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Empowering hospitality students for smart service roles: The influence of psychological capital on technology readiness

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ABSTRACT

Smart technologies are transforming the hospitality industry, requiring future graduates to be prepared for service roles involving artificial intelligence, robotics, digital platforms, and automated systems. However, technology readiness is not shaped by digital exposure alone; it also depends on students' psychological capacity to adapt, persist, and respond positively to technological change. This study examines the influence of Psychological Capital on technology readiness among hospitality students at Universiti Teknologi MARA, Pulau Pinang Branch. Specifically, it investigates the effects of hope, self-efficacy, resilience, and optimism on students' readiness to engage with smart service technologies. A quantitative, cross-sectional research design was employed, and data were collected from 386 hospitality students using a structured questionnaire. The measurement instrument assessed Psychological Capital through four dimensions and technology readiness using items adapted from the Technology Readiness Index. Data were analysed using SPSS through reliability analysis, correlation analysis, and multiple regression analysis. The findings show that overall Psychological Capital significantly predicts technology readiness, explaining 23.4% of the variance. However, when the four dimensions were examined separately, only optimism emerged as a significant predictor of technology readiness. Hope, self-efficacy, and resilience showed positive but non-significant effects. These results suggest that students' positive expectations toward technology play a more central role in shaping readiness than general confidence, goal orientation, or adaptability alone. The study contributes to hospitality education by highlighting that preparing students for smart service roles requires more than technical training. Hospitality programmes should also cultivate positive psychological resources, particularly optimism toward technology, while strengthening hands-on exposure to smart hospitality systems. The findings offer practical implications for curriculum design,

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digital training, and graduate readiness in an increasingly technology-driven hospitality industry.

1. INTRODUCTION

The hospitality industry is undergoing rapid transformation as smart technologies such as artificial intelligence (AI), robotics, self-service systems, and the Internet of Things increasingly reshape operations, guest interactions, service delivery, and employee roles (Chung & Tan, 2025). These developments have created new expectations for hospitality graduates, who are no longer required merely to perform conventional service tasks but must also operate confidently within technology-enabled service environments. In this emerging landscape, technology readiness has become an important graduate attribute. However, although today's students are often described as "digital natives," familiarity with everyday digital tools does not automatically translate into readiness to use complex technologies in real hospitality workplaces (Sastaviana, 2022).

Smart hospitality work therefore requires more than technical exposure. Students must also possess the psychological capacity to manage uncertainty, learn unfamiliar systems, overcome technology-related anxiety, and remain positive when faced with digital change. Without these internal resources, students may experience discomfort, insecurity, hesitation, or resistance when required to work with AI-enabled systems, automated platforms, robotic services, or smart service applications. Technology readiness should therefore be understood not only as a technical or behavioural issue, but also as a form of psychological preparedness.

Psychological Capital, or PsyCap, offers a useful framework for understanding this form of readiness. PsyCap refers to an individual's positive psychological state, comprising hope, self-efficacy, resilience, and optimism (Luthans, Youssef, & Avolio, 2006). These dimensions are especially relevant to students preparing for smart service roles. Hope enables students to identify alternative pathways toward their goals; self-efficacy strengthens confidence in performing technology-related tasks; resilience supports recovery from setbacks; and optimism encourages positive expectations toward future work demands. Previous studies have linked PsyCap to learning motivation, academic performance, e-learning success, and digital readiness (Huang, 2022; Li, Che Hassan, & Saharuddin, 2023; Khoshaim, 2024; Liu, Ma, & Chen, 2024). Recent evidence also indicates that PsyCap is positively associated with technology readiness, particularly by strengthening the motivational side of adopting new technologies (Kadiyono & Pardosi, 2023).

Despite this growing body of evidence, the role of PsyCap in hospitality education remains underexplored. Existing studies of technology readiness commonly rely on the Technology Readiness Index (TRI), which explains individuals' predisposition to adopt technology through optimism, innovativeness, discomfort, and insecurity (Parasuraman, 2000; Parasuraman & Colby, 2015). While TRI is useful for identifying positive and negative predispositions toward technology, it does not fully explain the deeper psychological resources

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that enable students to remain confident, persistent, and adaptive when facing unfamiliar smart service systems. As a result, current discussions of hospitality students' technology readiness may be incomplete when they focus mainly on technological familiarity or adoption tendencies without considering the Psychological Capital that supports readiness.

Three gaps are particularly important. First, hospitality education has increasingly emphasised digital competence, but psychological preparedness has received less attention. Students may be exposed to technology in classrooms, simulations, or daily life, yet still lack the confidence and resilience required to use smart technologies in professional service situations. Second, many technology-readiness studies remain largely descriptive, focusing on whether individuals are ready rather than explaining the internal resources that help build readiness. Feelings of discomfort, insecurity, fear of failure, and low confidence may prevent students from embracing hospitality technologies even when such technologies are available. Third, although PsyCap has been widely examined in organisational behaviour, learning, and e-learning contexts, its application in hospitality education remains limited, particularly in explaining students' readiness for smart service roles.

These gaps are especially relevant in the Malaysian hospitality education context, where the industry is gradually moving toward digitalised and smart service operations. Hotels increasingly use technology to improve efficiency, personalise guest experiences, and respond to changing service expectations. However, the success of this transformation depends not only on the availability of technology, but also on the readiness of future hospitality employees expected to work with such systems. If hospitality students are technically exposed but psychologically unprepared, a mismatch may emerge between digital literacy and actual workplace readiness. This makes it important to examine the psychological enablers that may strengthen students' preparedness for technology-driven hospitality careers.

Accordingly, this study investigates the influence of Psychological Capital on Technology Readiness among hospitality students. Specifically, it examines whether hope, self-efficacy, resilience, and optimism contribute to students' readiness to embrace smart technologies in hospitality service environments. By integrating PsyCap with Technology Readiness, the study offers a more holistic understanding of graduate preparedness for smart hospitality work. The findings are expected to contribute to hospitality education by highlighting the need to develop not only students' digital knowledge, but also their psychological capacity to thrive in technology-enabled service roles.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Technology Readiness Index (TRI)

The Technology Readiness Index (TRI) explains an individual's predisposition to accept, use, and engage with new technologies (Parasuraman, 2000). Unlike models that focus mainly on actual technology usage or behavioural intention, TRI captures the psychological tendency that shapes whether individuals are ready to approach or avoid technology. This makes TRI relevant in hospitality education, where students may be exposed to digital tools but may differ in their willingness, confidence, and emotional comfort when using smart technologies in service-related contexts.

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TRI consists of four dimensions: optimism, innovativeness, discomfort, and insecurity (Parasuraman & Colby, 2015). Optimism and innovativeness are regarded as enablers because they encourage individuals to view technology as beneficial and to explore new digital systems. In contrast, discomfort and insecurity are considered inhibitors because they create hesitation, perceived loss of control, and doubt toward technology use. In educational settings, these dimensions are important because students' readiness to adopt technology is not determined only by access or exposure, but also by their attitudes, confidence, and perceived ability to manage technology-related demands. Recent studies have used TRI to examine readiness toward technology adoption in higher education and smart learning contexts, showing that readiness is a key factor in supporting successful technology implementation (Anam, Prayogo, & Susandri, 2022; Berényi & Deutsch, 2023; Oktadini, Fernando, & Sevtiyuni, 2023).

In the context of hospitality education, TRI provides a useful foundation for understanding how prepared students are to engage with smart service technologies such as AI-enabled guest communication, robotic service systems, property management systems, self-check-in kiosks, and digital reservation platforms. Students with stronger technology readiness are more likely to see these technologies as useful tools that can improve service efficiency and guest experience. However, students who experience discomfort or insecurity may avoid technology, become anxious when using unfamiliar systems, or perceive smart service tools as threatening to traditional hospitality roles.

Although TRI is widely recognised and has been applied across different service and educational contexts, it mainly measures individuals' predisposition toward technology rather than explaining the deeper psychological resources that may develop or strengthen readiness. This is where Psychological Capital provides an important extension. Hope, self-efficacy, resilience, and optimism may help explain why some students are more willing to persist, adapt, and remain confident when facing smart technologies. Previous research suggests that Psychological Capital is associated with digital readiness, e-learning satisfaction, and technology readiness (Huang, 2022; Kadiyono & Pardosi, 2023; Khoshaim, 2024). Therefore, integrating PsyCap with TRI allows this study to move beyond a descriptive understanding of readiness and offer a more holistic explanation of how hospitality students become psychologically prepared for smart service roles.

For this study, Technology Readiness is positioned as the dependent variable, while the four dimensions of Psychological Capital—hope, self-efficacy, resilience, and optimism—are treated as independent predictors. This framework is consistent with the argument that students' readiness for smart hospitality work is shaped not only by technological exposure, but also by the psychological strengths that support confidence, persistence, adaptation, and positive expectations toward technology-enabled service environments.

2.2 Psychological Capital and Technology Readiness

Psychological Capital is commonly conceptualised as a positive psychological resource consisting of hope, self-efficacy, resilience, and optimism (Luthans, Youssef, & Avolio, 2006). Rather than functioning only as separate traits, these four dimensions may operate collectively as a higher-order psychological resource that strengthens individuals' motivation, confidence, adaptability, and positive expectations when facing change. In technology-driven learning and work environments, students with stronger Psychological Capital may be better prepared to manage uncertainty, learn new systems, and respond positively to digital transformation.

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This is particularly relevant in hospitality education, where students are increasingly expected to prepare for smart service roles involving artificial intelligence, robotics, digital reservation platforms, property management systems, and self-service technologies. Prior studies have suggested that Psychological Capital is associated with digital readiness, e-learning engagement, academic performance, and readiness to adopt new technology (Ahmed, Ismail, & Fati, 2021; Huang, 2022; Kadiyono & Pardosi, 2023; Khoshaim, 2024). Therefore, students with higher overall Psychological Capital are expected to demonstrate stronger technology readiness.

Based on this argument, the following hypothesis is proposed:

H1: Psychological Capital has a significant positive influence on technology readiness among hospitality students.

Hope

Hope is a key dimension of Psychological Capital that reflects an individual's ability to set meaningful goals, identify pathways to achieve them, and sustain the motivation needed to pursue those goals despite obstacles (Snyder et al., 1991; Luthans, Youssef, & Avolio, 2006). In the context of hospitality education, hope is particularly relevant because students are preparing for a service environment that is becoming increasingly shaped by smart technologies, automation, and digitally mediated guest interactions. Students with higher levels of hope are more likely to view technological change not as a threat, but as a pathway to future employability and professional growth.

In higher education, hope has been associated with students' persistence, motivation, and ability to cope with learning challenges, especially in digital and technology-supported learning environments (Huang, 2022; Rahman et al., 2025). This is important because technology readiness does not depend only on whether students have access to digital tools, but also on whether they believe they can learn, adapt, and progress when facing unfamiliar systems. For hospitality students, this may include learning to use property management systems, self-check-in platforms, service robots, AI-enabled guest communication tools, or other smart service applications. Hopeful students are more likely to search for alternative ways to solve problems, remain engaged when digital tasks become difficult, and connect technology use with their long-term career goals.

Recent studies suggest that positive psychological resources can strengthen students' readiness to engage with technology-based learning and work environments (Kadiyono & Pardosi, 2023; Khoshaim, 2024). Within this view, hope functions as an internal driver that helps students move beyond fear, hesitation, or passive acceptance of technology. Instead of avoiding smart systems because they seem complex or unfamiliar, hopeful students are more inclined to develop strategies to master them. This makes hope an important psychological enabler of technology readiness among hospitality students, particularly as the industry increasingly requires graduates who are prepared to perform in smart service roles.

Based on this argument, the following hypothesis is proposed:

H1a: Hope has a significant positive influence on technology readiness among hospitality students.

Self-Efficacy

Self-efficacy refers to an individual's belief in their ability to organise and perform the actions required to achieve desired outcomes (Bandura, 1997). As a dimension of Psychological Capital, self-efficacy

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reflects students' confidence in their ability to complete challenging tasks, solve problems, and succeed when facing unfamiliar situations (Luthans, Youssef, & Avolio, 2006). In the context of hospitality education, self-efficacy is particularly important because students are increasingly expected to engage with technology-supported learning and smart service systems that require confidence, adaptability, and active participation.

In digital and e-learning environments, self-efficacy has been shown to support students' motivation, engagement, and performance because students who believe they are capable are more likely to persist when facing technology-related challenges (Ahmed, Ismail, & Fati, 2021; Huang, 2022; Khoshaim, 2024). This is relevant to technology readiness because students who are confident in their own abilities may be more willing to explore unfamiliar digital platforms, learn new systems, and manage technology-related tasks. In hospitality education, such confidence may influence students' readiness to use property management systems, digital reservation platforms, self-check-in technologies, AI-enabled guest communication tools, and other smart service applications.

Self-efficacy may also reduce hesitation when students encounter new technologies. Students with higher self-efficacy are more likely to believe that they can learn from mistakes, practise new digital skills, and overcome difficulties in technology-supported service situations. This is important because technology readiness does not depend only on access to technology, but also on students' confidence to use technology effectively. Prior studies have also suggested that Psychological Capital and its components are associated with digital preparedness, e-learning success, and readiness to adopt new technologies (Kadiyono & Pardosi, 2023; Khoshaim, 2024).

In the hospitality context, self-efficacy can help students approach smart service roles with greater confidence. As hotels increasingly rely on digital platforms, AI, robotics, and automated service systems, students who believe they can master new tools are more likely to perceive technology as manageable and useful. Therefore, self-efficacy is expected to strengthen hospitality students' technology readiness by increasing their confidence to engage with smart technologies in future service environments.

Based on this argument, the following hypothesis is proposed:

H1b: Self-efficacy has a significant positive influence on technology readiness among hospitality students.

Resilience

Resilience refers to an individual's capacity to recover from setbacks, adapt positively to change, and continue functioning effectively under pressure (Luthans, 2002). As a dimension of Psychological Capital, resilience is especially important in technology-driven learning and work environments because students are often required to deal with uncertainty, system errors, unfamiliar platforms, and repeated learning attempts. In this sense, resilience does not simply mean "bouncing back"; it reflects the ability to remain engaged and adaptive when technology-related challenges become stressful or discouraging.

In digital learning contexts, resilient students are more likely to cope with technological difficulties and continue participating despite frustration, failure, or anxiety. Studies on e-learning and digital readiness suggest that psychological resources such as resilience are important for sustaining students' engagement, motivation, and academic performance in technology-supported environments (Ahmed, Ismail, & Fati, 2021; Ramgoolam-Atchiamith et al., 2022; Khoshaim, 2024). Similarly, Rahman et al. (2025) argued that

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resilience supports students' adaptation to digital platforms and helps reduce the risk of burnout when learning demands become increasingly technology-based.

For hospitality students, resilience is particularly relevant because smart service roles require them to work with technologies that may be complex, unfamiliar, or constantly changing. These may include robotic services, AI-powered reservation systems, digital check-in platforms, property management systems, and guest-facing service applications. Students who lack resilience may become discouraged when they experience technical problems or feel pressured by new service expectations. In contrast, resilient students are more likely to treat such challenges as part of the learning process, recover from mistakes, and continue developing the confidence needed to perform in smart hospitality environments.

Recent evidence also indicates that Psychological Capital is positively associated with technology readiness, particularly in strengthening individuals' motivation to adopt new technologies (Kadiyono & Pardosi, 2023). Therefore, resilience may act as an important psychological resource that enables hospitality students to manage technology-related stress and remain prepared for smart service roles.

Based on this argument, the following hypothesis is proposed:

H1c: Resilience has a significant positive influence on technology readiness among hospitality students.

Optimism

Optimism refers to an individual's tendency to expect positive outcomes and to interpret challenges as manageable rather than threatening (Snyder & Lopez, 2001). As a component of Psychological Capital, optimism enables students to maintain a positive outlook when facing uncertainty, change, or unfamiliar demands (Luthans, Youssef, & Avolio, 2006). In technology-driven learning and service environments, this positive orientation is important because students' willingness to engage with new systems is often shaped by how they interpret technological change. Optimistic students are more likely to view smart technologies as useful opportunities for learning and career development, rather than as risks that may replace or undermine their future roles.

In higher education, optimism has been associated with students' confidence, motivation, and openness toward digital learning experiences. Recent studies suggest that Psychological Capital is linked to students' digital readiness, e-learning satisfaction, and academic performance in technology-supported environments (Huang, 2022; Khoshaim, 2024). Optimism may also reduce students' anxiety when they encounter unfamiliar technologies because it encourages them to believe that they can benefit from digital transformation and overcome early difficulties. This is consistent with studies showing that positive psychological resources can support creativity, innovation, and readiness to engage with technology-based change (Kadiyono & Pardosi, 2023; Wang, Cheung, & Zhai, 2024).

In hospitality education, optimism is particularly important because students are preparing for an industry where digital transformation is changing both operational processes and guest-service expectations. AI-enabled guest communication, robotic services, automated reservation systems, smart rooms, and digital check-in platforms may create uncertainty among students who are more familiar with traditional service delivery. Optimistic students, however, are more likely to interpret these technologies as service enhancements rather than threats. They may be more willing to experiment with smart tools, accept technology-supported work processes, and develop confidence in performing future service roles.

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Therefore, optimism may serve as an important psychological enabler of technology readiness among hospitality students. By encouraging positive expectations toward smart hospitality technologies, optimism can strengthen students' willingness to learn, adapt, and participate in technology-enabled service environments.

Based on this argument, the following hypothesis is proposed:

H1d: Optimism has a significant positive influence on technology readiness among hospitality students.

2.3 Conceptual Framework and Hypotheses Development

The conceptual framework of this study examines the influence of Psychological Capital on technology readiness among hospitality students. Psychological Capital is conceptualised through four dimensions: hope, self-efficacy, resilience, and optimism (Luthans, Youssef, & Avolio, 2006). These dimensions represent students' positive psychological resources that may strengthen their confidence, persistence, adaptability, and positive expectations when engaging with smart technologies in hospitality education and service contexts.

Technology readiness is positioned as the dependent variable and refers to students' predisposition to accept, use, and engage with new technologies (Parasuraman, 2000). In this study, technology readiness is particularly important because hospitality students are preparing for future service roles increasingly shaped by artificial intelligence, robotics, digital reservation systems, self-service technologies, and other smart service applications. Therefore, the framework proposes that students with higher levels of hope, self-efficacy, resilience, and optimism are more likely to demonstrate stronger readiness to engage with technology-enabled hospitality environments.

Figure 1 illustrates the proposed conceptual framework, showing the direct relationships between the four dimensions of Psychological Capital and technology readiness.

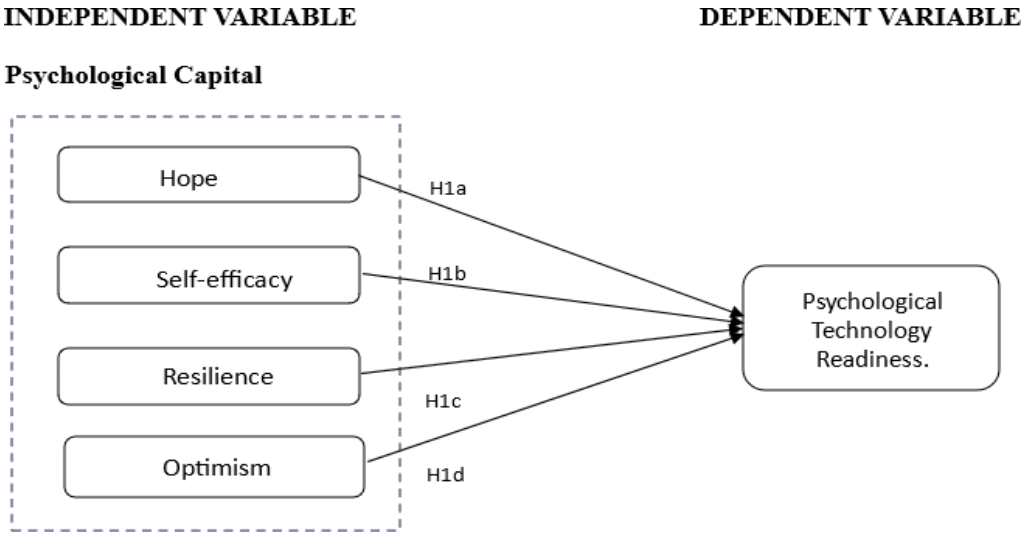

Fig. 1. Conceptual framework illustrating the influence of Psychological Capital (hope, self-efficacy, resilience, and optimism) on hospitality students' technology readiness.

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3. METHODOLOGY

3.1 Research Design

This study adopted a quantitative, cross-sectional research design to examine the influence of Psychological Capital on technology readiness among hospitality students at Universiti Teknologi MARA, Pulau Pinang Branch. A quantitative approach was considered appropriate because the study aimed to test the hypothesised relationships between four dimensions of Psychological Capital—hope, self-efficacy, resilience, and optimism—and students' technology readiness. A survey-based design was employed as it allows data to be collected systematically from a relatively large group of respondents and enables statistical testing using regression analysis.

3.2 Population and Sample

The target population comprised hospitality students enrolled at Universiti Teknologi MARA, Pulau Pinang Branch. This group was selected because hospitality students are future service employees who will be expected to work in increasingly digitalised and smart service environments. As technologies such as artificial intelligence, robotics, digital reservation systems, self-service kiosks, and property management systems become more common in the hospitality industry, students' readiness to engage with such technologies has become an important area of investigation.

A purposive sampling technique was used to ensure that only respondents who met the study criteria were included. The screening section of the questionnaire was used to verify respondents' eligibility based on programme, semester, faculty, and age. The minimum sample size was determined using G*Power analysis for multiple regression. Based on a medium effect size, a significance level of 0.05, statistical power of 0.80, and four predictors, the minimum required sample size was established to ensure adequate statistical power. To strengthen the reliability of the findings and reduce the impact of incomplete responses, the study targeted between 180 and 200 completed questionnaires.

3.3 Research Instrument

Data were collected using a structured, self-administered questionnaire. The questionnaire was prepared in dual language to enhance clarity and respondent understanding. The instrument consisted of four main sections. Part A contained screening questions to determine respondents' eligibility. Part B measured the independent variable, Psychological Capital, through four dimensions: hope, self-efficacy, resilience, and optimism. Each dimension consisted of four items. Part C measured the dependent variable, Technology Readiness, using items adapted from the Technology Readiness Index developed by Parasuraman (2000). Part D collected respondents' demographic information.

All construct items were measured using a six-point Likert scale ranging from 1, "strongly disagree", to 6, "strongly agree". The use of a six-point scale was intended to encourage respondents to indicate a clearer level of agreement or disagreement without relying on a neutral midpoint. The items were adapted from established measures to ensure that the constructs were relevant, understandable, and aligned with the objectives of the study.

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3.4 Reliability and Validity

Before the actual data collection, the questionnaire was reviewed by academic experts from UiTM Cawangan Pulau Pinang to ensure content validity, clarity of wording, and suitability for hospitality students. A pilot test was then conducted with 30 students to assess the reliability of the instrument. The pilot test results indicated that all constructs achieved Cronbach's Alpha values above the recommended threshold of 0.70. Specifically, the Cronbach's Alpha values ranged from 0.737 to 0.947, indicating acceptable to excellent internal consistency. Therefore, the instrument was considered reliable and suitable for use in the actual study.

3.5 Data Collection Procedure

The questionnaire was distributed online using Google Forms and shared through social media platforms such as WhatsApp, Telegram, and Instagram. Respondents were informed of the purpose of the study before completing the questionnaire. Participation was voluntary, and respondents were assured that their responses would remain anonymous and confidential. Only complete and eligible responses were retained for analysis.

3.6 Data Analysis

The collected data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 23. Descriptive statistics were first used to summarise the demographic profile of respondents. Reliability analysis was conducted to examine the internal consistency of the measurement scales. Multiple linear regression analysis was then employed to test the hypothesised relationships between the four dimensions of Psychological Capital and technology readiness. This analysis was appropriate because the study sought to determine the extent to which hope, self-efficacy, resilience, and optimism predict hospitality students' readiness to engage with smart technologies.

4. RESULTS

4.1 Introduction

This section presents the findings obtained from the data analysis using SPSS. The analysis includes the demographic profile of respondents, reliability analysis, Pearson correlation analysis, and multiple regression analysis. The purpose of the analysis was to determine the influence of Psychological Capital and its dimensions, namely hope, self-efficacy, resilience, and optimism, on technology readiness among hospitality students at UiTM Cawangan Pulau Pinang.

4.2 Respondent Profile

The demographic profile of respondents is presented in Table 1. A total of 386 usable responses were analysed. In terms of gender, the majority of respondents were female, representing 64.8% of the sample, while male respondents accounted for 24.5%. This indicates that the sample was predominantly female, which is consistent with the student composition commonly found in hospitality-related programmes.

In terms of age, most respondents were 19 years old, representing 43.3% of the sample, followed by respondents aged 20 years old at 24.5%. Smaller proportions were aged 21 years old, 22 years old, 23 years

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old, 18 years old, and 24 years and above. This suggests that the sample mainly consisted of young hospitality students who were in the early stages of their higher education journey.

With regard to race, Malay respondents formed the largest group, accounting for 87.5% of the sample. Bumiputera students represented 1.6%, while only 0.2% identified as others. In terms of programme enrolment, the largest group came from the Diploma in Culinary Arts Management, followed by the Diploma in Foodservice Management and the Diploma in Hotel Management. Overall, the demographic profile indicates that the respondents were mostly young, female, Malay, and enrolled in diploma-level hospitality programmes.

Table 1: Demographic Profile of Respondents (N = 386)

Item	Category	Frequency	Percentage (%)
Gender	Male	106	27.5
	Female	280	72.5
	Total	386	100.0
Age	18	10	2.6
	19	187	48.4
	20	106	27.5
	21	29	7.5
	22	26	6.7
	23	19	4.9
	24 and above	9	2.3
	Total	386	100.0
Race	Bumiputera	7	1.8
	Malay / Melayu	378	97.9
	Others / Lain-lain	1	0.3
	Total	386	100.0
Programme Enrolled	HM110 – Diploma in Hotel Management	65	16.8
	HM111 – Diploma in Tourism Management	57	14.8
	HM112 – Diploma in Foodservice Management	66	17.1
	HM115 – Diploma in Culinary Arts Management	89	23.1
	HM116 – Diploma in Pastry Arts	42	10.9
	HM240/HM260 – Bachelor of Science in Hospitality Management (Honours)	48	12.4
	HM245/HM265 – Bachelor of Science (Hons.) in Culinary Arts Management	19	4.9
	Total	386	100.0

4.3 Reliability Analysis

Cronbach's Alpha was used to assess the internal consistency of the measurement items. As shown in Table 2, all constructs recorded Cronbach's Alpha values above the recommended threshold of 0.70, indicating that the measurement scales were reliable and suitable for further analysis.

For the Psychological Capital dimensions, hope and self-efficacy each recorded a Cronbach's Alpha value of 0.886, while resilience recorded 0.883 and optimism recorded 0.890. These values indicate strong internal consistency across all four PsyCap dimensions. For the Technology Readiness Index dimensions, TRI optimism recorded 0.892, TRI innovativeness recorded 0.885, TRI discomfort recorded 0.917, and TRI insecurity recorded 0.879. Among all constructs, TRI discomfort achieved the highest reliability value. Overall, the results demonstrate that all constructs have acceptable to excellent reliability.

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Table 2. Reliability Analysis

Construct	Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of Items
Hope	0.886	0.887	4
Self-Efficacy	0.886	0.886	4
Resilience	0.883	0.885	4
Optimism	0.890	0.892	4

4.4 Pearson Correlation Analysis

Pearson correlation analysis was conducted to examine the relationships among the four dimensions of Psychological Capital. As shown in Table 3, all correlations among hope, self-efficacy, resilience, and optimism were positive and statistically significant at the 0.01 level.

Hope was strongly correlated with self-efficacy, resilience, and optimism. Self-efficacy also showed strong positive correlations with resilience and optimism. The strongest correlation was found between resilience and optimism, indicating that students who reported higher resilience also tended to report higher optimism. Overall, the findings suggest that the four PsyCap dimensions are closely related and may operate as interconnected psychological resources.

Table 3. Pearson Correlation Coefficients among PsyCap Dimensions

Variable	Hope	Self-Efficacy	Resilience	Optimism
Hope	1			
Self-Efficacy	0.771**	1		
Resilience	0.762**	0.780**	1	
Optimism	0.749**	0.779**	0.807**	1

Note: *** significance at 1% level.

The strong intercorrelations among the PsyCap dimensions suggest that these constructs are conceptually related. However, because the correlations are relatively high, further attention should be given to possible overlap among the predictors when interpreting the regression results.

4.5 Regression Analysis: Overall Psychological Capital and Technology Readiness

A simple linear regression analysis was conducted to examine the influence of overall Psychological Capital on technology readiness. As shown in Table 4, the model produced an R value of 0.484, indicating a moderate positive relationship between overall PsyCap and technology readiness. The R^2 value was 0.234, suggesting that Psychological Capital explained 23.4% of the variance in technology readiness.

Table 4. Model Summary for Overall PsyCap and Technology Readiness

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.484	0.234	0.232	9.12843

The ANOVA result shows that the regression model was statistically significant, $F(1, 384) = 117.616$, $p < 0.001$. This indicates that overall Psychological Capital significantly predicted students' technology readiness.

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Table 5. ANOVA for Overall PsyCap and Technology Readiness

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	9800.703	1	9800.703	117.616	0.000
Residual	31998.014	384	83.328		
Total	41798.718	385			

The coefficient results show that overall PsyCap had a positive and significant influence on technology readiness, $\beta = 0.484$, $p < 0.001$. The unstandardised coefficient, $B = 0.445$, indicates that for every one-unit increase in overall Psychological Capital, technology readiness increased by 0.445 units. Therefore, H1 was supported.

Table 6. Coefficients for Overall PsyCap and Technology Readiness

Predictor	B	Std. Error	Beta	t	Sig.
Constant	32.134	3.051	10.532	0.000	
Psychological Capital	0.445	0.041	0.484	10.845	0.000

4.6 Regression Analysis: Psychological Capital Dimensions and Technology Readiness

Multiple regression analysis was conducted to examine the influence of the four PsyCap dimensions—hope, self-efficacy, resilience, and optimism—on technology readiness. As shown in Table 7, the model produced an R value of 0.488, indicating a moderate positive relationship between the four predictors and technology readiness. The R^2 value was 0.238, suggesting that the four PsyCap dimensions collectively explained 23.8% of the variance in technology readiness. The adjusted R^2 value of 0.230 indicates that the model retained modest explanatory power after accounting for the number of predictors.

Table 7. Model Summary for PsyCap Dimensions and Technology Readiness

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.488	0.238	0.230	9.14198

The ANOVA result indicates that the overall regression model was statistically significant, $F(4, 381) = 29.782$, $p < 0.001$. This means that hope, self-efficacy, resilience, and optimism collectively predicted technology readiness among hospitality students.

Table 8. ANOVA for PsyCap Dimensions and Technology Readiness

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	9956.359	4	2489.090	29.782	0.000
Residual	31842.359	381	83.576		
Total	41798.718	385			

The coefficients in Table 9 show that only optimism significantly predicted technology readiness, $\beta = 0.231$, $p = 0.007$. Hope had a positive but marginally non-significant effect, $\beta = 0.152$, $p = 0.053$. Self-efficacy, $\beta = 0.053$, $p = 0.523$, and resilience, $\beta = 0.095$, $p = 0.270$, were positive but non-significant predictors. Therefore, H1d was supported, while H1a, H1b, and H1c were not supported.

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Table 9. Coefficients for PsyCap Dimensions and Technology Readiness

Predictor	B	Std. Error	Beta	t	Sig.
Constant	31.778	3.071	10.349	0.000	
Hope	0.514	0.265	0.152	1.940	0.053
Self-Efficacy	0.176	0.275	0.053	0.640	0.523
Resilience	0.320	0.290	0.095	1.105	0.270
Optimism	0.774	0.284	0.231	2.725	0.007

4.7 Hypotheses Testing

Table 10 summarises the results of the hypothesis testing. Overall Psychological Capital had a significant positive influence on technology readiness ($\beta = .484$, $p < .001$), supporting H1. Among the individual dimensions, optimism had a significant positive influence on technology readiness ($\beta = .231$, $p = .007$), supporting H1d. Hope ($\beta = .152$, $p = .053$), self-efficacy ($\beta = .053$, $p = .523$), and resilience ($\beta = .095$, $p = .270$) showed positive but non-significant influences; therefore, H1a, H1b, and H1c were not supported.

Table 10. Summary of Hypotheses Testing

Hypothesis	Statement	Beta (β)	Sig. (p)	Result
H1	Psychological Capital has a significant positive effect on technology readiness.	0.484	0.000	Supported
H1a	Hope has a significant positive effect on technology readiness.	0.152	0.053	Not supported
H1b	Self-efficacy has a significant positive effect on technology readiness.	0.053	0.523	Not supported
H1c	Resilience has a significant positive effect on technology readiness.	0.095	0.270	Not supported
H1d	Optimism has a significant positive effect on technology readiness.	0.231	0.007	Supported

5. DISCUSSION

The multiple regression model was statistically significant, $F(4, 381) = 29.782$, $p < .001$, indicating that hope, self-efficacy, resilience, and optimism collectively predict technology readiness among hospitality students. However, the model explained a modest proportion of the variance, $R^2 = .238$. This suggests that Psychological Capital contributes meaningfully to technology readiness, but students' readiness is also shaped by factors beyond the present model, including prior technological exposure, digital competence, perceived usefulness, perceived ease of use, lecturer support, curriculum design, facilitating conditions, and hands-on experience with hospitality technologies (Parasuraman, 2000; Parasuraman & Colby, 2015; Huang, 2022; Li et al., 2023; Khoshaim, 2024).

The findings are discussed according to their statistical strength. Optimism is considered first because it was the only significant individual predictor. This is followed by the non-significant findings for hope, self-efficacy, and resilience. The discussion concludes by interpreting the significant effect of overall Psychological Capital, the strong relationships among its dimensions, and the model's modest explanatory power.

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5.1 Optimism as the Strongest Predictor of Technology Readiness

Optimism was the only Psychological Capital dimension that significantly predicted technology readiness, $\beta = .231$, $p = .007$. This indicates that hospitality students who expect positive outcomes from technological change are more likely to demonstrate readiness to engage with smart service systems. In this context, optimism is more than a generally positive attitude. It shapes whether students perceive artificial intelligence, robotics, automated platforms, and digital hospitality systems as useful opportunities or as threats to their future service roles.

The result is theoretically consistent with both the Psychological Capital framework and the Technology Readiness Index. Within Psychological Capital, optimism reflects positive expectations concerning future outcomes and the belief that challenges can be managed successfully (Luthans et al., 2006). Within TRI, optimism is also identified as a principal enabler of technology readiness because it reflects beliefs that technology can provide greater efficiency, flexibility, convenience, and control (Parasuraman, 2000; Parasuraman & Colby, 2015). The present result therefore strengthens the conceptual connection between the two frameworks.

This finding is also consistent with prior evidence that positive psychological resources support digital readiness, technology-supported learning, and readiness to adopt new technologies (Huang, 2022; Kadiyono & Pardosi, 2023; Khoshaim, 2024). Kadiyono and Pardosi (2023), for example, found that Psychological Capital was more strongly associated with the motivational components of technology readiness than with its inhibitory components. This suggests that positive expectations may encourage individuals to approach technology even before they have fully developed the technical competence required to use it.

For hospitality students, optimism may be particularly important because technological change can produce uncertainty about the future of human service. Students may worry that AI, automation, or robotic service will reduce the value of traditional interpersonal hospitality skills. Optimistic students are more likely to interpret these technologies as tools that complement human service, improve operational efficiency, support personalisation, and enhance employability. Such students may therefore be more willing to explore new systems and prepare for technology-enabled roles.

The finding does not mean that optimism alone guarantees technological competence. Rather, it indicates that a positive orientation toward technology may create the willingness needed to begin learning, experimenting, and adapting. Hospitality educators should therefore complement technical instruction with activities that help students understand the benefits and realistic applications of smart technologies. Industry demonstrations, smart hotel visits, simulation exercises, and discussions with technology-enabled hospitality operators may strengthen students' positive expectations while maintaining a balanced understanding of technological change.

5.2 Non-Significant Hope and Technology Readiness

Hope had a positive but statistically non-significant influence on technology readiness, $\beta = .152$, $p = .053$. Although the result was close to the conventional significance threshold, it does not provide sufficient evidence to support the proposed relationship. The positive coefficient nevertheless suggests that hope may

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have some relevance, but its contribution was not strong enough to explain unique variance once the other Psychological Capital dimensions were considered.

Hope reflects the ability to establish goals, identify pathways toward those goals, and maintain the motivation required to pursue them (Snyder et al., 1991; Luthans et al., 2006). Theoretically, hopeful students should be more persistent when learning unfamiliar technologies because they are able to identify alternative strategies when difficulties arise. However, general academic or career hope may not directly translate into technology readiness unless students clearly understand how digital competence contributes to their desired hospitality careers.

Hospitality students may have strong aspirations to become hotel managers, chefs, tourism professionals, or entrepreneurs without necessarily viewing AI, robotics, digital reservation systems, or property management technologies as central pathways to those goals. Hope may therefore function as a broad motivational resource rather than a direct technology-specific driver. This interpretation is consistent with research suggesting that psychological resources support digital learning, but their effects may depend on whether learners perceive technology as relevant to their goals and future performance (Ahmed et al., 2021; Huang, 2022; Khoshaim, 2024).

The marginal value of $p = .053$ should not be interpreted as proof that hope has no role. Instead, the result suggests that the role of hope may become stronger when educational programmes explicitly connect technology learning with employability, career advancement, and professional identity. Clear digital competency pathways, industry-based projects, and career-oriented smart hospitality modules may help students see technology as a practical route toward their future goals.

5.3 Non-Significant Self-Efficacy and Technology Readiness

Self-efficacy had a positive but non-significant effect on technology readiness, $\beta = .053$, $p = .523$. This indicates that students' general confidence in their abilities did not uniquely predict their readiness to engage with smart hospitality technologies.

Self-efficacy refers to individuals' beliefs concerning their ability to organize and perform the actions required to achieve particular outcomes (Bandura, 1997, 2001). Within the Psychological Capital framework, it represents confidence in undertaking challenging tasks and investing the effort necessary to succeed (Luthans et al., 2006). However, Bandura emphasized that self-efficacy is task-specific. A student may be confident in academic work, teamwork, presentations, or interpersonal communication but may not possess the same confidence when using property management systems, AI-enabled guest communication, automated check-in platforms, or service robots.

This distinction may explain the non-significant result. The instrument measured self-efficacy as a general Psychological Capital resource rather than as technology-specific self-efficacy. Consequently, students' general confidence may not have closely reflected their perceived ability to perform smart service tasks. Previous studies have shown that self-efficacy supports engagement and performance in technology-supported learning, but this relationship is often strengthened by mastery experience, practical exposure, training, and access to appropriate technological support (Ahmed et al., 2021; Jaedun et al., 2022; Khoshaim, 2024).

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The sample was also largely composed of diploma students who may still have limited exposure to industry-specific technologies. Familiarity with smartphones, social media, and online learning platforms does not necessarily create confidence in using professional hospitality systems. Therefore, the result reinforces the argument that digital familiarity should not be treated as equivalent to workplace technology readiness.

Hospitality programmes should develop technology-specific self-efficacy through repeated hands-on practice. Simulation laboratories, property management system exercises, automated check-in role-plays, AI-assisted guest communication, and troubleshooting activities can provide mastery experiences that gradually strengthen students' confidence. In future studies, technology-specific self-efficacy may provide a more precise explanation of students' readiness than general self-efficacy.

5.4 Non-Significant Resilience and Technology Readiness

Resilience also showed a positive but non-significant effect on technology readiness, $\beta = .095$, $p = .270$. This suggests that students' ability to recover from difficulties did not independently predict their readiness to engage with technology when the other PsyCap dimensions were included in the model.

Resilience refers to the capacity to recover from setbacks, uncertainty, failure, or adversity and to continue functioning effectively (Luthans, 2002; Luthans et al., 2006). In digital learning environments, resilience may help students persist when they encounter technical problems, unfamiliar platforms, or demanding learning conditions (Ahmed et al., 2021; Huang, 2022; Khoshaim, 2024). Nevertheless, resilience is most likely to become visible after individuals have experienced genuine challenges that require recovery.

Many respondents may not yet have encountered the types of technology-related setbacks that arise in actual hospitality operations. Classroom technologies and general digital applications may not create the same pressure as a system failure during guest check-in, an error in a reservation platform, or a malfunctioning automated service system. Without substantial exposure to these situations, students' resilience may not yet function as a direct predictor of readiness.

Resilience may instead influence technology readiness indirectly. For example, it may reduce the negative effects of digital anxiety, technology-related stress, or previous system failure. It may also become more important during internships and workplace transitions, when students face real service consequences and operational demands. Because these mediating and contextual conditions were not examined, the direct relationship may have appeared weak.

The non-significant result should therefore not be interpreted as indicating that resilience lacks value. Hospitality educators should continue to provide safe opportunities for students to encounter, diagnose, and recover from technology-related problems. Scenario-based simulations involving system errors, service interruptions, and guest complaints may help students develop the capacity to remain calm and adaptive when technology does not function as expected.

5.5 Overall PsyCap, High Intercorrelations, and Modest Explained Variance

Although only optimism was significant when the four dimensions were examined simultaneously, overall Psychological Capital significantly predicted technology readiness, $\beta = .484$, $p < .001$. The overall

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PsyCap model explained 23.4% of the variance in technology readiness, while the four-dimensional model explained 23.8%. The small increase of only 0.4 percentage points suggests that separating PsyCap into its individual dimensions added limited explanatory power beyond the combined construct.

This pattern supports the argument that Psychological Capital may operate more effectively as a higher-order resource than as four entirely independent traits. Hope, self-efficacy, resilience, and optimism are theoretically distinct, but they are also mutually reinforcing and commonly conceptualised as a combined psychological resource (Luthans et al., 2006). Students who believe they can succeed may be more likely to remain hopeful, recover from setbacks, and maintain positive expectations. Therefore, the collective effect of PsyCap may be stronger and more stable than the unique effect of each dimension.

The correlation findings support this interpretation. The four PsyCap dimensions were strongly related, with correlations ranging from r = .749 to r = .807. These relationships indicate that the constructs share substantial variance. Although the correlations do not automatically confirm a serious multicollinearity problem, they help explain why hope, self-efficacy, and resilience lost statistical significance when all four predictors were entered together. Their effects may have overlapped, while optimism retained the strongest unique contribution.

The modest R^2 of .238 also indicates that Psychological Capital is only one part of a broader readiness process. Technology readiness is influenced by positive and negative predispositions, but it may also depend on digital competence, perceived usefulness, perceived ease of use, access to technology, facilitating conditions, curriculum exposure, prior experience, social influence, and institutional support (Parasuraman, 2000; Parasuraman & Colby, 2015; Huang, 2022; Li et al., 2023; Kumi et al., 2024). The unexplained 76.2% of variance therefore suggests that a wider set of educational and technological factors should be incorporated into future models.

This result should not be viewed as weakening the contribution of the study. Instead, it demonstrates that psychological readiness is meaningful but insufficient on its own. Hospitality students may possess strong PsyCap yet remain unprepared if they lack access to relevant systems, practical instruction, or industry exposure. Similarly, students may receive excellent technical training but remain reluctant to engage with technology if they perceive it negatively or fear its consequences.

Overall, the findings support an integrated approach to technology readiness. Hospitality education should develop positive psychological resources while also providing practical training, simulations, industry engagement, and sustained exposure to smart hospitality systems. The strongest preparation for smart service roles is therefore likely to emerge when psychological readiness and technological competence are developed together.

6. CONTRIBUTION

The regression model was statistically significant, $F = 29.782$, $p < 0.001$, indicating that the four dimensions of Psychological Capital—hope, self-efficacy, resilience, and optimism—collectively explain technology readiness.

This study contributes to hospitality education, Psychological Capital, and technology readiness literature by extending the application of PsyCap into the context of smart service readiness among hospitality

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students. Previous studies have examined Psychological Capital in organisational behaviour, academic performance, e-learning, and digital learning contexts, but its application to hospitality students' readiness for smart service roles remains limited (Ahmed et al., 2021; Huang, 2022; Kadiyono & Pardosi, 2023; Khoshaim, 2024). By examining PsyCap as a predictor of technology readiness, this study advances theoretical understanding of how psychological strengths shape students' preparedness for technology-enabled hospitality work.

A key theoretical contribution lies in showing that overall Psychological Capital significantly predicts technology readiness. This supports the view that technology readiness is not only a technical or behavioural construct, but also a psychological one. While the Technology Readiness Index explains individuals' predisposition toward technology through enablers and inhibitors, the present study adds that students' positive psychological resources can also shape their readiness to embrace smart hospitality technologies (Parasuraman, 2000; Parasuraman & Colby, 2015; Kadiyono & Pardosi, 2023).

Another theoretical contribution is the identification of optimism as the only significant individual predictor of technology readiness. This finding strengthens the conceptual link between PsyCap and TRI because optimism appears in both frameworks. In PsyCap, optimism reflects positive expectations toward future outcomes, while in TRI, optimism reflects positive beliefs about the benefits of technology. Therefore, the finding suggests that optimism may act as a bridge between general psychological capital and technology-specific readiness (Luthans et al., 2006; Parasuraman & Colby, 2015).

The non-significant effects of hope, self-efficacy, and resilience also provide useful theoretical insight. These findings suggest that not all dimensions of PsyCap contribute equally to technology readiness when analysed together. Hope may require clearer links to career goals, self-efficacy may need to be technology-specific, and resilience may become more relevant when students face actual technology-related setbacks. This adds nuance to PsyCap theory by showing that its dimensions may operate differently depending on the outcome and context.

Finally, the modest explanatory power of the model contributes to theory by reinforcing the multidimensional nature of technology readiness. Rather than viewing readiness as driven by psychological capital alone, the study situates technology readiness as an outcome shaped by the interaction of psychological, educational, technological, and contextual factors. This encourages future research to integrate PsyCap with other models such as TRI, TAM, UTAUT, career adaptability, and experiential learning to better explain students' readiness for smart hospitality work.

From a practical standpoint, the findings provide important insights for hospitality educators, curriculum designers, and industry partners seeking to prepare students for smart service roles. The significant effect of overall Psychological Capital suggests that hospitality programmes should not focus only on digital skills training. Students also need psychological preparation that strengthens confidence, adaptability, persistence, and positive expectations toward technology-enabled work (Ahmed et al., 2021; Huang, 2022; Kadiyono & Pardosi, 2023; Khoshaim, 2024).

The strong role of optimism highlights the need to cultivate positive technology mindsets among hospitality students. Educators should help students understand that AI, robotics, digital reservation systems, smart

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rooms, and self-service technologies are not necessarily threats to human hospitality. Instead, these technologies can be positioned as tools that enhance service efficiency, guest satisfaction, and graduate employability. This can be achieved through smart hotel case studies, industry talks, technology demonstrations, and simulation-based learning.

The non-significant result for self-efficacy suggests that general student confidence is not enough. Hospitality programmes should provide more hands-on, task-specific exposure to hospitality technologies. For example, students should be trained using property management systems, digital check-in simulations, AI-assisted guest communication scenarios, and service recovery simulations involving technology failure. Such practices can help transform general confidence into technology-specific competence.

The non-significant result for resilience also has practical implications. Students should be exposed to controlled technology-related challenges where they can practise troubleshooting, recover from errors, and learn from system-related mistakes. This is important because real hotel environments often require employees to remain calm when technology fails or when guests become frustrated with digital systems. Safe simulation environments can help students develop resilience before entering the workplace.

Finally, the modest explanatory power of the model indicates that technology readiness strategies must be multifaceted. While PsyCap development is important, it should be combined with curriculum innovation, lecturer support, peer collaboration, internship exposure, industry certification, and continuous technology practice. Hospitality schools should therefore adopt an integrated approach that develops both psychological readiness and practical digital competence.

7. CONCLUSION

This study examined the influence of Psychological Capital on technology readiness among hospitality students. The findings show that overall Psychological Capital significantly predicts technology readiness, confirming that students' preparedness for smart service roles is shaped not only by technical exposure but also by psychological resources. Among the four dimensions, optimism emerged as the only significant individual predictor, while hope, self-efficacy, and resilience showed positive but non-significant effects.

These findings suggest that students' positive expectations toward technology are particularly important in encouraging readiness for AI, robotics, automated systems, and other smart hospitality applications. At the same time, the modest explanatory power of the model indicates that Psychological Capital alone cannot fully account for students' technology readiness. Practical exposure, curriculum design, digital competence, institutional support, and experience with hospitality technologies are also likely to play important roles.

Overall, the study highlights the need for a balanced approach to preparing hospitality students for technology-enabled careers. Hospitality education should combine psychological development, particularly positive technology mindsets, with hands-on training and industry-based exposure. Such an approach can better equip graduates to enter smart service environments with both the confidence and competence required to adapt and perform effectively.

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7.1 Future Research

Future research should address several limitations of this study. First, longitudinal or time-lagged designs are recommended to better explain how Psychological Capital influences technology readiness over time. Cross-sectional studies are useful for examining relationships at one point in time, but they cannot fully capture how students' readiness develops through repeated digital exposure, academic progression, internship experience, or workplace learning.

Second, future studies should include additional predictors of technology readiness. The modest explanatory power of this study suggests that students' readiness is influenced by more than Psychological Capital alone. Future research may include perceived usefulness, perceived ease of use, digital anxiety, prior technology experience, lecturer support, peer influence, facilitating conditions, curriculum exposure, internship experience, and actual use of smart hospitality systems.

Third, future research should measure technology-specific self-efficacy and digital resilience more precisely. The non-significant findings for self-efficacy and resilience may be due to the use of general Psychological Capital dimensions rather than technology-specific measures. Future studies could examine AI self-efficacy, hospitality technology self-efficacy, digital troubleshooting confidence, or resilience toward technology failure.

Finally, future research should expand the sample to other universities, hospitality schools, and educational levels. Comparative studies between diploma and degree students, public and private institutions, or students with and without internship experience may provide stronger evidence on how Psychological Capital shapes technology readiness in hospitality education.

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9. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

10. AUTHORS' CONTRIBUTIONS

Fairuz Abd Hakim: conceptualisation, methodology; formal analysis, investigation, writing-original draft, writing-review and editing. **Suria Sulaiman:** conceptualisation, writing-original draft, writing-review and editing. **Irina Mohd Akhir**: methodology, investigation, validation. **Joesri Mohd Saber:** formal analysis, validation, writing-review and editing. **Khairil Anuar Bahri:** writing-review and editing.

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11. DECLARATION OF GENERATIVE AI IN THE WRITING PROCESS

During the preparation of this manuscript, AI-assisted tools, including ChatGPT (GPT-5.3, OpenAI), were used to enhance readability and clarity, while Grammarly was utilized to ensure grammatical accuracy. All outputs generated by these tools were critically reviewed and validated by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

12. DATA AVAILABILITY/SUPPLEMENTARY MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

13. ETHICS STATEMENT

The authors declare that this research did not involve human or animal subjects. All experimental procedures were performed following the institutional Safety, Health, and Environmental (HSE) protocols of UiTM Cawangan Pulau Pinang. This study was reviewed and approved by the Institutional Ethics Committee of UiTM Cawangan Pulau Pinang (Approval No: BERC/01/2026 (UG/MR/417)

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