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Personality Traits and Learning Effectiveness in Online Vocational Education: Insights from International Students in High-Tech Learning Contexts in China

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ABSTRACT

This study investigates how personality traits influence learning effectiveness in online vocational education among international students in China, with a particular focus on the mediating role of online learning self-efficacy and the moderating effect of perceived high-tech learning support. Using a mixed-methods design, data were collected from 412 international students enrolled in online or blended vocational programs across universities and vocational colleges in China through a structured questionnaire measuring personality traits (conscientiousness and openness), online learning self-efficacy, perceived high-tech learning support, and learning effectiveness. Quantitative data were analyzed using a PLS-SEM-based path model with bootstrapping to examine direct, indirect, and moderation effects, alongside reliability and validity assessments. In addition, 18 semi-structured interviews were conducted to explore students' experiences with high-tech learning environments. The findings indicate that personality traits significantly predict both online learning self-efficacy and learning effectiveness, while self-efficacy also serves as a significant predictor and partial mediator of learning effectiveness. Furthermore, perceived high-tech learning support strengthens the relationship between self-efficacy and learning outcomes. Qualitative insights further reveal that simulation-based practice, timely feedback, and multilingual instructional support enhance students' confidence and skill development.

Keywords: China, high-tech learning support, international students, online learning self-efficacy, online vocational education, personality traits, PLS-SEM

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INTRODUCTION

Online vocational education has moved rapidly from a niche supplement to a mainstream delivery mode, accelerated by pandemic-related disruptions and the longer-term digital transformation of teaching and training. However, online delivery changes the psychological demands of learning because students must regulate time, sustain motivation, and seek help through mediated channels rather than relying on the structure of face-to-face classrooms (Aristovnik et al., 2020; Mok et al., 2021). In China, universities and vocational colleges have expanded their learning management systems, synchronous platforms, and digital resources at scale, creating new possibilities for flexible access but also exposing uneven readiness for online learning (Han et al., 2020; Wen et al., 2018).

Vocational education and training (VET) places a distinct emphasis on procedural knowledge, hands-on practice, and performance feedback. These requirements make the transition to online environments more complex than in theory-heavy academic subjects as authentic skill development typically depends on repeated practice, coaching, and assessment in realistic settings (Martin & Bolliger, 2018; Liu et al., 2023). In response, many institutions have adopted high-tech learning contexts such as virtual simulation labs, remote or digital twins of equipment, AI-supported tutoring, and learning analytics dashboards. Smart learning environments aim to provide context-aware support, personalization, and timely feedback that can approximate some benefits of physical labs, although the quality of implementation varies substantially (Cheung et al., 2021; Zawacki-Richter et al., 2019).

International students in China are a particularly important group for understanding the effectiveness of online VET. International students often use multilingual learning materials, new assessment expectations, and culturally unfamiliar pedagogies. When learning is delivered online, these challenges can intensify because social cues are reduced and informal peer support may be more difficult to access (Tian & Lu, 2022; Mok et al., 2021). Moreover, international students in China are frequently enrolled in high-tech programs such as smart manufacturing, robotics, internet-of-Things networking, and digital media, where the curriculum is closely aligned with digital tools and industry-standard platforms. These conditions create a natural setting in which to study how high-

tech learning support interacts with learner characteristics to shape outcomes (Han et al., 2020; Cheung et al., 2021).

Recent evidence on international students' online learning in China suggests that technology conditions and affective experiences continue to shape learning outcomes. For example, internet access quality has been linked to learning satisfaction and performance among international students in synchronous online learning, with effects operating through interaction opportunities and online learning adaptability (Ren et al., 2024). Moreover, international undergraduates report that online learning self-confidence and anxiety vary with the usability of learning software and with the quality of the online learning environment (Zhang, 2025). Together, these findings highlight that online learning effectiveness is shaped by both learner psychological resources and the perceived reliability and usability of the technology ecosystem. This is especially relevant for online VET, where repeated practice with high-tech tools can amplify the consequences of confidence, support, and sustained engagement.

A central question is why some learners thrive in online vocational settings while others struggle, even when they have access to similar platforms and resources. In addition to instructional design and technology infrastructure, stable individual differences may explain the variability in engagement and performance. Personality traits, as relatively enduring patterns of thinking and behavior, have been linked to self-regulation, help-seeking, and persistence, all of which are critical in online learning contexts (Mammadov, 2022; Rivers, 2021). However, personality does not act alone; it influences learning through proximal motivational and cognitive mechanisms, including self-efficacy beliefs about managing tasks and challenges (Honicke & Broadbent, 2016; Yokoyama, 2019).

Online learning self-efficacy refers to students' confidence in their ability to learn effectively in online environments, including managing technology, communicating with instructors, and remaining on track. Self-efficacy is consistently associated with persistence, strategy use, and achievement, especially in contexts requiring autonomy and sustained effort (Honicke & Broadbent, 2016; Yokoyama, 2019). Recent work suggests that during online learning periods, learners with higher levels of conscientiousness and adaptive motivational profiles report fewer difficulties with time management and concentration, supporting a theoretical link between traits, self-efficacy, and performance (Mammadov, 2022; Broadbent & Poon, 2015).

Technology design and learning support can shape whether self-efficacy translates into effective learning. In high-tech learning contexts, support may include virtual lab guidance, adaptive practice recommendations, automated formative feedback, and multilingual scaffolds. These tools can reduce cognitive load, increase feedback frequency, and make performance expectations more transparent, which may particularly benefit students who are confident enough to engage but still need structured opportunities to practice (Cheung et al., 2021; Liu et al., 2023). In other words, high-tech learning support may operate as an enabling condition that amplifies the effect of self-efficacy on learning effectiveness (Zawacki-Richter et al., 2019; Martin & Bolliger, 2018).

Against this backdrop, the present study develops and tests a theoretical model that links personality traits to learning effectiveness through online learning self-efficacy while examining perceived high-tech learning support as a moderator in the self-efficacy-to-outcome pathway. Using survey data from 412 international students enrolled in online or blended vocational programs in China and supplementing the quantitative model with semistructured interviews, we aim to provide a multiperspective view of learning effectiveness in high-tech online VET. Methodologically, we follow contemporary recommendations for measurement reliability, validity testing, and bootstrapped path inference in PLS-SEM-style models (Hair et al., 2019; Hair & Alamer, 2022).

LITERATURE REVIEW

Personality traits

The Big Five framework remains a dominant approach for describing personality in educational research, capturing broad domains that summarize patterns in behavior, affect, and cognition. In online learning contexts, the Big Five are relevant because they align with self-regulatory tendencies and social interaction preferences that become salient when learners must plan, monitor, and coordinate learning activities through digital platforms (Mammadov, 2022; Rivers, 2021). Although all five domains can matter, evidence from online higher education highlights conscientiousness (organization, diligence, and persistence) and openness (curiosity and intellectual engagement) as particularly predictive of adaptive learning behaviors (Mammadov, 2022; Broadbent & Poon, 2015).

Trait-activation perspectives suggest that traits express themselves when situational demands call for trait-relevant behaviors. Online vocational learning creates frequent trait-relevant demands: learners must practice, manage deadlines, and troubleshoot technical issues without constant instructor supervision. Conscientiousness is therefore expected to support the consistent participation and completion of practice tasks, especially in competency-based online VET where progress depends on repeated demonstrations of skills (Martin & Bolliger, 2018; Rivers, 2021).

Openness may also be important in high-tech vocational programs because learners encounter novel tools (e.g., simulation environments, coding interfaces, digital manufacturing workflows) and must experiment with alternative strategies when initial attempts fail. Openness can facilitate exploration and a mastery-oriented response to difficulty, which in turn may strengthen learning in technology-rich environments (Cheung et al., 2021; Liu et al., 2023).

Personality is not assumed to determine performance directly in a deterministic way. Instead, traits shape patterns of engagement and coping that influence intermediate beliefs (e.g., self-efficacy) and behaviors (e.g., practice and help-seeking). Recent studies conducted during large-scale online learning periods have shown that conscientiousness and related facets are associated with fewer academic disruptions and more positive perceptions of online study, which

is consistent with a role for traits in supporting effectiveness under autonomy (Mammadov, 2022; Aristovnik et al., 2020).

In the present study, the personality construct reflects a vocationally relevant combination of conscientiousness and openness items, operationalized using an established short measure of the Big Five. This approach balances measurement quality with the practical constraint of survey length among multilingual respondents (Mammadov, 2022; Hair et al., 2019).

Online learning self-efficacy

Self-efficacy is a core motivational belief that describes a learner's confidence in performing the actions needed to achieve desired outcomes. In online contexts, efficacy beliefs extend beyond content mastery to include managing learning technologies, interacting through digital communication tools, and sustaining effort in less structured settings (Honicke & Broadbent, 2016; Yokoyama, 2019).

Social cognitive theory emphasizes that self-efficacy influences behavior through multiple pathways: it shapes goal setting, persistence under difficulty, emotional reactions, and the selection of learning strategies. These mechanisms are particularly relevant in online vocational education because learners frequently need to practice skills repeatedly, monitor their progress, and interpret feedback from simulations or automated systems (Honicke & Broadbent, 2016; Broadbent & Poon, 2015).

Empirical research in online higher education consistently links self-efficacy to satisfaction and perceived learning and shows that it predicts academic achievement when learners must self-regulate (Xu et al., 2022; Broadbent & Poon, 2015). Recent work has also examined learning motivation and self-efficacy among Indonesian international students in Malaysian universities (Handrianto, 2026). In vocational settings, self-efficacy can determine whether learners persist through complex tasks such as debugging code, calibrating virtual equipment, or completing iterative design projects. When efficacy is low, learners may disengage early, avoid help-seeking, or attribute difficulties to a lack of ability, reducing practice opportunities (Honicke & Broadbent, 2016; Yokoyama, 2019).

Online learning self-efficacy is not only an individual belief; it can be shaped by learning design. Timely feedback, clear performance criteria, and scaffolded task progression can provide mastery experiences that increase efficacy. Peer modeling and instructor presence can also strengthen confidence, although these mechanisms may be weaker in purely asynchronous delivery (Martin & Bolliger, 2018; Aristovnik et al., 2020).

In this study, online learning self-efficacy is conceptualized as confidence in completing online learning tasks and is measured using a validated online learning self-efficacy scale. This measure has been used to capture learners' perceived ability to succeed in online environments and is appropriate for multilingual samples when items are phrased in simple behavioral terms (Yokoyama, 2019; Hair & Alamer, 2022).

Perceived high-tech learning support

High-tech learning contexts in vocational education increasingly rely on smart learning environments, which integrate digital resources, interactive tools, and data-driven feedback to support personalized learning. Smart learning environments are often characterized by context awareness, adaptivity, and timely feedback, enabling learners to access the right support at the right moment (Cheung et al., 2021; Zawacki-Richter et al., 2019).

In online VET, high-tech learning support can include virtual simulation laboratories, remote access to equipment or software, intelligent tutoring, automated formative feedback, and learning analytics that visualize progress. Virtual simulations have been shown to enhance procedural learning when they provide opportunities for deliberate practice and error-based learning, especially when physical labs are limited (Liu et al., 2023; Han et al., 2020).

Perceived high-tech learning support refers to the learner's subjective evaluation that the technology ecosystem helps them learn effectively. Perceptions matter because the same tool can be experienced as empowering or overwhelming depending on usability, language accessibility, and alignment with course goals. When students perceive high-tech tools as supportive, they are more likely to engage in practice activities and to use feedback for improvement (Zawacki-Richter et al., 2019; Martin & Bolliger, 2018). Recent evidence shows that international students' confidence in digital tools develops through repeated use and structured support, whereas software complexity, platform-integration difficulties, and limited hands-on training remain key barriers (Anthonysamy et al., 2026).

Support may be especially important for international students in China who face additional barriers such as technical vocabulary, culturally unfamiliar instructional norms, and limited informal access to instructors. Features such as multilingual scaffolding, examples aligned with diverse prior knowledge, and clear rubrics can make high-tech environments more inclusive and can reduce the gap between confidence and performance (Tian & Lu, 2022; Mok et al., 2021).

From an interactionist perspective, technology support can amplify individual motivational beliefs. High-tech support may strengthen the effectiveness of self-efficacy by transforming confidence into action: students who believe that they can succeed are more likely to attempt challenging tasks, and supportive technology increases the likelihood that attempts produce constructive feedback and measurable skill gains (Cheung et al., 2021; Liu et al., 2023).

Influence of Personality Traits on Online Learning Self-Efficacy

Research on online learning increasingly highlights the role of learner characteristics, with personality being among the most stable predictors of how students approach self-directed tasks. During online learning periods, conscientiousness is associated with better time management and fewer reported

academic problems, whereas openness is linked to engagement with novel learning tasks and technologies (Mammadov, 2022; Abe, 2020).

Personality traits may support self-efficacy through repeated mastery experiences and adaptive interpretations of difficulty. For example, conscientious learners tend to plan and persist, which increases the probability of successful task completion; repeated success builds confidence. Similarly, open learners may interpret new tools as opportunities rather than threats, fostering exploratory learning that also strengthens efficacy beliefs (Honicke & Broadbent, 2016; Cheung et al., 2021).

In online vocational courses where learners often practice with simulations and platforms independently, these trait-driven behaviors may be especially important for developing confidence in online learning. Thus, we propose a positive relationship between personality traits and online learning self-efficacy among international students in China (Yokoyama, 2019; Rivers, 2021).

H1: Personality traits positively influence online learning self-efficacy.

Relationship between Personality Traits and Learning Effectiveness

Personality traits are also expected to be directly related to learning effectiveness. Learning effectiveness in online VET includes perceived mastery of vocational competencies, satisfaction with skill development, and the ability to apply learned procedures to tasks. Conscientiousness is consistently linked to academic performance because it promotes sustained effort and adherence to learning routines, which are critical in online environments that require self-organization (Mammadov, 2022; Martin & Bolliger, 2018).

Openness may contribute to increasing the willingness to experiment, reflect, and integrate feedback—processes that matter for developing complex skills in high-tech vocational programs. When tasks require iterative improvement (e.g., by refining a robot control sequence or improving a digital design), openness can support deeper engagement and learning transfer (Liu et al., 2023; Cheung et al., 2021).

Although online learning outcomes are influenced by course design and instructor presence, we argue that personality traits provide a stable foundation for effective learning behaviors even in diverse instructional contexts (Aristovnik et al., 2020; Chiu, 2022).

H2: Personality traits positively influence learning effectiveness in online vocational education.

Online Learning and Learning Effectiveness

Online learning self-efficacy has been repeatedly identified as a strong predictor of perceived learning, satisfaction, and achievement in online environments. Students with higher self-efficacy are more likely to persist during challenges, employ self-regulated learning strategies, and seek support when needed (Honicke & Broadbent, 2016; Broadbent & Poon, 2015).

In online vocational courses, self-efficacy can influence whether learners actively engage in practice activities, submit iterative assignments, and interpret automated feedback as useful rather than discouraging. Studies in online education show that self-efficacy is related to perceived learning and satisfaction and that it can buffer the negative effects of reduced face-to-face interaction (Xu et al., 2022; Martin & Bolliger, 2018).

Therefore, we hypothesize that online learning self-efficacy positively influences learning effectiveness among international students in high-tech online VET contexts (Yokoyama, 2019; Honicke & Broadbent, 2016).

> H3: Online learning self-efficacy positively influences learning effectiveness.

Online Learning Self-Efficacy as a Mediator

The relationship between personality and learning outcomes is often indirect because traits influence how learners regulate behavior and interpret experiences. Self-efficacy is a theoretically grounded mediator because it captures the learner's belief in capability, which affects strategy use and persistence (Honicke & Broadbent, 2016; Yokoyama, 2019).

In online learning, conscientious and open learners are more likely to generate mastery experiences (through consistent practice and exploration) and to interpret setbacks as manageable, which increases self-efficacy. High levels of self-efficacy subsequently promote sustained engagement and learning effectiveness, suggesting a mediated pathway from traits to outcomes (Mammadov, 2022; Broadbent & Poon, 2015).

Mediation is also plausible in multilingual and cross-cultural contexts, where international students may initially doubt their ability to perform in a new system. Trait-driven engagement with support resources can build confidence that then drives performance (Tian & Lu, 2022; Xu et al., 2022).

> H4: Online learning self-efficacy mediates the relationship between personality traits and learning effectiveness.

High-Tech Learning Support as a Moderator

High-tech learning support may condition the strength of the self-efficacy-to-outcome relationship. When learning environments provide actionable feedback, guided practice, and adaptive scaffolding, learners with higher self-efficacy can more effectively convert confidence into productive learning behaviors (Cheung et al., 2021; Zawacki-Richter et al., 2019).

Virtual simulations and intelligent feedback systems can reduce the cost of experimentation and allow learners to practice repeatedly without physical constraints. In such environments, students who believe that they can succeed are more likely to engage with challenging tasks and benefit from feedback loops, resulting in stronger learning gains (Liu et al., 2023; Han et al., 2020).

Conversely, when technology is perceived as poorly aligned, linguistically inaccessible, or unreliable, even confident students may face barriers that weaken the link between self-efficacy and effectiveness. Because international students often depend on technology-mediated explanations and examples, perceived high-tech support may be especially influential in this population (Mok et al., 2021; Tian & Lu, 2022).

> H5: Perceived high-tech learning support positively moderates the relationship between online learning self-efficacy and learning effectiveness.

Research Gap

Despite the rapid growth in online and blended VET, several gaps remain in understanding learning effectiveness for international students in high-tech learning contexts in China. First, much online learning research focuses on general higher education outcomes, whereas vocational learning involves distinctive skill-practice requirements and depends more heavily on feedback-rich environments (Martin & Bolliger, 2018; Liu et al., 2023).

Second, existing studies often examine technology factors or motivational factors separately. Fewer studies integrate stable individual differences (personality), proximal motivational mechanisms (self-efficacy), and perceived technology support into a single model that can explain why learners with similar access experience different outcomes (Mammadov, 2022; Xu et al., 2022).

Third, many analyses treat technology as a uniform exposure rather than a form of perceived support. In high-tech learning contexts, the same digital tools may be experienced differently depending on usability, language scaffolding, and alignment with vocational task demands. Understanding perceived high-tech learning support is therefore critical for identifying actionable design levers (Cheung et al., 2021; Zawacki-Richter et al., 2019).

Finally, empirical work focused specifically on international students in China within online VET is limited. International students face distinct adjustment and language challenges, making it important to test whether models developed in domestic or general university populations can be generalized to this context (Tian & Lu, 2022; Mok et al., 2021).

To address these gaps, we propose the theoretical model shown in Figure 1, which integrates personality traits, online learning self-efficacy, perceived high-tech learning support, and learning effectiveness. This study contributes by connecting three strands that are rarely examined together in online VET research. First, it focuses on high-tech vocational learning contexts in China, where simulations, analytics, and AI-assisted feedback are embedded in the curriculum and directly shape how learners practice and demonstrate competence. Second, it specifies a mechanism through which personality traits influence learning effectiveness via online learning self-efficacy while also testing whether perceived high-tech learning support strengthens or weakens the extent to which confidence translates into skill gains. Third, it extends recent international student

research in China that highlights the roles of technology conditions and emotional well-being in online learning by examining these processes within vocational, feedback-intensive environments (Ren et al., 2024; Zhang, 2025).

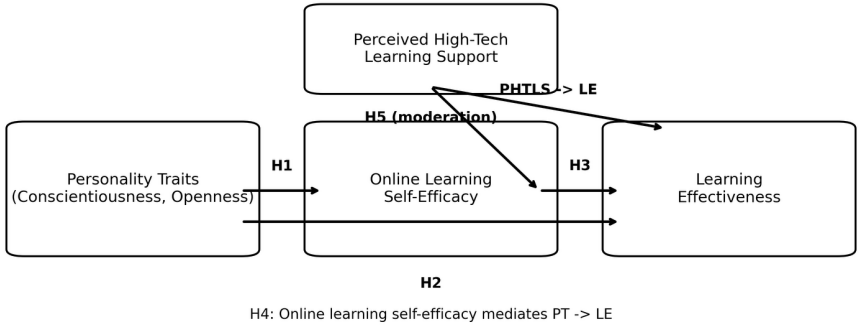

Figure 1: Theoretical Model

METHODOLOGY

This study employed a mixed-method explanatory design, combining a cross-sectional survey with follow-up semistructured interviews. The quantitative component tested hypothesized relationships among the constructs, whereas the qualitative component provided contextual explanations for how high-tech learning support is experienced and why it matters for learning effectiveness (Delcker & Ifenthaler, 2022; Aristovnik et al., 2020).

More specifically, the study followed an explanatory sequential mixed-method design in which the survey results informed the subsequent interview inquiry. In the quantitative phase, the hypothesized direct, indirect, and moderating relationships among personality traits, online learning self-efficacy, perceived high-tech learning support, and learning effectiveness were estimated. The interview phase then probed how students interpreted high-tech support features, how these features shaped confidence and practice behavior, and why technology-rich environments could be experienced as supportive or burdensome. Integrating the two phases strengthened the interpretation of the model by linking statistical patterns to participants' descriptions of concrete learning support and barriers.

Survey participants were international students enrolled in vocationally oriented programs delivered fully online or in blended formats in China. Programs included robotics and automation, smart manufacturing, AI applications, internet-of-Things networking, digital media technology, and e-commerce technology. The analytic sample included 412 valid responses. The respondents were 57.5% male, 39.8% female, and 2.7% other/prefer not to say. The oldest age groups were 18–20 years (36.7%) and 21–23 years (35.0%). The participants were from Asia (36.4%), Africa (29.6%), Europe (16.3%), the Middle East (10.0%), and Latin America (7.8%). Approximately 30.6% had been in China for less than one year,

31.6% for 1–2 years, 25.5% for 3–4 years, and 12.4% for 5+ years. The delivery modes included blended online-plus-lab formats (55.3%), fully online formats (32.0%), and mostly face-to-face online supplements (12.6%).

Data collection involved the use of an online questionnaire administered via an institutional learning platform and international student networks. The full research methodology was sent to the Ethical Committee of Sichuan Aerospace Vocational College, and full approval was obtained prior to conducting the study. Participation was voluntary and anonymous. Informed consent was waived in accordance with institutional and national regulations. Items were presented in English with brief clarifications, and respondents could request bilingual explanations when needed. To support data quality, the survey included attention checks and removed incomplete submissions. The study procedures followed standard ethical principles for educational research, including informed consent and confidentiality (Chiu, 2022; Delcker & Ifenthaler, 2022).

Because international students in online and blended vocational programs are dispersed across institutions and often lack an accessible sampling frame, recruitment relies on voluntary participation via the institutional learning platform and international student networks. This strategy supports access to multilingual cohorts that may be geographically distributed during online delivery periods and helps capture variation in learning experiences shaped by differing technology conditions. To reduce the risk of a narrow convenience sample, recruitment targeted a range of program areas and sought participation across regions of origin and delivery modes, which is reflected in the demographic profile. These design choices align with the study's aim of examining the relationships among learner traits, self-efficacy, perceived high-tech support, and learning effectiveness across diverse international student experiences in China.

Following the survey, 18 participants were invited for interviews using purposive sampling to maximize variation by region, Chinese language level, and delivery mode. The interviews were conducted online, audio-recorded with permission, and summarized using a thematic approach to identify recurring perceptions of high-tech learning support and barriers (Getenet et al., 2024; Delcker & Ifenthaler, 2022).

The follow-up interviews used purposive sampling to ensure that the qualitative explanations were grounded in diverse contextual conditions relevant to high-tech online VET. Variations in region, Chinese language level, and delivery mode were used to capture differences in how students navigated technical vocabulary, instructor communication, simulation tools, and feedback systems. This approach supports the transferability of the qualitative themes by showing how perceived high-tech learning support can operate across multiple subgroups rather than reflecting a single program context.

The measures used 5-point Likert response options (1 = strongly disagree to 5 = strongly agree). Personality traits were assessed with eight items adapted from a short form of the Big Five Inventory-2, emphasizing conscientiousness and openness facets relevant to vocational learning (Mammadov, 2022). Online learning self-efficacy was measured with four items adapted from an online learning self-efficacy scale, capturing confidence in managing online learning

tasks and requirements (Honicke & Broadbent, 2016). Perceived high-tech learning support was measured with six items capturing the perceived usefulness of simulations, feedback tools, analytics, and multilingual scaffolds in supporting skill learning (Cheung et al., 2021; Zawacki-Richter et al., 2019). Learning effectiveness was measured with four items capturing perceived competence gains, transfer, and overall effectiveness of online learning for vocational skills (Xu et al., 2022; Martin & Bolliger, 2018).

The quantitative analysis followed a PLS-SEM-inspired approach suitable for predictive modeling with multiple paths, mediation, and moderation. Reliability and validity were assessed through Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity tests (Hair et al., 2019; Hair & Alamer, 2022). Structural relationships were estimated using standardized composite scores, and bootstrapping (2,000 resamples) was applied to obtain standard errors and significance tests for direct, indirect, and interaction effects (Hair et al., 2019; Hair & Alamer, 2022).

Table 1: Questionnaire profile

Variable	Indicators (items)	Source/scale basis
Personality traits	PT1-PT8 (8 items)	Big Five Inventory-2 short form; vocationally relevant facets (Mammadov, 2022)
Online learning self-efficacy	SE1-SE4 (4 items)	Online Learning Self-Efficacy Scale (Honicke & Broadbent, 2016)
Perceived high-tech learning support	HT1-HT6 (6 items)	Smart learning environment and technology support constructs (Cheung et al., 2021; Zawacki-Richter et al., 2019)
Learning effectiveness	LE1-LE4 (4 items)	Perceived learning and competence gains in online learning (Xu et al., 2022; Martin & Bolliger, 2018)

Data screening was conducted before model estimation. The dataset contained minimal missing values and no duplicate records. Because the constructs were measured with short scales and the sample size was moderate, we used composite-score aggregation to reduce item-level noise while retaining meaningful variance for structural inference. Descriptive checks indicated that item distributions were approximately symmetric around the midpoint of the 5-point scale, which is typical for perception-based measures in online learning studies (Xu et al., 2022; Tian & Lu, 2022). Although normality is not a strict requirement for PLS-SEM-style estimation, we standardized the construct scores to facilitate the interpretation of the coefficients as standardized effects (Hair et al., 2019; Hair & Alamer, 2022).

To mitigate potential common method bias, the study incorporated procedural remedies such as assuring anonymity, reducing evaluation

apprehension, and separating construct blocks with brief transition statements. Statistically, we inspected collinearity diagnostics as a pragmatic check; variance inflation factors for predictors in the outcome model were below conservative thresholds, suggesting that common method bias was unlikely to dominate observed relationships (Hair et al., 2019; Hair & Alamer, 2022). Because international student respondents may interpret items differently because of language nuance, items were written in concrete behavioral language and piloted with a small group of multilingual students to refine clarity and reduce ambiguity (Honicke & Broadbent, 2016; Mammadov, 2022).

The moderation hypothesis (H5) was tested by creating a standardized interaction term between online learning self-efficacy and perceived high-tech learning support. This approach is consistent with interaction modeling in predictive frameworks, where the goal is to assess whether the slope of a key relationship changes as a function of a contextual condition (Hair et al., 2019; Zawacki-Richter et al., 2019). The mediation hypothesis (H4) was assessed using the product-of-coefficients approach and bootstrapped confidence intervals, which are widely recommended for indirect effects because the sampling distributions of products can be nonnormal (Hair et al., 2019; Honicke & Broadbent, 2016).

For the qualitative component, the interview recordings were summarized and coded using an inductive thematic analysis process. Codes were iteratively clustered into themes related to practice opportunities, feedback clarity, language support, and motivational experiences. To enhance trustworthiness, two rounds of coding were conducted with comparisons and reconciliation of differences, and analytic memos were maintained to document theme development (Getenet et al., 2024; Delcker & Ifenthaler, 2022). Qualitative themes were then used to interpret the quantitative moderation and mediation findings, particularly by identifying which features of high-tech environments students perceived as most supportive of converting effort into skill improvement (Cheung et al., 2021; Liu et al., 2023).

Interview Questions

1. Please describe your online vocational learning experience in China (program, delivery mode, and typical weekly learning activities).
2. Which high-tech tools or platforms do you use most often (e.g., simulations, virtual labs, learning analytics dashboards, AI feedback, remote lab access)?
3. How do these tools help or hinder your understanding of practical skills and procedures?
4. Can you describe a situation where technology-based feedback changed how you practiced or improved a skill?
5. What kinds of language or cultural challenges do you face in online learning, and what types of support are most helpful?
6. How confident do you feel about learning online, and what experiences have increased or decreased your confidence?

7. How do you manage time, motivation, and distractions when you are studying online?

8. What recommendations would you give instructors or platform designers to improve online vocational learning for international students?

RESULTS

Variable reliability and validity

Measurement quality was assessed before structural modeling. The Cronbach's alpha values exceeded the commonly used threshold of .70 for all the constructs, indicating acceptable internal consistency. The composite reliability values (rhoC) were also above .70, and the AVE values exceeded .50, supporting convergent validity. These criteria align with the recommendations for PLS-SEM measurement evaluation (Hair et al., 2019; Hair & Alamer, 2022).

Table 2: Construct reliability and convergent validity

Construct	rhoA	rhoC	Cronbach's alpha	AVE
Personality traits	0.888	0.901	0.874	0.533
Online learning self-efficacy	0.871	0.897	0.846	0.684
Perceived high-tech learning support	0.881	0.898	0.863	0.595
Learning effectiveness	0.899	0.917	0.880	0.735

Estimated Model

The structural model was estimated using standardized composite scores. The estimated model with standardized path coefficients and explained variance (R2) is presented in Figure 2. Bootstrapped inference was applied to test the statistical significance of hypothesized paths (Hair et al., 2019; Hair & Alamer, 2022).

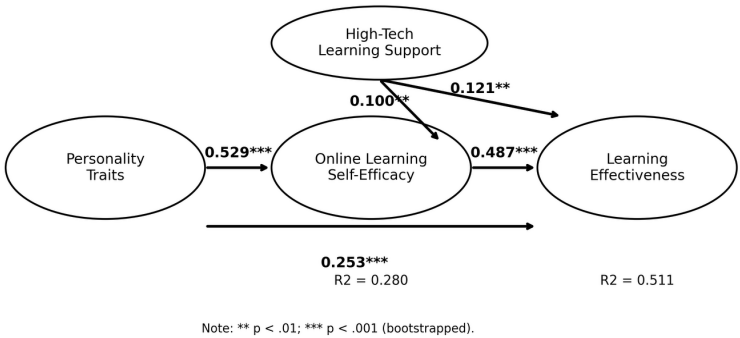

Figure 2: Estimated Model

Measurement item fitness statistics

Indicator loadings were examined as a practical diagnostic of how well items represent their intended constructs. All standardized loadings were above .65 (Table 1), suggesting acceptable item quality for the predictive modeling goals of this study (Hair et al., 2019; Hair & Alamer, 2022).

Discriminant Validity

Discriminant validity was assessed using the heterotrait–monotrait (HTMT) ratio and the Fornell–Larcker criterion. HTMT values less than .85 (or more conservatively, .90) are typically interpreted as supportive evidence that the constructs are empirically distinct (Tables S2, S3). Similarly, the square root of the AVE should exceed the interconstruct correlations to support discriminant validity (Hair et al., 2019; Hair & Alamer, 2022).

Overview of variable effects

Table 3 summarizes the direct, indirect, and total effects. The indirect effect captures mediation via online learning self-efficacy. Cohen's f2 effect sizes were calculated to evaluate the relative contribution of each predictor to the explained variance (Hair et al., 2019; Hair & Alamer, 2022).

Table 3: Effects overview

Effect	Direct effect (β)	Indirect effect (β)	Total effect (β)	Cohen's f2
Personality traits -> Online learning self-efficacy (H1)	0.529	-	0.529	0.389
Personality traits -> Learning effectiveness (H2)	0.253	0.258	0.511	0.094
Online learning self-efficacy -> Learning effectiveness (H3)	0.487	-	0.487	0.299
Indirect: Personality traits -> OLSE -> Learning effectiveness (H4)	-	0.258	0.258	-
Moderation: OLSE x High-tech support -> Learning effectiveness (H5)	0.100	-	0.100	0.018
High-tech learning support -> Learning effectiveness (additional)	0.121	-	0.121	0.025

R-square statistics Model Goodness of Fit Statistics

Model explanatory power was evaluated using R^2 and adjusted R^2 (Table S4). In addition, a 10-fold cross-validated predictive assessment was conducted to obtain the $Q^{2\ prediction}$, RMSE, and MAE for each endogenous construct, aligning

with the predictive orientation of PLS-SEM (Hair et al., 2019; Hair & Alamer, 2022).

Structural Model for Path Analysis

The hypothesized structural relationships tested in the path analysis, including direct effects (H1–H3), mediation (H4), and moderation (H5), are presented in Figure 3.

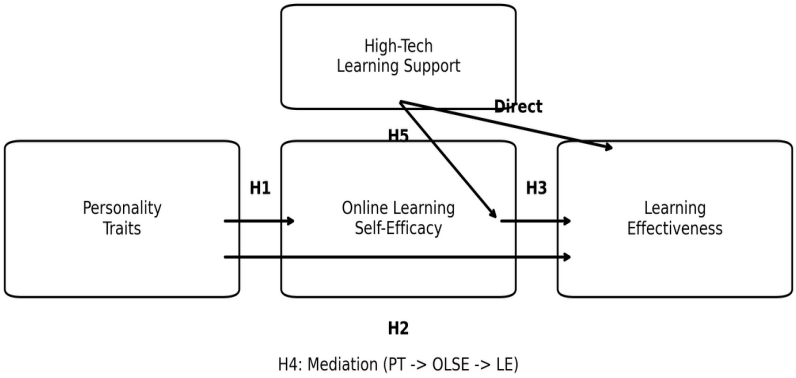

Figure 3: Structural Model for Path Analysis

Path Analysis

Bootstrapped path coefficients were used to test the hypotheses. Table 4 reports the standardized coefficients (original sample), bootstrapped standard deviations, t statistics, and p values. Following common practice, paths with $p < .05$ were interpreted as statistically significant (Hair et al., 2019; Hair & Alamer, 2022).

Table 4: Path analysis results (bootstrapping)

Hypothesis	Path	Original sample (β)	STDEV	T statistics	P values	Result
H1	Personality traits -> Online learning self-efficacy	0.529	0.036	14.842	<0.001	Supported
H2	Personality traits -> Learning effectiveness	0.253	0.043	5.935	<0.001	Supported
H3	Online learning self-efficacy -> Learning effectiveness	0.487	0.043	11.212	<0.001	Supported

Hypothesis	Path	Original sample (β)	STDEV	T statistics	P values	Result
H4	Personality traits -> OLSE -> Learning effectiveness (indirect)	0.258	0.029	8.898	<0.001	Supported
H5	OLSE x High-tech support -> Learning effectiveness	0.100	0.032	3.115	<0.01	Supported

Descriptive statistics for composite constructs were centered near the midpoint of the scale (M approximately 3.0), with standard deviations of approximately 1.0–1.2, reflecting meaningful heterogeneity in perceived self-efficacy, technology support, and learning effectiveness within the international student sample. The construct correlations indicated that personality traits were moderately correlated with online learning self-efficacy ($r = 0.529$) and learning effectiveness ($r = 0.532$), whereas perceived high-tech learning support was weakly correlated with learning effectiveness ($r = 0.379$). These patterns are consistent with a model in which stable learner traits are related to motivational beliefs and in which technology support operates as an enabling condition rather than a sole driver of outcomes (Mammadov, 2022; Cheung et al., 2021).

The moderation effect can be interpreted via simple slopes. Because the interaction coefficient was positive ($\beta = 0.100$), the predicted effect of self-efficacy on learning effectiveness was stronger when perceived high-tech learning support was high. At one standard deviation below the mean of high-tech support, the estimated slope of the effect of self-efficacy on learning effectiveness was approximately 0.387, whereas at one standard deviation above the mean, it increased to approximately 0.587. These findings illustrate that supportive high-tech environments amplify the benefits of learner confidence by providing feedback-rich opportunities to practice and correct errors (Zawacki-Richter et al., 2019; Liu et al., 2023).

Exploratory subgroup analyses by delivery mode suggested that the interaction effect may be stronger in fully online formats than in blended formats. For example, the interaction coefficient was approximately 0.135 in fully online courses compared with 0.055 in blended (online-plus-lab) courses. One interpretation is that when physical labs are limited, high-tech learning support becomes more consequential for translating confidence into performance; in blended formats, in-person lab access may partially substitute for technology-mediated scaffolding (Aristovnik et al., 2020; Han et al., 2020). These subgroup patterns are descriptive and should be tested with formal multigroup modeling in future research (Hair & Alamer, 2022; Tian & Lu, 2022).

DISCUSSION

The findings support the central premise that learning effectiveness in online vocational education is shaped by both stable learner characteristics and malleable

motivational and environmental factors. Consistent with research linking conscientiousness and openness to adaptive online learning experiences, personality traits were positively associated with online learning self-efficacy (H1) (Alkış & Temizel, 2018; Wong et al., 2019). This pattern aligns with social cognitive theory: trait-consistent behaviors (planning, persistence, exploration) generate mastery experiences and constructive interpretations of challenges, which build efficacy beliefs (Sghir et al., 2023; Yu, 2021).

The direct association between personality traits and learning effectiveness (H2) suggests that traits retain explanatory value even when self-efficacy is accounted for. In practical terms, conscientiousness-related routines (e.g., regular practice schedules) likely support sustained engagement with competency tasks in online VET, whereas openness-related curiosity may increase the willingness to use high-tech tools such as simulations and analytics dashboards for improvement (Dahalan et al., 2024; Granić & Marangunić, 2019). These results complement studies showing that engagement and persistence are key drivers of online success, especially when students must self-direct their learning (Sim et al., 2022; Iqbal et al., 2021).

Online learning self-efficacy exhibited a strong positive relationship with learning effectiveness (H3), reinforcing its central role as a proximal predictor of online learning outcomes. Self-efficacy likely affects learning effectiveness through persistence during difficulty and through greater adoption of self-regulated learning strategies such as planning, monitoring, and help-seeking (Yu, 2021; Wong et al., 2019). This also echoes prior work linking self-efficacy to perceived learning and satisfaction in online courses (Tian et al., 2021; Sim et al., 2022).

The results of the mediation analysis (H4) indicate that online learning self-efficacy partially affects the influence of personality traits on learning effectiveness. This is theoretically coherent: personality shapes patterns of engagement and coping, which then builds confidence; confidence, in turn, shapes persistence and effective practice, leading to better outcomes (Sghir et al., 2023; Dahalan et al., 2024). For international students, the mediated pathway may be particularly salient because confidence in navigating online systems and communicating across language barriers can be a prerequisite for sustained participation (Zhou et al., 2022; Crompton & Burke, 2023).

A key contribution of the study is the moderation result (H5), which shows that perceived high-tech learning support strengthens the relationship between self-efficacy and learning effectiveness. This suggests that confidence alone is insufficient; learners also need an environment that enables productive practice. When high-tech support is perceived as strong, self-efficacious students can more efficiently convert effort into improvement, likely through richer feedback and more frequent opportunities to rehearse skills (Crompton & Burke, 2023; Alkış & Temizel, 2018). This aligns with research emphasizing that effective online engagement depends on instructional and technological affordances that support interaction, feedback, and task clarity (Martin & Bolliger, 2018; Wong et al., 2019).

The interview findings help explain the moderation effect. Many participants described high-tech tools as "practice amplifiers": virtual labs and simulations allowed repeated attempts without fear of breaking equipment, while analytics dashboards helped them identify weak skills to revisit. Students also emphasized that the perceived usefulness of these tools depended on scaffolding: step-by-step guidance, clear rubrics, and example-based explanations increased both confidence and performance, whereas complex interfaces without support reduced motivation (Dahalan et al., 2024; Granić & Marangunić, 2019).

Several interviewees highlighted multilingual scaffolding as essential. Participants reported that technical vocabulary and fast-paced instructor speech could be barriers in synchronous sessions, but captioning, bilingual glossaries, and annotated examples reduced confusion and enabled independent practice. These accounts resonate with global survey findings that online learning can exacerbate inequities in access to support and that student experience is shaped by how well institutions provide structured guidance (Yu, 2021; Zhou et al., 2022).

The model also revealed a small but significant direct effect of perceived high-tech learning support on learning effectiveness (additional finding). These findings suggest that supportive technology can benefit learners broadly, not only those with high self-efficacy. Even students with moderate confidence may gain from well-designed simulations and feedback tools that lower barriers to practice and clarify performance expectations (Sghir et al., 2023; Sim et al., 2022). In the context of online vocational education, this finding reinforces the view that high-tech learning environments should be designed as skill-building ecosystems rather than as content-delivery channels (Crompton & Burke, 2023; Alkış & Temizel, 2018).

Overall, the results suggest a layered explanation of learning effectiveness for international students in China: personality provides a stable foundation for self-regulation, self-efficacy captures the learner's perceived ability to manage online vocational tasks, and high-tech learning support determines how efficiently confidence translates into measurable skill gains. This integrated view helps reconcile why the same online platform can produce highly diverse outcomes across learners and highlights the importance of aligning pedagogy, technology, and learner psychology in high-tech online VET (Hair et al., 2019; Hair & Alamer, 2022).

From a theoretical perspective, the results extend smart learning environment frameworks by showing that perceived technology support is not only directly helpful but also interacts with learner psychology. This finding supports an interactionist view in which learning environments and learner characteristics jointly shape outcomes: high-tech tools can function as "capability multipliers" when learners are prepared to engage and when support features reduce friction in practice and feedback cycles (Crompton & Burke, 2023; Alkış & Temizel, 2018).

This study contributes to international education research by focusing on international students in China, a population that is often underrepresented in empirical studies of online vocational learning. By combining survey modeling

with interviews, the study highlights that design features such as multilingual scaffolding and transparent performance criteria are not optional add-ons; they are central for enabling equitable skill learning in technology-rich online VET (Yu, 2021; Zhou et al., 2022).

A practical extension of the findings is the case for 'adaptive support rather than adaptive sorting'. Personality traits are relatively stable and should not be used to label students as likely to succeed or fail; instead, they can inform proactive scaffolding. For example, learners lower in conscientiousness may benefit from nudges, progress reminders, and structured weekly routines, whereas learners lower in openness may benefit from guided introductions to unfamiliar simulation tools before being asked to explore independently. Learning analytics can help instructors detect patterns of disengagement early, but the analytics must be coupled with supportive interventions and human communication to avoid surveillance-like perceptions (Sghir et al., 2023; Sim et al., 2022). In this sense, personality-informed design is best framed as a pathway to more inclusive support rather than a mechanism for selection (Audet et al., 2021; Tian et al., 2021).

The efficacy results also suggest that online VET programs should intentionally design a “confidence-building ramp” at the start of the course. Short tasks that are challenging but achievable, combined with fast feedback, can create mastery experiences that increase self-efficacy and reduce attrition in the early weeks when learners are most likely to disengage. This finding is consistent with social cognitive theory, which emphasizes mastery experiences and feedback as key sources of efficacy, and with online engagement research highlighting the importance of early instructor presence and clear expectations (Iqbal et al., 2021). In high-tech vocational contexts, this ramp can include simple simulation exercises, guided walkthroughs of digital tools, and microcredentials or badges that make progress visible and motivating (Dahalan et al., 2024).

Implications of the study

Implications for instructors and course designers: Online vocational courses should incorporate structured routines that help learners with lower levels of conscientiousness develop consistent practice habits. Examples include weekly practice schedules, short formative checkpoints, and explicit guidance for how to use feedback. Activities that invite exploration (e.g., optional challenge tasks and reflective prompts) can engage learners high in openness and can also cultivate curiosity among other learners (Abe, 2020; Alkış & Temizel, 2018).

Implications for building self-efficacy: Because online learning self-efficacy is a central driver of learning effectiveness, instructors should design early mastery experiences, provide timely feedback, and communicate clear performance criteria. Short guided practice sessions with immediate feedback can increase confidence, especially for international students who may be uncertain about expectations and language demands (Honicke & Broadbent, 2016; Yu, 2021).

Implications for high-tech learning support: The findings suggest that investments in high-tech tools are most effective when they are perceived as

supportive and usable. Institutions should prioritize usability, multilingual scaffolding, and alignment of simulations with authentic vocational tasks. Learning analytics dashboards should be paired with actionable recommendations, and automated feedback should be interpretable and connected to rubrics (Sim et al., 2022; Cheung et al., 2021).

Implications for international student services: Digital orientation sessions, bilingual support channels, and peer mentoring can reduce barriers to using high-tech learning tools and can strengthen confidence. This recommendation is reinforced by recent findings from Chinese universities showing that language barriers, unfamiliar pedagogies, and inadequate language and mental health support can intensify distress among international students, whereas peer support and institutional navigation strategies serve as important coping resources (Mahmood et al., 2026). Providing technical vocabulary glossaries and culturally responsive examples can help international students bridge knowledge gaps and participate more fully in online vocational practice (Tian et al., 2021; Wen et al., 2018; Iqbal et al., 2021).

Implications for evaluation and continuous improvement: Programs should monitor not only completion rates but also self-efficacy indicators and perceptions of technology support, using feedback loops to improve learning design. Because high-tech support enhances the translation of self-efficacy into learning outcomes, regular diagnostic surveys can identify where tools are perceived as barriers rather than supports (Hair et al., 2019; Hair & Alamer, 2022; Crompton & Burke, 2023).

An additional implication is the value of industry-aligned digital practice ecosystems. For high-tech vocational programs, partnerships with companies that provide simulation software, cloud platforms, or remote equipment access can increase authenticity and relevance, which may strengthen motivation and perceived learning. However, such partnerships should be accompanied by learner support (tutorials, feedback guidance, and bilingual resources) to ensure that advanced tools remain inclusive for international cohorts (Dahalan et al., 2024; Delcker & Ifenthaler, 2022; Zhou et al., 2022).

Implications for platform and tool design: High-tech learning support is most powerful when it reduces friction in the learning process. Platform features should make it easy for learners to (a) find the next practice task, (b) understand what counts as good performance, and (c) receive interpretable feedback with concrete next steps. Examples include simulation dashboards that translate performance data into recommendations (e.g., 'repeat module X' or 'review parameter Y'), embedded glossaries for technical terms, and low-barrier help channels integrated into the practice environment. Such designs align with the smart learning environment principles of context-aware, timely, and actionable support (Cheung et al., 2021; Sghir et al., 2023; Granić & Marangunić, 2019).

Implications for assessment and learning analytics: Online VET programs should align assessment with authentic tasks and leverage digital traces responsibly. Simulation logs, virtual lab checklists, and iterative project submissions can provide richer evidence of skill development than can end-of-term exams alone. When combined with clear rubrics and formative feedback cycles, these data can support continuous improvement for both students and

instructors. Moreover, transparent communication about data use and privacy is essential for maintaining trust, particularly for international students who may be unfamiliar with local data governance practices (Liu et al., 2023; Hair et al., 2021; Dahalan et al., 2024).

Limitations and Future Research Directions

Several limitations should be considered when the findings are interpreted. First, the survey design was cross-sectional, limiting causal inference. Although the hypothesized directions are theoretically grounded, longitudinal designs provide stronger evidence for temporal ordering among personality, self-efficacy, and learning effectiveness (Honicke & Broadbent, 2016; Hair et al., 2019).

Second, the constructs were measured using self-report scales, which may be subject to common method variance and social desirability. Future work should incorporate objective indicators of skill acquisition (e.g., simulation performance logs, assessment scores, or industry certification outcomes) to validate perceived learning effectiveness (Dahalan et al., 2024; Liu et al., 2023).

Third, personality was operationalized using a vocationally focused subset of traits (conscientiousness and openness) to reduce survey burden. While theoretically justified, future research could examine the full Big Five and investigate whether extraversion, agreeableness, or neuroticism play distinct roles in online vocational learning and help-seeking (Abe, 2020; Alkış & Temizel, 2018).

Fourth, perceived high-tech learning support was treated as a single construct. Future studies may unpack specific components (e.g., simulation fidelity, feedback quality, analytics usefulness, and language scaffolding) and test which components most strongly drive learning effectiveness for international students (Cheung et al., 2021; Liu et al., 2023).

Finally, the study focused on international students in China. Replication across countries, program types, and institutional settings can clarify generalizability and reveal how policy and infrastructure differences interact with learner characteristics (Tian et al., 2021; Mok et al., 2021).

CONCLUSION

This study investigated how personality traits and online learning self-efficacy jointly shape learning effectiveness in online vocational education among international students in high-tech learning contexts in China. Using survey data from 412 students and follow-up interviews, we found that personality traits (conscientiousness and openness) positively predicted online learning self-efficacy and learning effectiveness. Online learning self-efficacy emerged as a strong predictor of learning effectiveness and partially mediated the relationship between personality traits and outcomes. Moreover, perceived high-tech learning support strengthened the link between self-efficacy and effectiveness, highlighting the role of technology-enabled scaffolding in vocational skill development (Wong et al., 2019).

The findings underscore that effective online VET design requires both learner-centered and technology-centered perspectives. Personality traits help explain the variability in learners' readiness for autonomy, but supportive high-tech environments can create conditions that allow a broader range of learners to succeed (Crompton & Burke, 2023).

Looking forward, the expansion of smart manufacturing and digital industry ecosystems suggests that online vocational education will remain a strategic pathway for developing international talent in China. In this context, the proposed model can serve as a practical diagnostic: programs can assess incoming learners' online learning self-efficacy early, monitor perceptions of high-tech support during the semester, and implement targeted interventions when confidence or support perceptions decline. Because technology-enhanced environments are not automatically supportive, continuous user-centered improvement is essential—especially for multilingual cohorts—to ensure that high-tech tools reduce barriers rather than introduce new ones. Embedding these diagnostic and improvement cycles into program quality assurance can help institutions move beyond emergency remote teaching toward sustainable, evidence-informed high-tech online VET (Dahalan et al., 2024; Hair et al., 2019; Martin & Bolliger, 2018).

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✓ *None*
☐ *Some sections, with minimal or no editing*
☐ *Some sections, with extensive editing*
☐ *Entire work, with minimal or no editing*
☐ *Entire work, with extensive editing*

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