies. Organising workshops or seminars by inviting guest lecturers and industry professionals share their views and skills with TVET students, which makes education more practical and industry relevant or to create curriculum that incorporate modern farming techniques, technology breakthroughs, and sustainability. The program should cover precision farming with drones, sensors, and IoT, sustainable organic farming, and new water conservation approaches including hydroponics and vertical farming. This will ensure that students learn relevant, up-to-date skills, preparing them to meet the demands of the modern agriculture business.

B. Awareness Campaigns

Changing public perceptions of agriculture through campaigns that emphasise the sector's relevance and technical improvements will help recruit more students to agricultural TVET programs. Agriculture frequently suffers from perception issues, with many younger generations viewing it as a low-status or undesirable vocation. Execute a targeted public awareness campaign to highlight modern agriculture's technological developments, feature successful young entrepreneurs and professionals, and emphasise the possibilities for entrepreneurship and economic growth in agribusiness. This campaign could include social media, school outreach programs, and agricultural fairs to engage youngsters and spark their interest in the area.

The government could offer financial incentives such as scholarships and grants to students pursuing vocational education in agriculture, as well as non-financial incentives such as establishing guaranteed job placement programs for graduates of agriculture-focused TVET courses, to encourage students to enrol in agriculture-focused TVET programmes. Moving ahead, entrepreneurship coaching programs to be introduced through mentorship, seed capital, and access to agricultural incubators to assist graduates in starting their own agribusiness.

C. Incentives for Participation

Aside from offering scholarships, grants, and other incentives to encourage students to enrol in agriculture-focused TVET programs with the aim of helping address the issue of declining interest in agriculture careers, government policies should prioritise the development of agriculture within the TVET system, for example, allocating more financial resources to agriculture-focused TVET programs for curriculum development, infrastructure, and research, ensuring that TVET initiatives

D. Technology Integration

By introducing digital tools like drones, IoT devices, and data analytics into the curriculum, TVET institutions may make agriculture more appealing and relevant to tech-savvy students. TVET institutions should be outfitted with cutting-edge agricultural technologies like smart farming tools, simulation software, and laboratory equipment. This would give students hands-on experience with cutting-edge agricultural technologies, develop an innovative culture by exposing students to emerging agricultural trends, and allow institutions to do research on sustainable and efficient farming methods.

By implementing these recommendations, Penang's TVET programs may play an important role in closing the agricultural skills gap, stimulating innovation, and contributing to a more sustainable and resilient agriculture economy. These actions will not only raise the profile of agriculture as a viable and satisfying job and career development, but will also ensure that Penang's agricultural sector is future-ready and capable of meeting the demands of modern food production.

VI. CONCLUSION

Agriculture's integration into TVET programs in Penang provides an important opportunity to bridge the skills gap, modernise the agricultural industry, and inspire a new generation of agricultural professionals. This study emphasises the importance of specialised curriculum that focusses on modern farming techniques, sustainable practices, and agricultural entrepreneurship in preparing students for the challenges and opportunities of the 21st-century agricultural landscape.

Key issues include negative perceptions of agriculture as a low-status profession, limited collaboration between TVET institutions and the agriculture industry, and a lack of technical infrastructure within educational programs. However, these issues can be minimised through strategic measures such as public awareness campaigns, the establishment of strong industry-education partnership, and the provision of incentives like scholarships, job placements, and so on.

Furthermore, including current agricultural technologies and sustainability practices into TVET curriculum is critical to ensuring that graduates possess the skills required to foster innovation and economic success in Penang's agricultural sector. Agriculture-focused TVET programs may play an important role in building a competent and inventive workforce, contributing to regional food security, and encouraging long-term economic development by investing strategically in technology, partnerships, and policy.

The findings and recommendations of this study are intended to enlighten policymakers, educators, and industry stakeholders, as well as provide a road map for increasing TVET's involvement in Penang's agricultural transformation. Penang can establish a vibrant, future-ready agricultural workforce by prioritising education, innovation, and collaboration.

A. Limitations of the study

The study's emphasis on qualitative data means that the findings are based on interviews conducted in a specific context. Participants' unique experiences and biases may potentially influence the viewpoints gained. The study may not include all key stakeholders or cover the entire range of agricultural techniques and technology suitable to TVET. The perspectives of those selected may not entirely represent the interests of all TVET educators, students, and industry experts. The findings are unique to Penang and may not be immediately transferable to other locations or nations with varying agricultural, economic, and educational environments. While insights might be useful, they should be assessed within the local context rather than presumed to be universally applicable. The agricultural sector and TVET systems are both quickly changing. Technology, industrial trends, and educational policies may have changed during or after the study period, affecting the findings' validity and applicability.

B. Implications of the study

The study's findings will have significant ramifications for Penang's agricultural workforce, including matching education with industry needs, integrating technology, and influencing public opinions. This study's conclusions will be useful for TVET institutions seeking to modify and modernise their curricula. By emphasising the integration of advanced technologies such as drones, IoT, and data analytics, TVET programs can ensure that students have the relevant and up-to-date skills needed in the agriculture industry. TVET colleges will adapt their curricula to include modules on precision farming, smart agriculture, and digital tools, increasing graduates' labour market competitiveness. The agricultural industry's integration with TVET institutions requires the development of a competent workforce capable of meeting the sector's changing technical needs.

Collaboration with TVET institutions to co-develop curriculum and provide practical training, ensuring that graduates are equipped to use cutting-edge agricultural instruments and processes. A stronger talent pipeline will ensure that the industry has access to a consistent stream of well-prepared graduates who can drive innovation and growth. Government investment in modernising TVET infrastructure, particularly in agricultural technology, is critical to ensuring that institutions are prepared to train the next generation of workforce. The need for policies that incentivise industry collaboration with TVET institutions, such as tax breaks, grants, or public-private partnership schemes, as well as promote agriculture as a high-tech, viable career option through national campaigns and educational initiatives, will encourage more students to pursue careers in this sector. This study also emphasises the growing role of technology in agriculture, which makes the industry more desirable and provides a variety of job prospects. A greater understanding of how current technology are affecting agriculture may help modify attitudes of the field as outmoded or uninteresting, especially among younger people. Agricultural TVET programs have become more appealing as a result of the emphasis on sophisticated, technology-driven training, which provides students with a path to future-proof, high-demand agricultural occupations.

REFERENCES

[1] Ahmad, S., Latif, R., & Rahman, H. (2020). Rural vs Urban Perceptions of Agriculture in Malaysia. *Journal of Rural Studies*, 29(2), 115-132.

[2] Alvarez, M., & Duran, P. (2019). Industry collaboration in agricultural education: Opportunities and challenges. *Journal of Agricultural Education, 30(2), 112-126.*

[3] Anderson, P., Jones, M., & Smith, D. (2019). Curriculum design for modern agricultural TVET programs. *Journal of Vocational Education, 32(4), 122-138.*

[4] Aziz, M., & Rahim, F. (2021). Work-Based Learning and Its Role in Enhancing TVET Graduates' Employability in the Agriculture Sector. *Journal of Technical Education*, 13(2), 142-158.

[5] Aziz, N., Salleh, R., & Yusoff, N. (2021). Public Awareness of Modern Agricultural Practices: A Study in Urban Malaysia. *Journal of Agricultural Education*, 18(3), 144-159.

[6] Dar, A. A., & Singh, J. (2020). Curriculum Development for Agricultural Education: Current Practices and Future Directions. *Journal of Agricultural Education, 61(2), 45-60.*

[7] FAO (Food and Agriculture Organization of the United Nations) (2021). *Promoting Sustainable Agricultural Practices through TVET in the Asia-Pacific Region.*

[8] Kamaruddin, S., & Othman, R. (2022). Integrating Smart Farming Technologies into TVET Programs in Malaysia: A Case Study from Penang. *Journal of Agricultural Education*, 22(1), 77-93.

[9] Kassim, A., & Rahim, F. (2021). Youth Reluctance Towards Farming: A Challenge for Malaysia's Agricultural Future. *Journal of Vocational Education*, 12(4), 299-318.

[10] Kearney, A., & Rudd, R. (2017). Strengthening Industry-Education Partnerships: A Pathway to Enhanced Agricultural Training. *Journal of Vocational Education and Training, 69(3), 364-379.*

[11] Mahendra, P., & Malik, S. (2018). Enhancing employability through industry partnerships in vocational education. *Vocational Training and Skills Journal, 14(2), 55-72.*

[12] Ministry of Agriculture and Food Industries Malaysia. (2021). *National Agrofood Policy (NAP) 2021-2030*. Government of Malaysia.

[13] Ng, W., Tan, R., & Chen, Y. (2020). The Use of Virtual Reality in Agricultural TVET: Enhancing Practical Skills and Student Engagement. *Journal of Educational Technology*, 45(4), 155-170.

[14] Nguyen, T., Lee, J., & Chen, Y. (2021). Changing Perceptions of Agriculture: Strategies for Attracting Youth to Agricultural Careers. *Journal of Agricultural Education and Extension, 27(1), 78-92.*

[15] Patel, S., & Murphy, D. (2020). Incorporating Emerging Technologies into Agricultural Education: A Review of Current Practices. *International Journal of Agricultural Technology, 24(3), 341-356.*

[16] Penang Green Council (2020). *Integrating Sustainability into Vocational Education in Penang: The Case for Agriculture*.

[17] Penang Institute (2019). *Penang Economic Report: The Shifting Dynamics of Industry and Agriculture*.
[18] Ramli, A., & Hassan, S. (2022). Industry Collaboration in TVET Curriculum Development: A Focus on Agricultural Education in Penang. *Journal of Vocational Education and Training*, 14(2), 185-200.
[19] Rashid, S., Salleh, N., & Rahman, I. (2020). E-Learning and Its Impact on Agricultural TVET in Malaysia. *Journal of E-Learning in Rural Education*, 9(1), 45-57.
[20] Rasiah, R., & Choong, S. (2020). Policy frameworks for enhancing TVET in Malaysia: Opportunities and challenges. *Malaysian Journal of Policy and Innovation, 5(1), 65-81*.
[21] Said-Usmanovich, M., Bagov, A., & Razina, I. (2023). Application of new technologies in narrow Fields. *E3S Web of Conferences*. https://doi.org/10.1051/e3sconf/202346004036.
[22] Salleh, M., & Othman, R. (2020). Economic Instability in Agriculture: Public Perception and Its Impact on Career Choices. *Journal of Economic Development*, 19(1), 45-60.
[23] Sharma, P., & Patel, V. (2021). Industry partnerships in TVET: Enhancing employability in the agricultural sector. *International Journal of Vocational Training, 30(1), 77-92.*
[24] Smith, L., & Rees, J. (2019). Collaborative Models for Industry-Institutional Partnerships in Agricultural Education. *Agricultural Education Journal, 45(4), 213-225.*
[25] UNESCO-UNEVOC (2020). *Strengthening TVET for Agricultural Development: Case Studies and Policy Recommendations*.
[26] UNEVOC. (2020). Technical and Vocational Education and Training (TVET) in the context of sustainable development. *UNESCO-UNEVOC International Centre for TVET.*
[27] Wilson, R., Henderson, C., & Thomas, D. (2018). Hands-On Training in Agricultural Vocational Education: Bridging the Gap between Theory and Practice. *International Journal of Vocational Education and Training, 26(1), 29-42.*
[28] World Bank. (2020). Skills for the future: Supporting TVET programs through policy innovation. *World Bank Report.*
[29] Wrzecińska, M., Czerniawska-Piątkowska, E., Kowalewska, I., Kowalczyk, A., Mylostyvyi, R., & Stefaniak, W. (2023). Agriculture in the face of new digitization technologies. *UKRAINIAN BLACK SEA REGION AGRARIAN SCIENCE*. https://doi.org/10.56407/bs.agrarian/3.2023.09.
[30] Yusoff, R., Ahmad, A., & Mohamed, S. (2021). Precision Agriculture in TVET: A Pathway to Sustainable Farming Practices in Malaysia. *Journal of Sustainable Agriculture*, 39(3), 120-136.
[31] Zhang, X., Xu, Z., & Liu, Y. (2019). Technological Innovations in Agriculture: Implications for Vocational Training. *Technology in Agriculture Journal, 12(2), 112-127*.