Experiential Learning and Technology Acceptance: Agrotechnology Students' Readiness to Adopt Industrial Internet of Things in Smart Fertigation

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ABSTRACT

The integration of digital technologies into agricultural education is increasingly important for preparing graduates for Agriculture 4.0. Industrial Internet of Things (IIoT) technologies offer opportunities for automated monitoring, remote management and data-driven agricultural production. This study examined agrotechnology students' knowledge, perceptions and acceptance of IIoT following structured experiential exposure to an IIoT-enabled fertigation system. A quantitative cross-sectional survey was conducted among 100 undergraduate students at Universiti Malaysia Kelantan, Malaysia. Students participated in face-to-face technology knowledge-transfer activities involving theoretical instruction and practical exposure at a fertigation site. A structured questionnaire comprising 47 closed-ended items was administered using a five-point Likert scale, and data were analysed using descriptive statistics and reliability analysis in SPSS version 26.0. The findings indicated high levels of knowledge and understanding of IIoT applications in agriculture (M = 4.34, SD = 0.80), positive perceptions and willingness towards IIoT (M = 4.35, SD = 0.62), and favourable attitudes, acceptance and readiness **(**M = 4.44, SD = 0.79**).** Thus, students showed a significant desire to use the technology in agricultural activities and take part in IIoT-related training. However, they highlighted the importance of skilled operators, technical guidance, affordability and service availability. The findings suggest that structured experiential exposure provides a relevant educational context for developing students' understanding and readiness towards IIoT and supports the integration of practical, industry-linked digital technology competencies into agricultural education curricula.

Keywords:
Industrial Internet of Things; Experiential learning; Technology acceptance; Technology readiness; Agrotechnology education; Smart fertigation; Agriculture 4.0

Introduction

The rapid development of digital technologies is transforming the agricultural sector, with production increasingly supported by sensors, automation, connected devices, remote monitoring and data-driven decision-making. This transformation, commonly associated with Industry 4.0 (IR4.0) and Agriculture 4.0, creates new expectations for agricultural graduates who will enter an increasingly technology-oriented workforce. In Malaysia, the National Agrofood Policy 2021–2030 (NAP 2.0) emphasises agricultural modernisation, productivity, profitability, food security and improved agricultural support services (MAFI, 2021). The integration of Industry 4.0 technologies is therefore increasingly relevant to both agricultural production and education, particularly in efforts to improve agricultural productivity, efficiency and competitiveness through precision agriculture and data-driven approaches (Mohamed et al., 2021; Wee & Lim, 2022).

This transformation also increases the need for agricultural education to develop practical competencies aligned with emerging industry requirements. The National TVET Policy 2030 emphasises the development of highly skilled human resources capable of responding to technological transformation and emerging industries (Majlis TVET Negara, 2024). For agricultural students, this means that conventional agricultural knowledge increasingly needs to be complemented by the ability to understand and apply digital technologies in real production environments. The Internet of Things (IoT) provides important opportunities in this regard by connecting sensors, devices and communication platforms to support monitoring, automation and decision-making in agriculture (Antony et al., 2020; Elijah et al., 2018; Ndjuluwa et al., 2023).

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Within this broader IoT ecosystem, the Industrial Internet of Things (IIoT) focuses on interconnected sensing, communication and control technologies used within operational and industrial processes. Compared with consumer-oriented IoT applications, IIoT generally involves more complex systems, larger-scale networks and greater requirements for reliability, control and data security (Devrath & Kadam, 2018; Almadani & Mostafa, 2021). In agriculture, IIoT-enabled systems can support crop and environmental monitoring, irrigation and nutrient management, and remote farm operations. These capabilities are particularly relevant to fertigation, where water and nutrients must be managed continuously according to crop requirements. Appropriate fertigation management can improve water and nutrient-use efficiency, but effective implementation also requires adequate technical knowledge and operational skills (Kim et al., 2022; Wang et al., 2021). Integrating IIoT into fertigation can therefore provide an authentic context for students to understand the relationship between agricultural production, automation and digital technologies.

The integration of Industrial Internet of Things (IIoT) technologies into agricultural production has created new opportunities for improving farm monitoring, resource management and operational efficiency. In smart fertigation systems, IIoT applications enable the integration of sensors, monitoring platforms and automated control mechanisms to support more precise management of water and nutrient delivery. However, the successful adoption of these technologies depends not only on the availability of technological infrastructure but also on users' knowledge, perceptions and readiness to apply them in practical agricultural settings. For undergraduate agrotechnology students, exposure to IIoT-based agricultural technologies is particularly important because they represent potential future users and practitioners of digital agricultural systems. Therefore, higher education institutions need to provide learning experiences that connect theoretical knowledge with practical applications. Such exposure may help students understand the relevance of IIoT technologies to agricultural production and develop more positive perceptions towards their potential adoption.

However, exposure to agricultural technology should extend beyond learning how to operate a particular device. Students also need to understand the potential benefits, limitations, risks and implementation requirements associated with digital technologies. Previous studies have identified technical competence, financial constraints, infrastructure, digital literacy, training and technology support as important considerations in agricultural technology adoption (García et al., 2024; Nor Diana et al., 2024). This is particularly relevant for agricultural students, who represent a potential future workforce for Agriculture 4.0 and may subsequently work as farm managers, agricultural officers, consultants, extension personnel, entrepreneurs or technology users (Barman et al., 2026). Developing their knowledge and confidence in using emerging technologies during higher education may therefore contribute to their preparedness for technology-oriented agricultural environments.

In the context of agricultural education, experiential learning provides an approach through which students develop knowledge by connecting theoretical concepts with direct experiences and practical applications. Based on Kolb's (1984) Experiential Learning Theory (ELT), learning involves four interconnected stages: concrete experience, reflective observation, abstract conceptualisation and active experimentation. Within agrotechnology education, an IIoT-enabled fertigation system can serve as an authentic learning environment in which students observe sensor operations, examine real-time agricultural data, understand automated irrigation and nutrient delivery, and relate technological functions to actual crop production requirements. Such exposure allows students to move beyond conceptual understanding towards a more practical appreciation of how digital technologies operate within agricultural production systems.

Experiential learning provides a relevant educational approach for connecting theoretical knowledge with practical technology applications. Instead of learning about IIoT only in the classroom, students may see and engage with technology in a real agricultural production setting. Students may gain a more tangible grasp of how digital technology might be used as a result of this exposure, which also enables them to identify their operational needs and constraints. Although the application of digital technologies in agriculture has received increasing attention, understanding students' readiness to adopt IIoT technologies within agricultural education remains important. In particular, there is a need to examine how students perceive the usefulness and ease of use of IIoT-based smart fertigation technologies following structured learning and practical exposure. Addressing this issue may provide useful insights for improving teaching and learning approaches in agrotechnology programmes, particularly in preparing graduates to engage with the digital transformation of the agricultural sector.

Therefore, after being exposed to an IIoT-enabled fertigation system in a systematic manner, undergraduate agrotechnology students at Universiti Malaysia Kelantan (UMK) were the subject of this study. Students' knowledge and comprehension, attitudes, acceptance, and preparedness for IIoT in agricultural activities were then assessed using a structured questionnaire. The study adds to the conversation of preparing next professional agricultural graduates that utilize the digital transformation such as IIoT in farming by offering a descriptive evaluation of students' IIoT related knowledge and technological preparedness within an agricultural education framework.

Literature Review

Agriculture 4.0 and the Digital Transformation of Agriculture

Agriculture 4.0 represents the integration of digital technologies into agricultural production, management and decision-making, including the Internet of Things (IoT), sensors, automation, artificial intelligence, robotics, cloud computing and data analytics (Abbasi et al., 2022; Dhal et al., 2024). Since digital agriculture seeks to develop more interconnected data drive, and responsive production systems that can enhance productivity, resource management, and decision making, its significance extends beyond the adoption of specific technology (Abbasi et al., 2022; Elijah et al., 2018). However, the infrastructure, cost, technical complexity, connectivity, and consumers' technological preparedness contribute to have an impact on the shift (Abbasi et al., 2022).

The IoT is a key technological foundation of Agriculture 4.0 because it enables physical devices, sensors and control systems to communicate and exchange information. In agricultural production, IoT- and IIoT-enabled systems can support environmental monitoring, irrigation and fertigation management, crop monitoring and automated input delivery (Dhal et al., 2024; Elijah et al., 2018). These technologies can reduce dependence on manual monitoring while providing timely information for agricultural decision-making. Consequently, future agricultural professionals require not only conventional agricultural knowledge but also an understanding of how digital technologies can be applied to production systems (Dhal et al., 2024).

This development has important implications for agricultural higher education. Students entering the agricultural workforce may increasingly encounter sensor-based monitoring, automated production systems and digital farm management platforms. Evidence from Malaysian agricultural graduates indicates that perceived usefulness, perceived behavioural control and social influences are associated with IoT readiness, leading to recommendations for IoT-related subjects and hands-on training in agricultural education (Zainal Abidin et al., 2024). Thus, agricultural education provides an important context for developing students' knowledge and understanding of IIoT before they enter technology-enabled agricultural environments.

Industrial Internet of Things in Agricultural Production

The Internet of Things represents one of the key technological foundations of Agriculture 4.0. IoT systems connect physical devices, sensors and control systems through communication networks, allowing agricultural conditions to be monitored and, in some applications, controlled remotely (Elijah et al., 2018; Dhal et al., 2024). When these principles are applied to industrial and production-oriented agricultural environments, the Industrial Internet of Things (IIoT) provides opportunities for greater integration between sensing, communication, automation and decision-making. In agricultural production, IoT- and IIoT-enabled systems can support functions such as environmental monitoring, irrigation management, fertigation control, crop monitoring and automated input delivery (Dhal et al., 2024; Elijah et al., 2018). Such systems can potentially reduce dependence on manual monitoring and enable agricultural operators to respond to changes in crop and environmental conditions more efficiently. The value of these technologies is therefore associated not only with automation but also with their capacity to generate timely information that can support agricultural decision-making (Dhal et al., 2024).

The increasing use of connected technologies also changes the nature of agricultural work. Instead of relying exclusively on direct physical observation of crops, farmers and agricultural personnel can obtain information through sensors, dashboards and automated monitoring systems. This creates opportunities for more precise management of water, fertilizers and other agricultural inputs (Dhal et al., 2024). At the same time, the successful implementation of

these systems depends on reliable infrastructure, connectivity, affordability, technical support and users' ability to understand and operate the technology (Abbasi et al., 2022; Dhal et al., 2024). These considerations are particularly relevant in agricultural education. Students may understand the theoretical benefits of digital agriculture without necessarily possessing the practical confidence required to interact with an operational system. Consequently, exposure to functioning IoT or IIoT systems may provide an important bridge between theoretical knowledge and practical agricultural technology competencies (Kolb, 1984; Zainal Abidin et al., 2024). The importance of practical exposure is consistent with recent educational initiatives involving IoT-based agricultural systems, which have been designed to provide students with hands-on experience in both agricultural production and IoT technology to prepare students for industry requirements (Khairuddin et al., 2024; Thiagarajah et al., 2024; Abd Rahman & Shamsi, 2024).

Technology Acceptance and IIoT Adoption among Agricultural Students

The Technology Acceptance Model (TAM), introduced by Davis (1989), provides a theoretical basis for understanding individuals' acceptance of technology. The model identifies perceived usefulness and perceived ease of use as two important determinants influencing users' attitudes towards a particular technology. Perceived usefulness refers to the extent to which an individual believes that using a technology can improve task performance, whereas perceived ease of use refers to the extent to which an individual believes that using the technology requires minimal effort. These perceptions influence users' attitudes and intentions towards adopting a technology. Thus, technological availability alone does not necessarily lead to adoption, as users must also recognise its practical benefits and consider it manageable within their operating environment.

In agricultural education, these dimensions are relevant to understanding students' perceptions of IIoT-based smart fertigation technologies. Students may perceive such technologies as useful when they recognise their potential to improve crop monitoring, resource utilisation and fertigation management. Similarly, their perceptions of ease of use may be influenced by their understanding of the technology, familiarity with digital interfaces and opportunities to interact with the system. Therefore, TAM provides a relevant theoretical perspective for examining students' perceptions and acceptance of emerging digital agricultural technologies.

Recent evidence supports the relevance of technology acceptance perspectives in agriculture. Gouroubera et al. (2026), through a meta-analytic structural equation modelling study involving 33 studies and 13,660 farmers across 17 countries, found that perceived usefulness remained an important factor associated with attitudes towards digital agricultural technologies, although the influence of perceived ease of use varied across contexts. This implies that users' recognition of the practical advantages of agricultural technology together with their adoption circumstances, plays an important role in technology acceptance.

Empirical evidence from Malaysia also highlights the relationship between students' knowledge and technology acceptance. Abd Rahman and Shamsi (2024) examined IoT awareness and acceptance among 196 agrotechnology students at Universiti Teknologi MARA. Their multiple regression analysis showed that social influence ($B = 0.325$, $p < 0.001$) and knowledge ($B = 0.233$, $p = 0.009$) were significant predictors of IoT acceptance. The model explained 44.6% of the variance in students' acceptance ($R^2 = 0.446$). These findings indicate that students' understanding of IoT and their social environment are relevant considerations when examining technology acceptance.

Similarly, Zainal Abidin et al. (2024) investigated IoT readiness among 204 agricultural graduates from four Malaysian universities. Their findings identified perceived usefulness as the strongest predictor of IoT readiness ($\beta = 0.532$, $p < 0.001$), followed by social influences ($\beta = 0.193$, $p = 0.004$) and perceived behavioural control ($\beta = 0.132$, $p = 0.034$). The regression model explained 65.0% of the variance in readiness ($R^2 = 0.650$), while attitude was not a significant predictor. The findings highlight the importance of recognising the practical benefits and perceived value of IoT technologies when preparing future agricultural professionals for digital technology adoption.

Unlike practising farmers, students may not yet be responsible for technology investment or farm-level adoption decisions. Their perceptions may instead be influenced by knowledge, educational exposure, confidence and perceived relevance to future careers. Therefore, examining students' knowledge, perceptions, willingness and attitudes towards IIoT can provide an early indication of their preparedness for technology-enabled agricultural environments.

In this study, TAM serves as an interpretive theoretical lens for discussing students' perceptions and acceptance of IIoT-based smart fertigation technologies. The study focuses on descriptive responses concerning students' knowledge, perceptions, attitudes and readiness. It does not attempt to statistically test the causal relationships between the individual TAM constructs.

Experiential Learning and Readiness for Digital Agriculture

Knowledge of IIoT alone may not be sufficient to develop readiness for its practical application. Digital agricultural systems often involve interactions among sensors, software, communication networks, control systems and agricultural processes (Dhal et al., 2024). Experiential learning therefore provides a useful educational perspective for connecting technological knowledge with practical agricultural applications. Kolb (1984) conceptualised learning as a process through which knowledge develops through the transformation of experience. The experiential learning cycle comprises four stages: concrete experience, reflective observation, abstract conceptualisation and active experimentation. These stages highlight the importance of connecting direct experience with reflection, conceptual understanding and the practical application of acquired knowledge.

In the context of agricultural education, practical exposure to IIoT-based smart fertigation systems can provide students with opportunities to observe and interact with technologies used in modern agricultural production. For example, students may gain practical experience in understanding sensor functions, monitoring environmental parameters, observing automated irrigation processes and interpreting information generated through digital monitoring platforms. These activities can help connect theoretical concepts with actual agricultural applications.

The relationship between practical learning and technology acceptance is also supported by studies examining students' knowledge and readiness towards IoT. Abd Rahman and Shamsi (2024) found that students' knowledge was a significant predictor of IoT acceptance ($B = 0.233$, $p = 0.009$), while Zainal Abidin et al. (2024) identified perceived usefulness as the strongest predictor of IoT readiness among Malaysian agricultural graduates ($\beta = 0.532$, $p < 0.001$). Although these studies did not directly measure the effects of experiential learning, their findings highlight the relevance of students' technological knowledge and recognition of practical benefits when examining acceptance and readiness.

Empirical studies have demonstrated the potential of integrating practical and technology-supported activities into agricultural and STEM education. Thiagarajah et al. (2024) developed an IoT-based smart farming workshop model that combined theoretical instruction with hands-on learning activities. The programme involved 350 secondary school students and 50 teachers from four schools in the Klang Valley, while a separate workshop was conducted for 60 teaching undergraduates. Their post-programme analysis reported a 57.2% average increase in awareness of STEM-related careers among student participants. In addition, Z-score analysis indicated general improvements in participants' awareness and understanding of IoT, 5G and smart farming technologies, with increases in average scores across the post-tests. These findings provide empirical support for combining theoretical instruction with practical activities to improve learners' awareness and understanding of emerging agricultural technologies.

Taken together, these findings suggest that exposure to IIoT technologies within authentic agricultural learning environments may provide students with opportunities to develop a more practical understanding of the technologies, including their functions, operational requirements, potential benefits and limitations. Such exposure may help students connect theoretical knowledge with real-world agricultural applications and recognise the relevance of digital technologies to agricultural production. This provides an important rationale for examining students' knowledge, perceptions, attitudes and readiness following structured theoretical and practical exposure to IIoT-based smart fertigation technologies.

In this study, experiential learning provides the pedagogical perspective for understanding the educational context in which students encounter IIoT technologies. However, the study does not directly measure changes across the four stages of Kolb's experiential learning cycle. Instead, the practical learning activities are considered an educational context for examining students' reported knowledge, perceptions and readiness towards IIoT adoption.

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Benefits, Barriers and Future Agriculture Technopreneur

The potential benefits of agricultural IIoT include improved monitoring, labour savings, more efficient resource utilisation, timely information and greater consistency in agricultural operations (Dhal et al., 2024). Example like cost, infrastructure, connectivity, system complexity, maintenance requirements and lacks of technical assistance, however, may limit the adoption (Abbasi et al., 2022; Dhal et al., 2024). Therefore, it is important to take into account both consumers' awareness of implementation, obstacles and positive attitudes toward IIoT. Technology acceptance is more meaningful when users perceive that the technology can realistically be implemented and supported within their operating environment (Gouroubera et al., 2026).

Training and institutional support are therefore important for developing agricultural technology competencies. Malaysian evidence indicates that IoT-related subjects and practical training can strengthen graduates' preparedness for technological integration (Zainal Abidin et al., 2024), while research among Malaysian agricultural students highlights the importance of knowledge, awareness and attitudes in smart farming acceptance (Majid et al., 2025). Universities can consequently contribute to digital agricultural readiness by combining agricultural knowledge with practical technology exposure and collaboration with technology providers and agricultural stakeholders.

Agriculture 4.0 may also create new employment and entrepreneurial opportunities. Graduates with combined agricultural and digital competencies may participate in services such as IoT installation, sensor-based monitoring, automated fertigation, data interpretation and precision agriculture consultancy (Abbasi et al., 2022; Dhal et al., 2024). Exposure to IIoT can therefore be viewed not only as preparation to become technology users but also as an opportunity to develop future agriculture technopreneur who can identify technology-based solutions and services for agricultural production.

However, the specific relationship between students' IIoT knowledge, perceptions, attitudes and readiness and their potential engagement with technology-oriented agricultural opportunities remains insufficiently examined, particularly within the Malaysian agricultural education context. This gap provides the rationale for the present study, which examines agrotechnology students' readiness to adopt IIoT technologies in smart fertigation applications following structured theoretical and practical exposure.

Theoretical and Conceptual Perspective

This study draws on two complementary theoretical perspectives: Experiential Learning Theory (ELT) and the TAM. ELT, proposed by Kolb (1984), provides the pedagogical perspective for understanding the importance of practical learning experiences in developing students' knowledge and understanding of IIoT-based smart fertigation technologies. Meanwhile, TAM (Davis, 1989) provides the technology acceptance perspective for interpreting students' perceptions of the usefulness and ease of use of these technologies.

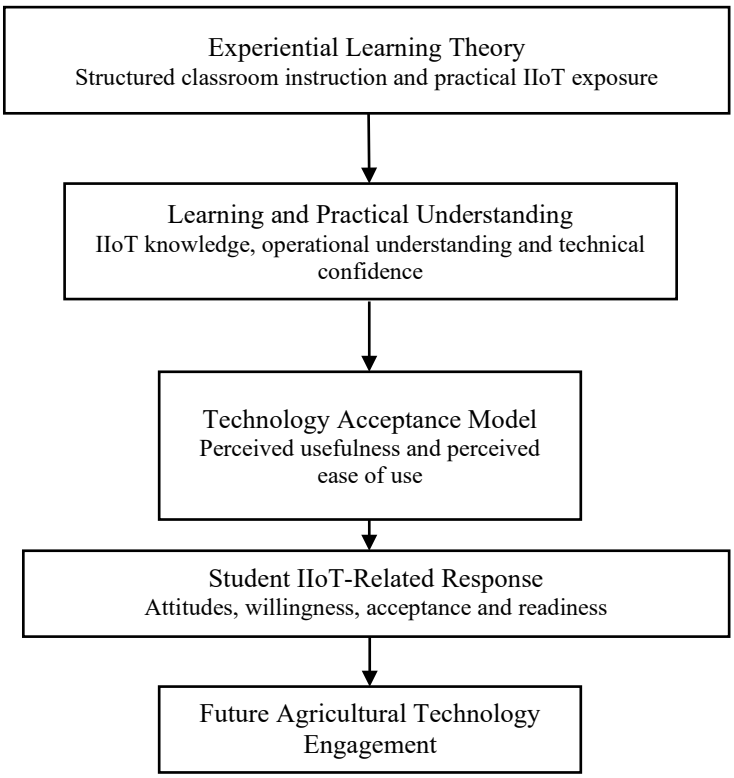
The relationship between these perspectives provides the conceptual foundation for examining students' readiness to adopt IIoT technologies in agricultural applications. Practical exposure to smart fertigation systems offers students opportunities to connect theoretical knowledge with real-world technological applications. Their understanding and perceptions of these technologies can subsequently be examined through their reported attitudes, willingness and readiness to adopt them.

Accordingly, this study uses experiential learning as the educational context and TAM as the theoretical lens for interpreting technology acceptance. The framework is intended to guide the interpretation of the descriptive findings rather than to establish or statistically test causal relationships among the theoretical constructs.

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Figure 1

Theoretical and Conceptual Framework for Interpreting Students' IIoT Technology Readiness Following Structured Experiential Exposure



Research Objectives

Accordingly, the research objectives of this study are as follows:

1. To assess agrotechnology students' knowledge and understanding of IIoT technology in smart fertigation application.
2. To examine students' perceptions of the usefulness and applicability of IIoT technologies in smart fertigation application. Attitudes and willingness towards the adoption and use of IIoT technology in agricultural activities.
3. To evaluate students' attitudes, willingness and readiness to use IIoT-based smart fertigation technologies.

By analysing the IIoT acceptability from the viewpoint of students as future agricultural professionals rather than just farmers, the study adds to the body of literature on agricultural education. More significantly, it emphasizes how students' preparedness for digitally altered agricultural industries is developed through hands-on technology experience.

Research Questions

The present study was guided by the following research questions:

1. What is the level of agrotechnology students' knowledge and understanding of IIoT technology and its applications in agricultural production?
2. What are students' perceptions, attitudes and willingness towards the adoption and use of IIoT technology in agricultural activities?
3. What is the level of students' acceptance and readiness to use IIoT technology, including perceived benefits, confidence, learning intention, technical support needs and perceived potential for agricultural development?

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Methods

Research Design

This study employed a quantitative cross-sectional descriptive survey design to examine agrotechnology students' knowledge, perceptions, attitudes and readiness towards adopting Industrial Internet of Things (IIoT) technologies in smart fertigation applications. Data were collected using a structured questionnaire following students' participation in organised learning activities involving theoretical instruction and practical exposure to IIoT-based fertigation technologies. The purpose of the exposure was to familiarize students with the basic ideas, features, and possible agricultural uses of IIoT while giving them the chance to see the technology in a real-world agricultural production setting.

Students filled out a standardized questionnaire with mostly five-point Likert-scale items after the exposure exercises. The descriptive survey approach was considered appropriate because the study aimed to obtain an overview of students' responses and perceptions at a particular point in time. The study did not employ an experimental or quasi-experimental design, and therefore, the findings are interpreted descriptively rather than as evidence of a causal effect of practical exposure on technology acceptance.

Samples and Population / Participants

The target population comprised undergraduate students enrolled in the Agrotechnology programme at Universiti Malaysia Kelantan (UMK). A non-probability total population sampling approach, also known as a census approach, was employed. Under this approach, all students who met the eligibility criteria within the identified student cohort were invited to participate in the study rather than selecting a smaller sample through random sampling. A total of 100 students participated in the survey and their responses were included in the data analysis. Participation was voluntary, and the questionnaire was administered to obtain students' responses following their exposure to the relevant theoretical and practical learning activities. This sampling approach enabled the study to obtain responses from the entire eligible cohort available for the study. The participants were deemed pertinent to the study because, as Agriculture 4.0 is incorporated into agricultural production and management, agricultural graduates are likely to come into contact with digital technology (Abbasi et al., 2022; Dhal et al., 2024). Through organized knowledge-transfer activities that included both theoretical instruction and hands-on experience with an IIoT-enabled fertigation system, the participants were introduced to IIoT.

While the practical component gave students first-hand experience with IIoT in a fertigation production setting, the theoretical component presented them to the fundamental ideas, capabilities, and uses of IIoT in agriculture. After completing these exercises, participants answered a questionnaire that evaluated their knowledge, attitudes, willingness, preparedness, acceptability, and perspectives on IIoT. In the context of agricultural higher education, the sample was deemed suitable for an exploratory descriptive evaluation of students' attitudes and technological preparedness. Instead of concentrating on seasoned commercial farmers, the study deliberately targeted students as prospective future agricultural professionals and technology users.

Research Instruments

A self-administered structured questionnaire with 47 closed-ended items which was newly developed by the researcher specifically for this study was used to gather data. The items were formulated based on the research objectives, the context of IIoT adoption in smart fertigation, and the researcher's professional expertise in IoT and smart farming. The purpose of the questionnaire was to gather data on the demographic and background characteristics of the respondents as well as to evaluate their knowledge, attitudes, perceptions, and readiness of adopting IIoT technology in smart fertigation applications. There were four sections on the questionnaire. The demographic and background characteristics of the respondents were gathered in Section A. Students' broad knowledge and comprehension of IIoT applications in farming were evaluated in Section B. Students' opinions, attitudes, and willingness to embrace and use IIoT in agricultural operations were investigated in Section C. Students' attitudes, acceptability, and preparedness for IIoT were evaluated in Section D.

Before data collection, the questionnaire was reviewed by the co-authors to identify and improve potential issues relating to wording, grammar, language accuracy and statement clarity. However, formal external expert validation and a systematic content validity assessment were not conducted prior to data collection. This is acknowledged as a limitation of the instrument development process.

Thirty IIoT-related items were included in the dependability analysis, with ten items in each of Sections B, C, and D. A five-point Likert scale, with 1 denoting strongly disagree and 5 denoting strongly agree, was used to measure the attitudinal and perception-based items. Positive reactions to the corresponding IIoT-related comments were indicated by higher scores. After students had engaged in structured IIoT knowledge-transfer activities that included both theoretical education and hands-on experience at a fertigation site, the questionnaire was given to them. Prior to the main data collection, a preliminary readability and clarity exercise was conducted to assess the comprehensibility of the questionnaire items. This exercise focused on ensuring that the statements and response options were understandable and appropriate for the intended student respondents. Feedback obtained during this process was considered in refining the wording and presentation of the questionnaire before its administration in the main study. However, this preliminary exercise should not be interpreted as formal expert validation of the instrument.

Data Analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS), version 26.0. Descriptive statistics, including frequency, percentage, mean and standard deviation, were used to summarise respondents' characteristics and responses to the IIoT-related questionnaire items. Item-level means and standard deviations were calculated to describe students' overall responses to the five-point Likert-scale statements, while frequencies and percentages indicated the distribution of responses across the respective categories. For the interpretation of mean scores, a consistent classification scheme was applied across all questionnaire domains. The classification was based on the five-point Likert scale and used to distinguish the levels of students' responses as showed in the Table 1.

Table 1
Classification to Distinguish the Level of Student's Responses

Mean score	Interpretation
1.00 – 1.80	Very low
1.81 – 2.60	Low
2.61 – 3.40	Moderate
3.41 – 4.20	High
4.21 – 5.00	Very high

The analysis focused on descriptive statistics, as the study aimed to examine students' reported knowledge, perceptions, attitudes, acceptance and readiness towards IIoT following structured exposure. No inferential statistical analyses were performed.

Reliability Analysis

Reliability analysis was conducted using Cronbach's alpha (α) to assess the internal consistency of Sections B, C and D. The analysis involved 100 student respondents and 30 IIoT-related items. As presented in Table 2, all three sections demonstrated excellent internal consistency**.** A Cronbach's alpha of 0.914 was obtained from Section B, which assessed students' knowledge and comprehension of IIoT. An alpha of 0.939 was found in Section C, which measured attitudes, willingness, and perceptions toward IIoT. With an alpha of 0.952, Section D, which evaluated attitudes, acceptance, and preparedness for IIoT, showed the highest section-level coefficient. The overall Cronbach's alpha was 0.971 when the 30 items from Sections B–D were evaluated collectively.

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Table 2
Reliability Analysis of the Questionnaire

Questionnaire section	Construct measured	Items	N	Cronbach's α	Interpretation
Section B	Knowledge and understanding of IIoT	10	100	0.914	Excellent
Section C	Perceptions, willingness and views towards IIoT	10	100	0.939	Excellent
Section D	Attitudes, acceptance and readiness towards IIoT	10	100	0.952	Excellent
Overall B–D	All multi-item constructs	30	100	0.971	Excellent

The coefficients show that each questionnaire section's items have a high degree of internal consistency. The dependability coefficient was highest in Section D (α = 0.952), followed by Section C (α = 0.939) and Section B (α = 0.914). Strong consistency among the 30 IIoT-related elements is further demonstrated by the overall coefficient of 0.971. Nevertheless, the overall coefficient should not be interpreted as evidence that all 30 items measure a single underlying construct. The questionnaire was intentionally divided into conceptually distinct dimensions covering knowledge, perceptions and willingness, and attitudes, acceptance and readiness. Therefore, the section-specific Cronbach's alpha values provide the more appropriate evidence of internal consistency for the respective dimensions. This interpretation is consistent with the recommendation that Cronbach's alpha should be considered alongside the conceptual structure and characteristics of the measurement instrument (Tavakol & Dennick, 2011).

Results

Socio-demographic Characteristics

In recent years, the agriculture industry has witnessed significant advancements in technology for example like the Industrial Internet of Things (IIoT) which is playing a pivotal role for crop production through fertigation planting system. The demographic characteristics provide important contextual information for interpreting the findings because exposure to farming, family agricultural background and previous experience may influence students' perceptions of IIoT. The socio demographic profile of the respondents was displayed in Table 3. 100 students were involved in total, and every single one of them answered to the survey. Male (55%) and female (45%) respondents made up each half of the sample. Malay students made up the bulk of those who participated in the poll, followed by Bumiputera from Sabah and Sarawak, and Indian and Chinese students. Regarding the parents of the pupils, it was discovered that the majority of them (55%) did not work in or have previous experience with the farm industry.

According to Table 3, the majority of students (48%) have had less than one year of farming experience, followed by students with experiences of between one and three years (32%), four to seven years (14%), and, surprisingly, more than seven years (5%) of farming experience. This may be because some members of the respondents' families are involved in farming and work in the industry, passing on knowledge and skills to them, or it may simply be a result of chance. Even though research has shown that younger generations are not interested in working in or pursuing careers in agriculture due to career perceptions and the lack of social mobility, this study's findings have revealed something different, with half of the students continuing their studies because they have prior farming experience and are aware of the industry's potential (Shaharudin and Rahim, 2020). A further 68% of respondents have family farms with less than an acre of land, followed by 18 students (18%) with farms between one and three acres, 5% of students with farms between four and seven acres, and one responder with farms between seven and ten acres. Surprisingly, there were about 8 students (8%) that their family had farm sizes more than 10 acres. Vegetables (52%) were the most grown crop among the respondents, followed by oil palm (27%), corn (25%), pineapple (20%), paddy (18%), rubber (13%), and durian (12%), which was the least.

Table 3
Socio-demographic Profiles of Students

Profile	Frequency (n)	Percentage (%)
Gender		
Male	55	55

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Profile	Frequency (n)	Percentage (%)
Female	45	45
Race		
Malay	68	68
Chinese	9	9
Indian	9	9
Bumiputera Sabah & Sarawak	14	14
Parents work in Agriculture sector		
Yes	45	45
No	55	55
Student farming experiences		
Below 1 year	48	48
1 – 3 years	32	32
4 – 7 years	14	14
7 – 10 years	3	3
> 10 years	3	3
Family farm size (acre)		
Below 1	68	68
1 – 3	18	18
4 – 7	5	5
7 – 10	1	1
> 10	8	8
Major crop cultivated		
Paddy	18	18
Oil palm	27	27
Pineapple	20	20
Rubber	13	13
Durian	12	12
Corn	25	25
Vegetables	52	52

Note: n = 100

Students' Awareness on the Industrial Internet of Things (IIoT) for Agriculture

Several questions were posed to the students during the survey interview in order to gauge their awareness of the recent trend of IIoT utilization in the agriculture sector. The results are shown in Table 4. The majority of students who answered chose an amount below RM 15,000 as the most they would be ready to spend on an IIoT application for their farming activity. Only about 30% of students would be willing to spend between RM 15,000 and RM 20,000 for the IIoT application for farming, with the remaining students willing to spend between RM 20,000 and RM 25,000 (5% of students), RM 25,000 to RM 30,000 (1% of students), and no respondents willing to spend more than RM 30,000. This demonstrates the significance of offering IIoT products, services, and technology at reasonable prices so that more people may include this technological advancement into their regular farming operations. In addition, the majority of respondents (98% of respondents) indicated that they would embrace and use IIoT for their agricultural activity, and the majority (97%) also indicated that they would enrol in any future courses connected to IIoT for farming.

Furthermore, 96% of students said they would prefer to work as IIoT agropreneur after graduating if given the option to learn and use the technology in farming. This demonstrated that the use of cutting-edge technology in the agriculture sector, such as Industrial Internet of Things (IIoT) and other cutting-edge modern agro-technology available in the Industrial Revolution 4.0 (IR4.0), should be prioritized in the future. In addition, when asked which IIoT brand was currently popular in Malaysia for the agriculture sector, respondents overwhelmingly chose REDtone (43%), followed

by Maxis brand (32%), Xperanti IoT (20%), and Vnet (5%). The majority of the brand currently offered comprehensive IIoT services and products for use in Malaysia's farming industry and had proven to be acceptable and well-known among farmers and other agriculture businesses, including students who are still enrolled in agriculture courses.

Table 4
Students' Awareness on the Industrial Internet of Things (IIoT) for Agriculture

Profile	Frequency (n)	Percentage (%)
Willingness to pay for a maximum cost to use IoT for farming		
< RM 15,000	64	64
RM 15,000 – RM 20,000	30	30
RM 20,000 – RM 25,000	5	5
RM 25,000 – RM 30,000	1	1
> RM 30,000	0	0
Will use IoT to ease farming activity?		
Yes	98	98
No	2	2
Interested to join any course related to IoT for farming?		
Yes	97	97
No	3	3
Interested to become an IoT agropreneur?		
Yes	96	96
No	4	4
Type of IoT brand that you know available in the market?		
REDtone	43	43
Maxis	32	32
Xperanti IoT	20	20
Vnet	5	5

Note: n = 100

Students' Knowledge and Understanding of IIoT

The students demonstrated generally favourable responses regarding their understanding of IIoT applications in agriculture. The descriptive results showed in the Table 5 and describe high mean scores across most knowledge items, with the overall knowledge construct reported at approximately M = 4.34, SD = 0.80. The strongest knowledge-related response concerned awareness of the risks associated with IIoT use, followed by recognition of IIoT's ability to monitor crops across wider areas. Students also strongly recognised the potential of IIoT to save time and reduce labour. The original response distributions showed that more than 90% of students agreed or strongly agreed with several of these statements.

The finding is important because agricultural automation is not solely associated with productivity benefits. Students also recognised possible system breakdown, irrigation failure and crop-loss risks. This suggests that their understanding was not limited to the advantages of IIoT but also included awareness of operational risks. Interestingly, the lowest mean in this construct concerned the suitability of IIoT for open cultivation. The mean of approximately 3.91 indicates that students recognised practical constraints related to implementation cost and the limited availability of service providers. This is a valuable finding because it demonstrates that acceptance of IIoT does not necessarily

mean that students perceive the technology as universally applicable. Instead, students appear to distinguish between the technological benefits and the practical conditions required for successful implement.

Table 5
Students' Knowledge on the Industrial Internet of Things (IIoT) for Agriculture

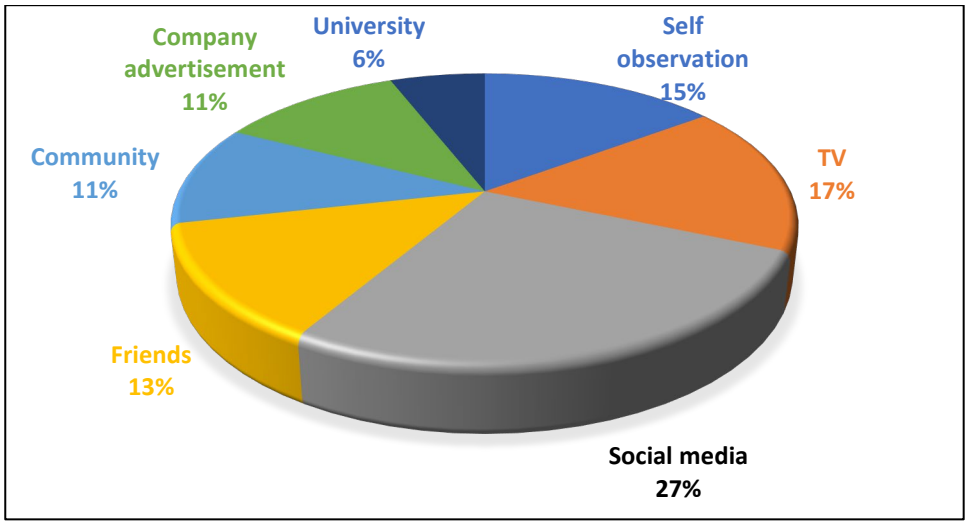
Knowledge statement	Mean ± SD*	Interpretation
IIoT is a technology introduced to ease fertigation work	4.35 ± 0.79	High
IIoT can monitor crop growth and provide inputs automatically	4.37 ± 0.80	High
IIoT can increase crop yield	4.41 ± 0.80	High
Students understand risks associated with IIoT	4.47 ± 0.75	High
IIoT can save time and reduce labour	4.43 ± 0.84	High
IIoT can monitor crops over wider areas	4.44 ± 0.78	High
Appropriate pesticide/herbicide dosage is important	4.29 ± 0.79	High
IIoT installation requires qualified operators	4.42 ± 0.80	High
IIoT may be less suitable for open cultivation because of cost/service limitations	3.91 ± 0.95	Moderate–high
Students obtain IIoT knowledge through multiple information sources	4.33 ± 0.71	High

Sources of IIoT information

Students obtained IIoT-related information from multiple channels. Figure 2 displayed the findings of the many information sources used by students studying agro-technology to keep up with emerging trends in agriculture technology, such as IIoT. Social media was identified as an important information source, followed by television, independent research, peers and other community-based sources. The study reported that approximately 27% of students identified social media as an information source, while television accounted for approximately 17%. This result emphasizes how younger agriculture students' use of informal digital learning is evolving. Technical knowledge, farmer experiences, technological marketing, and demonstrations may all be quickly accessed through social media. However, the quality of information gleaned from unofficial sources could differ.

As a result, universities can serve as a trustworthy source of organized IIoT knowledge. In addition to introducing students to the theoretical underpinnings of IIoT, formal agriculture education should give them the chance to assess commercial systems, contrast technology, and comprehend practical constraints. Additionally, just a tiny percentage of students cited university instructors as their source of IIoT information, according to the survey, which supports the idea that agricultural curricula should incorporate more IIoT content.

Figure 2
Source of Information about IIoT Technology Obtained by the Respondents.



Students' Perceptions and Willingness towards Practical IIoT Use

Students' opinions about the useful application of IIoT in agriculture were favourable. The simplified results for students' attitudes and willingness to employ IIoT technology in agriculture are summarized in Table 6. The findings show that students' interest in IIoT went beyond its technical aspects. Additionally, they showed a practical desire to use the technology, especially when there is sufficient technical assistance and reasonably priced services. Government support for IIoT-related start-up businesses had the strongest response, followed by a readiness to consult agricultural officers and qualified specialists. The dataset revealed a mean of 4.45 for obtaining expert advice and 4.49 for government support to build IIoT-related start-ups.

Technical advice is especially important. About 90.1% of respondents said they felt more confident when IIoT technology was supported by relevant agencies and technology companies, while about 91.9% of respondents agreed that they would seek help from agricultural officials, recognized agencies, or qualified specialists. These results show that students view the adoption of IIoT as an ecosystem rather than just a purchase of hardware or software. Technology suppliers, agricultural organizations, knowledgeable operators, training opportunities, and sufficient funding are all necessary for successful deployment.

Table 6
Students' Perceptions and Willingness towards IIoT

Perception and willingness statement	Mean ± SD*	Interpretation
Prefer IIoT over conventional methods	4.21 ± 0.82	High
IIoT is easier to manage and economical in the long term	4.16 ± 0.76	High
Will use IIoT if service providers and costs are reasonable	4.22 ± 1.02	High
Will seek advice from agricultural officers/experts	4.45 ± 0.75	Very high
More confident with technical guidance	4.38 ± 0.75	Very high
Will attend IIoT-related agricultural training	4.38 ± 0.75	Very high
IIoT exposure programmes should be expanded	4.38 ± 0.77	Very high
Government subsidies should support IIoT adoption	4.41 ± 0.72	Very high
Entrepreneurial training should be expanded	4.45 ± 0.73	Very high
Government support for IIoT start-ups should increase	4.49 ± 0.73	Very high

Students' Attitudes, Acceptance and Readiness towards IIoT

Students' attitudes, acceptability, and preparedness for IIoT were displayed in Table 7, which is the third significant construct that was looked at. A high overall acceptance means of roughly 4.44 ± 0.79 was found in the study analysis, suggesting a generally favourable attitude toward IIoT adoption in agriculture. The findings show that IIoT is widely accepted. The potential of IIoT to save time, boost crop output, and lower labour costs was the most substantive reaction. About 93.1% of students agreed or strongly agreed with this statement, according to the frequency distribution. In a similar vein, students demonstrated a significant desire to learn how to manage and run IIoT systems. From an educational standpoint, this finding is very encouraging because adopting technology necessitates both positive attitudes and a willingness to learn the skills required to use it. The findings also showed that students thought IIoT should be run by reliable and knowledgeable people.

This result confirms the previous conclusion that students understand the value of technical proficiency and expert assistance. The findings show a crucial mix of high acceptance and complexity awareness. Students acknowledged that IIoT needed technical know-how and reliable operators in addition to expressing enthusiasm for the technology. This implies that a somewhat practical grasp of the implementation requirements preceded acceptance. This is especially important from an educational standpoint. When suitable training opportunities are offered, students' willingness to learn and maintain IIoT shows that apparent technical complexity does not always deter learning. This lends credence to Kolb's (1984) experiential learning theory, which holds that students may make connections between abstract ideas and real-world applications through hands-on experience.

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Table 7
Students' Attitudes, Acceptance and Readiness towards IIoT

Attitudes, acceptance and readiness statement	Mean ± SD*	Interpretation
IIoT can save time, increase yield and reduce labour costs	4.51 ± 0.72	Very high
IIoT can increase crop yield and profit	4.31 ± 0.74	Very high
IIoT can reduce agricultural inputs	4.30 ± 0.77	Very high
IIoT should be operated by trusted and skilled parties	4.73 ± 0.85	Very high
IIoT can reduce risks associated with chemical handling	4.44 ± 0.77	Very high
IIoT can optimise spray application	4.35 ± 0.74	Very high
Students will consult agricultural experts when problems arise	4.43 ± 0.82	Very high
IIoT requires high technical skills and knowledge	4.35 ± 0.84	High
Students are willing to learn and maintain IIoT	4.52 ± 0.70	Very high
IIoT has substantial potential for agricultural development	4.51 ± 0.73	Very high

Overall interpretation of IIoT acceptance

The overall pattern is consistent across the three constructs and depicted in the Table 8. Students first demonstrated strong knowledge and understanding of IIoT, followed by favourable perceptions and willingness to use the technology, and finally very high acceptance and readiness. This pattern is theoretically meaningful. Knowledge can provide the foundation for positive perceptions, while positive perceptions can contribute to willingness and eventual acceptance. Students in this study who were aware of the possible advantages and drawbacks of IIoT also indicated a desire to receive technical assistance and training. The results also imply that adoption of IIoT is not seen by students as a straightforward substitute for current agriculture methods. Rather, they seem to acknowledge that IIoT necessitates institutional backing, financial resources, technological expertise, and suitable service providers.

Table 8
Overall Summary of the Three Principal Constructs

Construct	Original overall Mean ± SD*	Overall interpretation
Knowledge and understanding (Section B)	4.34 ± 0.80	High
Perceptions and willingness (Section C)	4.35 ± 0.62	High
Attitudes, acceptance and readiness (Section D)	4.44 ± 0.79	Very high

Discussions

Students' positive perceptions towards IIoT-based smart fertigation technologies may reflect their recognition of the potential usefulness of these technologies in agricultural production. Applications such as automated irrigation, real-time monitoring and more precise management of water and nutrients may contribute to students' understanding of the practical value of IIoT in improving agricultural operations. In addition, students' reported attitudes and willingness towards adopting these technologies provide an indication of their acceptance of digital agricultural applications. Familiarity with the technologies through theoretical instruction and practical exposure may help students better understand their functions and potential applications. This interpretation is consistent with the relevance of perceived usefulness and perceived ease of use in explaining technology acceptance. However, the present study primarily employed descriptive analysis and did not statistically examine the relationships between perceived usefulness, perceived ease of use, attitudes and behavioural intention as separate TAM constructs. Therefore, TAM is used as a theoretical lens for interpreting the findings rather than as a model that has been empirically tested in this study.

The results show that agricultural students' knowledge, attitudes, and preparedness for IIoT are generally favourable. Students saw how IIoT might enhance agricultural input management, productivity, labour efficiency, and crop monitoring. This favourable opinion aligns with the wider function of digital technologies in facilitating more data-driven and efficient agricultural production (Abbasi et al., 2022; Dhal et al., 2024). The results also imply that upcoming agricultural professionals might be open to digital solutions that tackle real-world farming problems. The results, however, show that adoption of technology goes beyond its alleged advantages. Affordability, technical support, service accessibility, and training were also noted by students as crucial factors to take into account when implementing IIoT. This is in line with earlier studies that demonstrate how infrastructure, technical assistance, and

favourable circumstances can affect the uptake of digital agricultural technology (Abbasi et al., 2022; Gouroubera et al., 2026). Students' readiness to ask agricultural officers and technical specialists for help emphasizes the value of institutional and technical support.

The findings also have implications for agricultural education. Such as highlight the importance of incorporating practical exposure to emerging digital agricultural technologies into agrotechnology education. Integrating IIoT-based smart fertigation systems into teaching and learning activities may help students understand the practical relevance of digital technologies and their potential applications in modern agricultural production. Students expressed willingness to participate in IIoT-related training despite recognising that the technology can be complex and requires technical knowledge. This implies that integrating IIoT into agricultural curriculum shouldn't always be hampered by complexity. Alternatively, practical learning can be organized in a step-by-step manner, starting with basic IoT ideas and moving on to sensors, connectivity, data monitoring, and automated agricultural systems. This method is in line with experiential learning, which aims to assist students make the connection between academic knowledge and practical applications (Kolb, 1984).

The significance of knowledge, real-world experience, and practical training in enhancing preparedness for smart farming and IoT technologies was also highlighted in earlier studies involving Malaysian agricultural students and graduates (Majid et al., 2025; Zainal Abidin et al., 2024). From an educational perspective, practical learning activities can complement classroom instruction by providing students with opportunities to observe and interact with technological systems used in agricultural operations. Such approaches may contribute to the development of graduates who are more familiar with digital agricultural applications and better prepared to engage with the evolving requirements of the agricultural sector. Higher education institutions may therefore consider strengthening the integration of smart farming technologies into relevant courses, laboratory activities and field-based learning experiences.

Therefore, encourage more cooperation in the development of IIoT competences between government, business, and academic institutions. While industry partners can offer cutting-edge technologies and technical know-how, universities can offer organized instruction and hands-on experience. Through training, technology-transfer initiatives, and assistance for young agricultural technology entrepreneurs, government organizations may promote these initiatives. However, the results should not be taken as proof that increased IIoT readiness or acceptance was brought about by experiential exposure. There was no pre-test, control group, or long-term follow-up in the cross-sectional design. Therefore, rather than proving a causal influence of the learning experience, the results should be interpreted as characterizing students' knowledge, perceptions, and preparedness after organized exposure.

Conclusion

The study shows that after organized exposure to an IIoT-enabled fertigation system, agrotechnology students reported high levels of knowledge, favourable impressions, and strong adoption of IIoT. Students saw how IIoT might increase agricultural productivity, lower labour costs, and enable more accurate crop management. Additionally, they showed a readiness to interact with new technologies through additional instruction, technical support, and lifelong learning. The potential relevance of digital agricultural technology to the development of future-oriented agricultural skills and career pathways is further highlighted by the considerable interest in IIoT-related courses and agricultural technopreneurs.

The results encourage a change in agriculture education from mostly theoretical technology awareness to learning that is practical and practice-oriented. Fertigation sites, smart farms, and technology-enabled field laboratories are examples of experiential learning environments that can be used to integrate IIoT into agricultural courses. Experiential learning provides a relevant pedagogical context for connecting classroom knowledge with practical applications, while the TAM offers a useful perspective for interpreting students' perception of technology usefulness and ease of use. However, exposure to devices alone is not enough for technology-oriented education to be effective. Additionally, students should learn how to troubleshoot, comprehend the limitations of technology, be economically conscious, and seek out the right technical assistance. All things considered the results show how important organized experience exposure is as a learning environment for preparing agrotechnology students for Agriculture 4.0. Integrating digital agricultural technologies into higher education, supported by industry collaboration and practical learning, can help

develop graduates who are not only knowledgeable in agriculture but also better prepared to understand, evaluate, adapt and innovate with technologies available in the agricultural sector.

Although the descriptive findings suggest positive student response, further research involving pre-test and post-test assessments, larger and more diverse student populations, and practical performance evaluations is recommended to provide stronger evidence of students' actual readiness to adopt IIoT technologies. Overall, the integration of smart fertigation technologies into agricultural education may contribute to preparing future graduates for the increasing digitalization of the agricultural sector.

Limitations and Future Studies

When interpreting the results, a number of restrictions should be taken into account. First, because the study only included undergraduate students from one university, its conclusions cannot be automatically applied to all Malaysian agriculture students. Second, rather than reflecting students' actual long-term technology adoption behaviour, the cross-sectional design and use of self-reported questionnaire results represent students' attitudes, knowledge, and expressed willingness. Third, the questionnaire offers a post-exposure assessment without a pre-exposure comparison because it was given after structured IIoT knowledge-transfer activities.

Pre-test and post-test designs should be used in future research to compare students' knowledge, attitudes, and acceptance of technology before and after practical IIoT learning. The results' generalizability would also be enhanced by multi-institutional research with bigger and more varied sample sizes. In order to provide a more comprehensive understanding of the technical, institutional, and economic variables driving agricultural IIoT adoption, future study might also involve farmers, agricultural extension officers, technology providers, and policymakers.

Although the questionnaire demonstrated high internal consistency, formal external expert validation and systematic content validity assessment were not conducted prior to data collection. Therefore, future studies should consider undertaking a structured validation process involving experts in IoT, smart farming, agricultural education and research instrument development to further establish the content validity of the instrument.

Conflict of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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