

Higher Education to Support Sustainable Development

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Article

Higher Education to Support Sustainable Development: The Influence of Information Literacy and Online Learning Process on Chinese Postgraduates' Innovation Performance

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Abstract: Digitalization provides opportunities for sustainable development. Cultivating postgraduates' digital skills is an important task of higher education to support sustainable development (HESD). As a crucial way of cultivating digital skills, high-quality online learning processes are of great significance to achieve "Quality Education", in line with the 2030 sustainable development agenda. Based on Biggs's 3P (Presage-Process-Product) learning model, this study focused on the whole learning process and explored the relationship among postgraduates' information literacy, online platforms, online knowledge-sharing processes and their innovation performance. The analysis of a questionnaire survey of 501 Chinese postgraduates showed that (1) information literacy has a positively predictive effect on postgraduates' innovation performance; (2) different online learning processes lead to different learning results. Compared to the quantity-oriented online knowledge sharing process (Qty-KSP), the quality-oriented online knowledge sharing process (Qlty-KSP) is related to better innovation performance, which opens onto this study's third finding: (3) Qty-KSP and Qlty-KSP play a parallel mediating effect between postgraduates' information literacy and their innovation performance. Compared to Qty-KSP, Qlty-KSP is a more powerful intermediary variable, which leads to this study's fourth finding; (4) an efficient online learning environment can contribute to higher-quality online learning process, thus improving postgraduates' innovative performance. This study suggests that policy makers should develop postgraduates' digital skills for sustainable development in the digital age. This can be achieved by (1) cultivating postgraduates' information literacy; (2) encouraging them to practice high-quality online learning processes; and (3) providing an efficient sharing platform for sustainability, resilience, and digitalization in higher education.

Keywords: digital age; talents cultivation; information literacy; online learning process; innovation performance



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1. Introduction

One crucial way for higher education to support sustainable development (HESD) is to cultivate talented individuals who can create new knowledge and apply new technology to achieve Sustainable Development Goals (SDGs) (Sonetti, Brown & Naboni, 2019 [1]; Cai, Ma & Chen, 2020 [2]; Lattu & Cai, 2020 [3]). These innovative individuals are key in promoting the sustainable development of society (Acosta-Prado et al., 2020) [4].

Postgraduates are highly skilled members of the workforce who can promote national innovation and development, and they will play a leading role in future knowledge and technology enterprises (Reichert, 2019 [5]; Ministry of Education of the People's Republic of China, 2020 [6]). The innovation performance of postgraduates is of great significance for the realization of Sustainable Development Goals (SDGs), especially Goal 4 "Quality

Education” (Žalėnienė & Pereira, 2021) [7]. Therefore, exploring the factors affecting postgraduates’ innovation performance and cultivating their innovative capacities are of great significance to the realization of HESD.

Because a vast amount of knowledge in the digital age is stored, communicated, and created through online platforms (Zhu & Hu, 2021 [8]; Dhawan, 2020 [9]), postgraduates face higher requirements for innovative capacities. First, the digital information is complex and not screened. The information literacy of effectively acquiring, identifying, and applying information has become an important factor affecting postgraduates’ participation in sustainable online learning (Association of College and Research Libraries, 2015 [10]; Gómez-García et al., 2020 [11]). Second, due to constraints posed by the COVID-19 pandemic, academic activities increasingly rely on online learning platforms. The learning process of postgraduates via online platforms has an important impact on learning outcomes (Prasetyo et al., 2021) [12]. Therefore, information literacy and high-quality online-learning processes are very important skills in the digital age (Yuan, Liu & Kuang, 2021) [13]. These skills are related to postgraduates’ innovation performance and their capacity to foster sustainable development, and are key factors affecting SDGs, especially Goal4 “Quality Education”.

However, few studies pay attention to the development of postgraduates’ digital skills, especially the impact of these abilities on their innovation performance. Brundiens et al. (2021) [14] regard having future-thinking competency and interpersonal competency as keys to training students in sustainable development, which is important for realizing HESD. Some scholars argue that the “self-awareness ability” (being capable of self-reflection, self-assessment, and self-regulation) is also a key ability for sustainable development (UNESCO, 2017b [15]; Brundiens & Wiek, 2017 [16]; Wamsler et al., 2018 [17]). As mentioned in the above discussions, the skills of communicating, applying, and innovating knowledge in the digital context have gradually become key to affect postgraduates’ innovation performance and promote their individual self-development (Pilav-Velić et al., 2021) [18]. However, there is a dearth of academic discussion in this regard. In addition, online platforms are the medium of online learning, which is a key factor that distinguishes online learning from traditional learning (Castro-Schez et al., 2021) [19].

Based on Biggs’s Presage-Process-Product (3P) learning model [20], this study hypothesizes that postgraduates’ perception of environmental factors of online learning will have a significant impact on their online-learning process and innovation performance. Therefore, this study aims to answer the following research question: How do information literacy, perception of online learning platform, and online learning process affect postgraduates’ innovation performance?

2. Theoretical Reference

2.1. Presage-Process-Product (3P) Learning Model

Biggs’s Presage-Process-Product (3P) learning model provides a theoretical framework to answer the research question concerned in this study. It provides an enlightening overview of the key elements of the learning process and their relationships. It proposed three learning stages of Presage, Process, and Product (Biggs, 1989) [20]: (1) Presage: factors such as student characteristics and learning environment; (2) Process: learning methods used by students during the learning process; and (3) Product: learning outcomes. Existing studies have used the 3P model to explore the relationship between students’ individual backgrounds such as cognitive level and subject interest (Lee & Chan, 2018) [21], environmental factors such as teaching methods perception (Deng, Benckendorff & Gannaway, 2019) [22], process factors such as learning strategies and learning methods (Biggs & Moore, 1993) [23], and product such as academic performance and learning satisfaction (Barattucci, Pagliaro, Cafagna, & Bosetto, 2017) [24].

Biggs (1989) [20] argued that personal and environmental factors (Presage) may influence students practicing a specific learning process (Process), thereby affecting the final learning outcome (Product). The 3P model is widely used in traditional learning contexts,

but few studies have applied it to explore the online learning process of postgraduates. This study applies 3P model to online environment to explore the impact of postgraduates' sustainable development skill on their innovation performance in the digital age. Specifically, Presage includes postgraduates' information literacy and their perception and evaluation of environmental factors of online learning platform. Process refers to the online learning process of postgraduates. Product refers to the innovation performance of postgraduates.

2.2. Research Hypothesis

2.2.1. Information Literacy (Presage) and Innovation Performance (Product)

Information literacy, as an important skill in the digital age, is an important prerequisite factor affecting the effect of online learning (Dong & Jiao, 2014) [25]. This article defines information literacy as "individuals' set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning" (Association of College and Research Libraries, 2015) [10]. It is divided into four dimensions: information awareness, information acquisition, information discrimination, and information application. It is believed that the Internet with complex information has become an important reference source for postgraduates. Therefore, the skill of selecting, evaluating, and managing information has become an important foundation for them to participate in learning activities (Gómez-García et al., 2020) [11]. Individual information literacy such as information acquisition and information management are closely related to their innovation abilities (Chang & Hsu, 2015) [26]. People with higher information literacy can achieve innovation actively, efficiently, and can critically use the resources in the environment to produce more innovative results. Based on these, this study raised the following hypotheses:

Hypothesis 1 (H1a). *Postgraduates' information awareness literacy has a positive impact on their innovation performance.*

Hypothesis 1 (H1b). *Postgraduates' information acquisition literacy has a positive impact on their innovation performance.*

Hypothesis 1 (H1c). *Postgraduates' information discrimination literacy has a positive impact on their innovation performance.*

Hypothesis 1 (H1d). *Postgraduates' information application literacy has a positive impact on their innovation performance.*

2.2.2. Information Literacy (Presage) and Online Learning Process (Process)

The notion of the online-learning process in this article is different from the mandatory online courses arranged by universities. It refers to the process in which postgraduates exert their autonomy to actively participate in online knowledge sharing outside the university curriculum arrangement. That is, postgraduates realize the process of knowledge processing, integration, and innovation by online learning methods such as browsing, liking, forwarding, commenting, posting, and through other online-learning exercises. To some extent, information literacy reflects students' skill to absorb, internalize, express, and apply information (Association of College and Research Libraries, 2015) [10]. These abilities are helpful for students to transform tacit knowledge into explicit knowledge and share it on online-learning platforms and thus to promote active forms of learning (Lu & Li, 2019 [27]; Nonaka, Von Krogh, & Voelpel, 2006 [28]). However, Hemmati (2017) [29] found that the impact of information literacy on the online learning process varies among different individuals: teachers' information literacy will positively predict their online knowledge sharing behavior, while undergraduates' information literacy has no significant correlation with their knowledge sharing and knowledge application behavior. Facing

such contradictory findings, it is necessary to further explore the impact of postgraduates' information literacy on their online learning process. Thus, this study raises the following hypothesis:

Hypothesis 2. *Postgraduates' information literacy has a positive impact on their online knowledge sharing process.*

2.2.3. Online Learning Process (Process) and Innovation Performance (Product)

Based on the different emphases of shared content, this study is concerned with the quantity-oriented and quality-oriented online knowledge sharing processes (Hereafter referred to as Qty-KSP and Qlty-KSP) (Chang, Hsu, Hsu, & Cheng, 2014) [30]. The former focuses on the number and activity of posts rather than the quality of information, while the latter focuses on the value and innovation of shared information. Studies have shown that online-learning processes, such as online knowledge sharing, provide individuals with opportunities to gain different information and experiences, and increase their knowledge, ideas, and skills. This will help them realize the externalization and socialization of knowledge in different fields, so as to improve the innovation skill and stimulate innovation behavior and increase innovation performance (Nonaka et al., 2006 [28]; Nonaka, 2007 [31]). Biggs proposed in the Process link of 3P model that students' differentiated learning process will have different effects on their learning results. Huang (2007) [32] found that both the quantity and quality of individuals' participation in the process of knowledge transfer in virtual communities have a significant impact on innovation performance. Compared to the methods that value quantity more, quality-oriented knowledge transfer methods will lead to the innovation performances with higher conversation rates. Based on this, this study raises the following hypotheses:

Hypothesis 3 (H3a). *Postgraduates' Qty-KSP has a positive impact on their innovation performance.*

Hypothesis 3 (H3b). *Postgraduates' Qlty-KSP has a positive impact on their innovation performance.*

2.2.4. Mediating Role of Online Learning Processes

Individuals with high information literacy have strong information awareness. They can participate in knowledge exchanges actively by using information technology. This interactive process will help individuals generate new ideas and knowledge for the dissemination, blending, absorption and transformation of knowledge, and thus improve their creativity and achieve more innovative performance. Jinadu and Kiran (2014) [33] found that individuals with high information literacy have more information search channels and can distinguish the effectiveness of information. At the same time, they can construct knowledge through sharing information with others. Therefore, they can obtain more experience that can be applied to innovation activities. This process will further develop individuals' related skills and promote their innovative performance. Yin (2018) [34] further found that only some of the new technologies and methods acquired through information knowledge and information capabilities directly stimulated the creativity of knowledge workers. However, other parts are further interacted, integrated, transformed, and innovated through knowledge sharing behaviors such as information collection and exchange among individual employees, thereby improving the innovation performance of enterprises. Based on this, this study raises the following hypotheses:

Hypothesis 4 (H4a). *Qty-KSP has a mediating effect between information literacy and innovation performance.*

Hypothesis 4 (H4b). *Qlty-KSP has a mediating effect between information literacy and innovation performance.*

2.2.5. Environmental Factors in Online Learning (Presage) and Innovation Performance (Product)

In addition to the individual characteristics of students, learning environments, such as interaction with peers, discussion atmosphere between peers, teaching context and positive interaction with tutors, are also important components of the predictive variables in the 3P model (Biggs, 1987) [20]. Students' perception and evaluation of the above learning environment are related to their learning process, which will eventually lead to different learning outcomes (Biggs, 1987) [20]. During online learning platform, peers with common goals and vision can help with and learn from each other. Positive peer effect is an important factor to encourage postgraduates to actively participate in the online learning process and promote their innovative achievements (Van Popta, Kral, Camp, Martens, & Simons 2017) [35]. In addition, the online knowledge-sharing process relies on the online-learning platform. Researcher (Davis, 1989) [36] identified two factors that play key roles in predicting individuals' learning process and outcomes: the Perceived Usefulness (PU) of an information system that reflects users' perceived improvement of their performance; and Perceived Ease of Use (PEU) that reflects users' perceived ease of using an information system. Therefore, the platform support is also an important environmental factor affecting students' participation in online learning process, and innovation performance. Based on this, this study regards the environmental factors perceived by postgraduates as an important "Presage Factor". These include two dimensions: platform peer support and online-platform support. Based on this, this study raises the following hypotheses:

Hypothesis 5. *Environmental factors have a positive impact on postgraduates' innovation performance.*

Hypothesis 6 (H6a). *Qty-KSP has a mediating effect between environmental factor and innovation performance.*

Hypothesis 6 (H6b). *Qlty-KSP has a mediating effect between environmental factor and innovation performance.*

Based on the above theoretical review and literature review, this study proposes a theoretical model of the influencing factors of online-learning results based on the 3P model (shown in Figure 1).

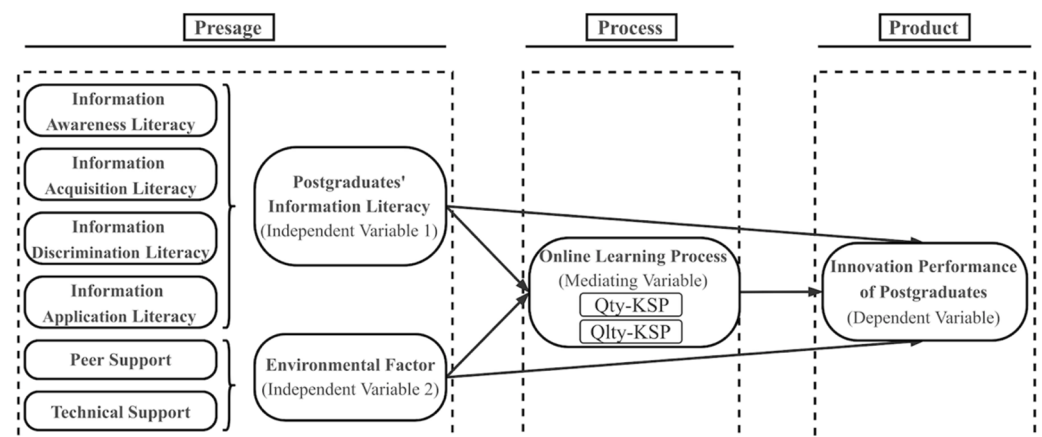


Figure 1. Process model of online-learning results based on 3P model.

3. Data and Methods

This study explores students' self-evaluation and views on information literacy, online knowledge-sharing behaviors and innovation performance through Survey.

3.1. Data Collection

Due to the lockdown during the COVID-19 pandemic, this study collected data through online platforms and face to face. Online knowledge-sharing platforms are used to advertise posts, such as Jing-guan-zhi-jia (a virtual community widely popular among Chinese postgraduates). Posts were also collected from public elective classes. Postgraduates were encouraged to answer an online or physical questionnaire that takes about 8–12 min to finish. Their participations were completely voluntary and anonymous. Students were informed that it has nothing to do with the assessment of any classroom performance, and they have the right to choose to join or quit halfway. The questionnaire provided participants with the overview of the research and researchers' contact information. After obtaining the consent of participants, they filled in the background information form and answered questions related to information literacy, online-learning process, and innovation performance (the questions were presented in random order).

3.2. Participants

The data was collected from April 2021 to June 2021; during this period of time, 642 questionnaires were collected. Through the screening of questionnaire response time and logic-related questions, 501 valid questionnaires were finally identified, with an effective recovery rate of 78.04%. The average age of participants was 25.56 years old (SD = 2.39), and the proportion of male (42.91%) and female (57.09%) was balanced, similar to that of masters (50.3%) and PhD students (49.7%). In addition, the proportion of students majoring in natural science and humanities and social sciences was 57.48% and 42.52%, respectively, with a certain representativeness of the samples.

3.3. Survey Administration

First, it summarizes the variables, specific dimensions, and data types involved in this study (shown in Table 1).

Table 1. Operational Information of Core Variables.

Variable	Dimension	Number of Question	Reference	Type
Information Literacy	Information Awareness	5	Information Literacy skill of College Students in Higher Education in Beijing by University Library Society in Beijing (2005) [37]	Six subscales of Likert; disagree (1) to agree (6).
	Literacy	3		
	Acquisition Literacy	3		
	Information Discrimination Literacy	3		
Environmental Factor	Application Literacy	3		
	Peer Support	4	Mckinney, Yoon, and Zahedi (2002) [38];	
	Platform Support	4	Chiu, Hsu, and Wang (2007) [39]	
Online Knowledge Sharing Behaviour	Qty-KSP	4	Panel Studies of Chinese University Student (PSCUS) questionnaire	
	Qlty-KSP	5	Wasko and Faraj (2005) [40]	
Innovation Performance		9	Janssen and Yperen (2004) [41]; Han, Lian and Long (2007) [4]	

The information literacy scale is adapted from the index system of Information Literacy Skill of College Students in Higher Education in Beijing by the University Library Society in Beijing (2005) [37]. The index system is based on the Information Literacy Competency Standards for Higher Education (ILCSHE) [42] issued by the Association of College and

Research Libraries (ACRL) in 2000 and supplemented in combination with the current situation of information literacy education in universities in China. It consists of 7 primary indicators, 19 secondary indicators and 61 tertiary indicators. Referring to the definition of information literacy by the ALA, this study deleted and merged some secondary indicators, and obtained 14 questions covering the four dimensions of information awareness, information acquisition, information discrimination, and information application. The topics included: “I understand the ethics and laws related to online knowledge sharing”, “I can compare information and knowledge from different sources on the platform and evaluate its quality, identifying bias and fraud in information”, and so on.

The environmental factor scale includes a peer support subscale and platform support subscale, which are adapted from Chiu, Hsu, and Wang (2007) [39] and Mckinney, Yoon and Zahedi (2002) [38]. Given that the mother tongue of the samples in this study is Chinese, this study uses double translation technology (McGorry, 2000) [43] to translate them into Chinese problems and options, and corrects the mistranslation, omission, and ambiguity to form the final scale. The peer support subscale includes four questions, such as “the platform gathers a group of members with rich professional knowledge and skills” and “in the process of discussion, members use understandable communication modes”; and the platform support subscale includes four questions, such as “I think the system of the network sharing platform is reliable” and “I think the network sharing platform is useful”.

The online-learning-process scale includes Qlty-KSP subscale and Qty-KSP subscale, which are adapted from Wasko and Faraj (2005) [40] and Panel Studies of Chinese University Student (PSCUS) questionnaire, respectively. The quality-oriented subscale has been widely cited in related fields, and its effectiveness and reliability have been verified. The author forms the final scale based on double translation technology. The sample items included five questions, such as “the knowledge I participated in online sharing is reliable” and “the knowledge I participated in online sharing is complete”. The quantity-oriented subscale is adapted according to the fifth part of “social communication—knowledge sharing in a network virtual academic community” of the PSCUS launched by the Chinese Academy of Social Sciences; the subscale includes the following option for assessing respondents’ use of online-learning resources: “I often use network sharing platform to browse the information I need, or express my likes regards others’ information and forward them”.

The innovation-performance scale is adapted from the innovation performance scale developed by Han, Lian and Long (2007) [44], which is based on Janssen and Yperen’s re-search results (2004) [41] and measures the individual innovation performance of knowledge workers from three dimensions: generation of innovative thinking, the promotion of innovative thinking, and the realization of innovative thinking. Given that the respondents of this study are postgraduates, and the dependent variable assessed in the research questions of this paper focuses more on learning achievements, i.e., scientific research innovation performance, the expression of the items contained in the above scale is slightly adjusted; it contained twelve questions, such as “I am often praised for putting forward new ideas”, “I can well evaluate the feasibility of innovative ideas”, “in academic research, I will put some innovative ideas into practice”.

3.4. Reliability and Validity Test

This study used SPSS26.0 and Mplus8.3 to test the reliability and validity of 501 valid sample data. Among them, the overall reliability coefficient of the questionnaire Cronbach’s alpha is 0.970, which has passed the reliability test. Considering that the molecular weight scale used in this study is based on the adaptation and translation of existing projects and lacks strong verification from previous empirical studies, it is necessary to use Exploratory Factor Analysis (EFA) to examine the underlying factor structure and communality of items. The overall KMO value of the questionnaire is 0.970, and the Chi-square value of Bartlett’s Test of Sphericity is 18,380.757 ($df = 780, p < 0.001$), which meets the prerequisites of factor analysis. To test the validity of the questionnaire, the EFA adopts the Principal Component Method to extract the factors, and the optimal oblique method is used for

rotation. The characteristic root is greater than 1, and the factor load is not less than 0.4. After excluding irrelevant items, we obtained 40 items, and the total explained variance was 70.144%. Subsequently, this study carried out EFA and Confirmatory Factor Analysis (CFA) on each subscale (shown in Table 2).

Table 2. Reliability and validity test of sub-scales.

Subscale	KMO	Chi-Square Value of Bartlett Test	Cronbach's Alpha	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Information Literacy	0.954	7138.971 (df = 91, $p < 0.001$)	0.961	240.005 **	70	3.429	0.970	0.961	0.070	0.045
Environmental Factor	0.936	2314.608 (df = 28, $p < 0.001$)	0.909	84.609 **	18	4.700	0.965	0.946	0.086	0.045
Online Knowledge Sharing Behaviour	0.870	2753.475 (df = 36, $p < 0.001$)	0.871	70.061 **	25	2.802	0.977	0.968	0.060	0.054
Innovation Performance ¹	0.936	3197.058 (df = 36, $p < 0.001$)	0.933	84.123 **	25	3.365	0.977	0.967	0.069	0.026

¹ In the early stage of research design, the environmental factor was divided into two dimensions: peer support and platform support. Yet the results of EFA showed that the environmental factor was a one-dimensional construct. ** $p < 0.05$.

According to Table 1, it is found that the KMO values of the four subscales are greater than 0.8, and have passed the Bartlett's Test, which is suitable for factor analysis. The Cronbach's alpha of the four subscales is 0.961, 0.909, 0.871, and 0.933, respectively, which indicates the subscales have high reliability. In addition, four subscales' χ^2/df are less than 5, CFI (>0.90), TLI (>0.90), RMSEA (<0.08) and SRMR (<0.08) are almost within the acceptable range, which proved that the subscales have good validity. Therefore, the next step of statistical analysis can be carried out based on the data recovered from this scale.

3.5. Data Analysis

This study aims to explore the relationship and influence path among information literacy, environmental factors, online knowledge sharing process, and postgraduates' innovation performance from a whole-process perspective. First, this study conducts descriptive statistics on the basic situation of sample subjects participating in the online learning process by Stata15.1. Second, this study uses the four dimensions of information literacy of postgraduates as independent variables 1, environmental factors as independent variables 2, and innovation performance as dependent variable, and uses the Mplus 8 to construct a structural equation model Model 1 to explore the impact of information literacy and environmental factors on innovation performance. Third, the mediating variable is added to Model 1 to form Model 2, to explore the mediating role of online knowledge sharing process in the impact of postgraduates' information literacy on their innovation performance.

4. Results

4.1. Descriptive Statistics of Samples' Basic Information

As digital aborigines in the Internet age, more than 80% of postgraduates have used the Internet for more than nine years. Influenced by the thinking mode and lifestyle in the data age, they have unique advantages in taking advantage of extracurricular online platforms such as virtual academic communities and participating in online knowledge sharing. From the perspective of basic consciousness, most postgraduates realize the importance of online learning and online knowledge sharing; 91.82% of them believe that it is necessary to participate in online knowledge sharing. From the perspective of participation behavior,

95% of postgraduates have used extracurricular online learning platforms such as a virtual academic community for more than one year. Mobile phones and mobile computers are the most used devices for them to log into online-learning platforms. Among the 501 valid samples, 466 samples participated in online knowledge sharing activities at least once a week, of which 53.49% even participated in high frequency every day. In addition, about half of the samples participated in the online-learning platform for more than one hour at a time. The basic situation of the sample objects participating in the online-learning process is shown in Table 3.

Table 3. Basic information of postgraduates participating in online-learning process ($n = 501$).

Variable	Category	Frequency
Years of Using Internet	<9 Years	94
	9–11 Years	161
	>12 Years	246
Years of Using Online Learning Platform	<1 Years	36
	1–3 Years	125
	>3 Years	340
Common Login Devices for Online Learning Platform	Mobile Phone	239
	Mobile Computer	231
	Desktop Computer	31
Frequency of Using Online Learning Platform	Every Day	268
	Every Week	198
	Every Month	35
Time per Use of Online Learning Platform	<30 min	35
	30 min–1 h	216
	>1 h	250
Importance of Online Knowledge Sharing	Importance	460
	Unimportance	41

4.2. The Impact of Information Literacy and Environmental Factor on Innovation Performance

This study takes the four dimensions of information literacy as independent variable 1, environmental factors as independent variable 2, and postgraduates' innovation performance as dependent variables to build a structural equation Model 1 (shown in Figure 2): $\chi^2(414) = 1211.858^{**}$, $\chi^2/df = 2.927 < 5$, RMSEA = 0.062, CFI = 0.931, TLI = 0.923, SRMR = 0.062. The model has a good fit.

According to Figure 2, in addition to information acquisition literacy, postgraduates' information awareness literacy, information discrimination literacy, information application literacy, and environmental factors of online learning platforms positively predict postgraduates' innovation performance at the significance level of 0.01. Compared to postgraduates' information application practice literacy ($\gamma = 0.29$, $p < 0.01$), correct information awareness ($\gamma = 0.47$, $p < 0.01$) and keen information-discrimination literacy ($\gamma = 0.338$, $p < 0.01$) have a more significant impact on innovation performance. In addition, the environmental factors composed of peer and platform support also have a significant positive impact on postgraduates' innovation performance ($\gamma = 0.62$, $p < 0.01$). High level peers with a common vision actively participate in the online knowledge-sharing process, which can produce more effective information, while an efficient and stable platform accelerates the dissemination of effective information. A high quality online learning environment helps postgraduates obtain effective information, stimulate innovation behavior, and increase innovation output. The above research findings support the H1a, H1c, H1d, and H5, while H1b has not been verified.

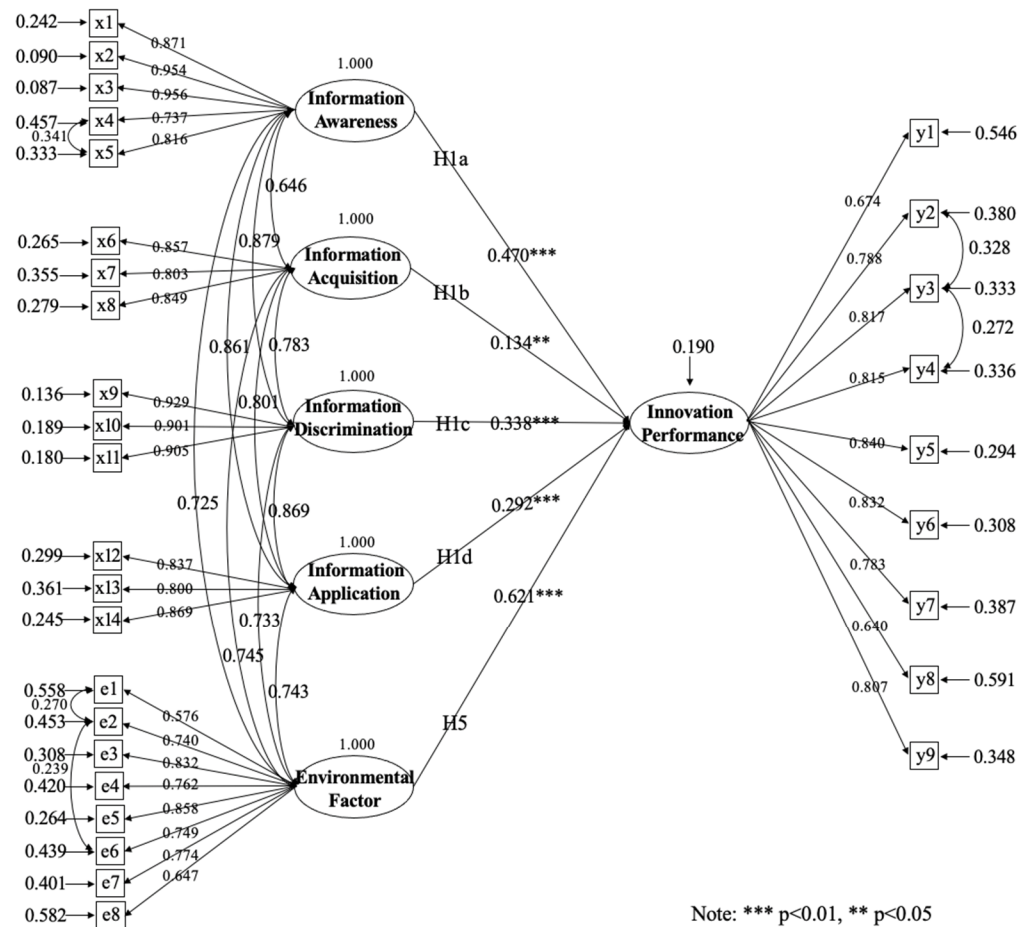


Figure 2. The impact of postgraduates’ information literacy on innovation performance.

4.3. Mediating Effect Test of Online Knowledge Sharing Behaviour

After adding the mediating variable of “Qty-KSP” and “Qlty-KSP” to Model 1, this study obtains the theoretical hypothesis Model 2 of the impact mechanism of information literacy and environmental factor on postgraduates’ innovation performance (shown in Figure 3): $\chi^2(707) = 2219.832^{**}$, $\chi^2/df = 3.140 < 5$, RMSEA = 0.065, CFI = 0.917, TLI = 0.908, SRMR = 0.067. All indicators are within the acceptable range.

Figure 3 shows that postgraduates with high information awareness literacy ($\gamma = 0.99$, $p < 0.01$), information acquisition literacy ($\gamma = 0.50$, $p < 0.01$), and information discrimination literacy ($\gamma = 0.30$, $p < 0.05$) prefer to practice Qlty-KSP, while information application literacy ($\gamma = 0.43$, $p > 0.01$) has no statistically significant effect on Qlty-KSP. However, except for information acquisition literacy ($\gamma = 0.29$, $p < 0.1$), other information literacy has no direct relationship with Qty-KSP, and H2 has deviation. In addition, compared to the Qty-KSP ($\gamma = 0.13$, $p < 0.05$), the Qlty-KSP has a more significant positive prediction effect on postgraduates’ innovation performance ($\gamma = 0.35$, $p < 0.01$), and both H3a and H3b pass the test.

This study tests the mediation effect of online knowledge sharing behavior based on bootstrap. After repeatedly sampling 5000 bootstrap samples for estimation, we found that the Qlty-KSP (M1) plays a partial mediating role between information awareness literacy (X1), information acquisition literacy (X2), information discrimination literacy (X3), information application literacy (X4), and innovation performance (Y), and there are four mediation paths: A1, B1, C1, and D1. H4b passed inspection. For example, path A1 indicates $X1 \rightarrow M1 \rightarrow Y$. Part of the impact of postgraduates’ information literacy on their innovation performance is realized through the intermediary effect of the online-learning process of Qlty-KSP, which accounts for 42.75% of the total effect.

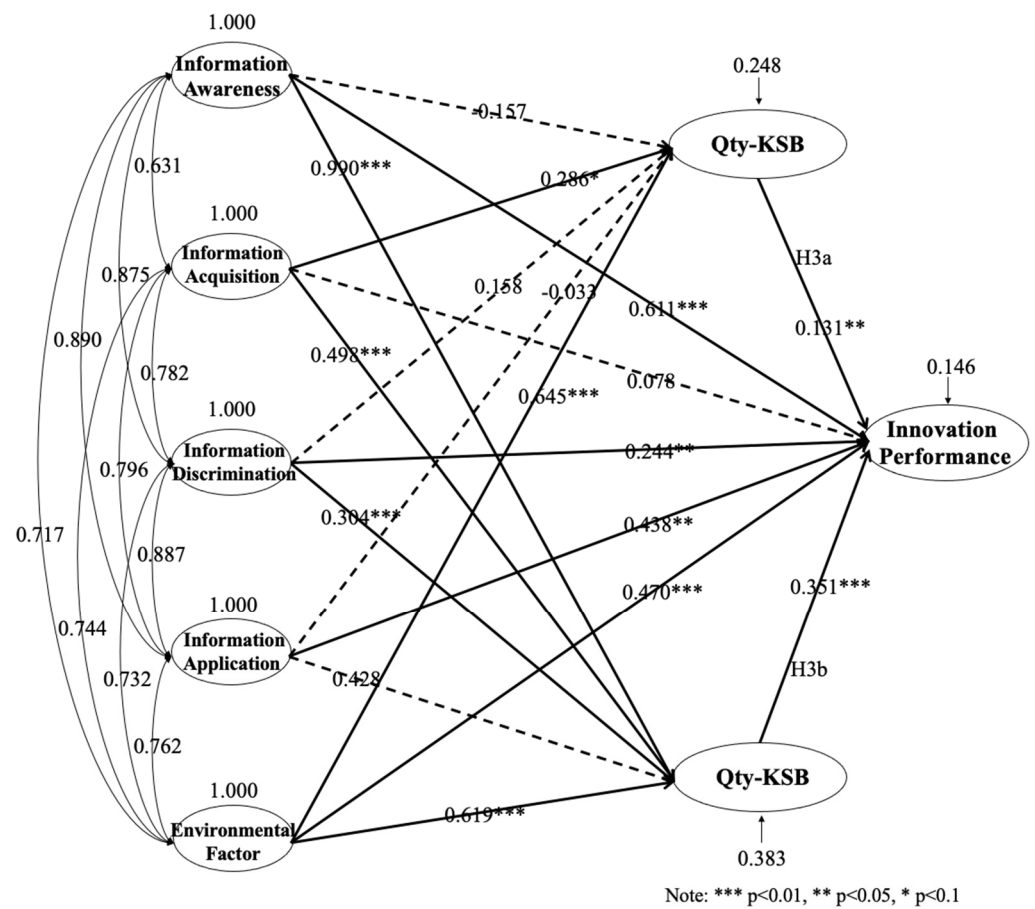


Figure 3. The impact of information literacy, environmental factors, and learning process on post-graduates’ innovation performance.

Qty-KSP (M2) also plays a partial mediating role between the four dimensions of information literacy and postgraduates’ innovation performance. There are four mediation paths A2, B2, C2, and D2, of which path D2 represents X4→M2→Y, the effect ratio is 1.92%, and the mediating coefficient test is significant. However, the 95% confidence intervals of the other three mediation paths contain zero, so the mediation effect is not significant, and H4a is partially established. See Table 4 for the specific mediation paths.

In addition, the results of model 2 show that the environmental factors composed of stable, safe, and efficient online learning platforms and members with shared language, common vision and mutual trust can significantly predict the online knowledge sharing behavior. Qty-KSP plays a partial mediating role between environmental factors and innovation performance (path E1). The proportion of mediating effect is 36.43%, and the 95% confidence interval is [0.283, 0.437], excluding zero. H6b passed the test. However, the Qty-KSP fails to play a significant mediating role between environmental factors and innovation performance (path E2). The mediating effect value is −0.006, and the 95% confidence interval is [−0.030, 0.020], including zero; H6a was not tenable. Combined with Figure 3 and Table 3, compared to the Qty-KSP, the Qty-KSP is a more powerful mediating variable and plays a positive role in the active prediction of information literacy and environmental factors on postgraduates’ innovation performance.

Table 4. Total effect and details of each mediation path.

Pathways	Mediation Analysis	Effect	BootSE	95% Confidence Interval		t-Value	p-Value
				BootLLCi	BootULCI		
X1→M→Y	Total Effect	0.510	0.027	0.457	0.563	18.773	0.000
	Direct Effect	0.294	0.027	0.242	0.346	11.086	0.000
	Indirect Effect A1	0.218	0.023	0.175	0.264	X1→M1→Y	
	Indirect Effect A2	−0.002	0.006	−0.014	0.010	X1→M2→Y	
X2→M→Y	Total Effect	0.832	0.036	0.761	0.903	23.029	0.000
	Direct Effect	0.454	0.040	0.376	0.532	11.456	0.000
	Indirect Effect B1	0.382	0.036	0.314	0.454	X2→M1→Y	
	Indirect Effect B2	−0.004	0.012	−0.028	0.019	X2→M2→Y	
X3→M→Y	Total Effect	0.534	0.024	0.487	0.581	22.271	0.000
	Direct Effect	0.322	0.025	0.273	0.371	12.983	0.000
	Indirect Effect C1	0.205	0.022	0.164	0.249	X3→M1→Y	
	Indirect Effect C2	0.007	0.005	−0.003	0.020	X3→M2→Y	
X4→M→Y	Total Effect	0.780	0.036	0.709	0.851	21.500	0.000
	Direct Effect	0.437	0.035	0.368	0.507	12.407	0.000
	Indirect Effect D1	0.328	0.034	0.264	0.397	X4→M1→Y	
	Indirect Effect D2	0.015	0.007	0.003	0.030	X4→M2→Y	
X5→M→Y	Total Effect	0.980	0.034	0.914	1.047	28.857	0.000
	Direct Effect	0.629	0.044	0.542	0.716	14.254	0.000
	Indirect Effect E1	0.357	0.040	0.283	0.437	X5→M1→Y	
	Indirect Effect E2	−0.006	0.013	−0.030	0.020	X5→M2→Y	

5. Discussions

5.1. Strengthening Individual Information Literacy Helps to Improve Postgraduates' Innovation Performance

Information literacy has become an important skill for training individuals in sustainable development in the digital age. Cultivating postgraduates' information literacy is of great significance in improving their innovation performance and promoting forms of higher education oriented toward sustainable development. This empirical study found that in addition to information acquisition literacy, postgraduates' information awareness literacy, information discrimination literacy, and information application literacy all significantly and positively predict postgraduates' innovation performance. In the digital age, the information content is complex, the access is diverse, and its cost is low. The relevant access skill seems not to be the key factor affecting postgraduates' participation in innovation activities and improving the output of innovation achievements. However, for postgraduates to conduct innovative activities in the information society, it is important to understand the importance of information and abide by information-related ethics and corresponding laws. In addition, effectively identifying the content and quality of information from different sources and having the quality of extracting and forming their own knowledge from complex information will also help postgraduates improve their critical thinking and practical skill and inspire more innovative behaviors and innovative outputs. It resonates with previous studies such as Gómez-García et al. (2020) [11] and Chang & Hsu (2015) [26]. They also found that the skill to effectively obtain, evaluate, and manage information has become an important prerequisite for students to participate in learning activities in the digital age, which is closely related to their innovation ability.

5.2. Efficient Online Learning Environments Help to Improve Postgraduates' Innovation Performance

Digital transformation is becoming a necessary part of people's lives (Căpușeanu, 2021) [45]. The sustainable development of higher education is inseparable from the application of the online learning environment (Wu, 2020) [46]. Online learning environments are gradually transforming from the face-to-face interaction to a blended one (Angouri,

2021) [47]. Therefore, the stability and effectiveness of the online-learning platform itself and the positive peer effect among online-platform users have certain impacts on postgraduates' innovation performance (Tang, Lu & Naumann, 2020) [48]. In addition, the study found that some of the positive effects of environmental factors on postgraduates' innovation performance are indirectly produced through postgraduates' Qlty-KSP. This means that an efficient online platform can encourage postgraduates to practice a higher quality online-learning process and promote their innovation performance. Lastly, the two dimensions of peer support and platform support complement each other: the benign communication network, positive sharing atmosphere, and stable system construction of the platform are conducive to the aggregation effect and attract more high-quality users to participate in the collision and exchange of ideas (Akram et al., 2021) [49]. At the same time, the platform users' active sharing behavior, high-quality and effective sharing content and open discussion atmosphere will also improve the effectiveness of the platform and form a favorable circle. This exploratory factor analysis also proves that the two dimensions are inseparable, constituting the environmental factor together to encourage postgraduates' innovative output.

5.3. Engagement in High-Quality Online Learning Process Helps Postgraduates to Improve Their Innovation Performance

Different online learning processes have different impacts on postgraduates' innovation performance (Razmerita et al., 2020) [50]. Echoing Huang (2007) [32], this study finds that encouraging postgraduates to practice more quality-oriented online sharing processes may be an important way to encourage their high-quality and sustainable online learning processes and improve their innovation achievements. Biggs (1987) [20] proposed in the process link of 3P model those different motivations will result in different learning behaviors and learning methods, which will impact the learning results of the final link (Deng, Benckendorff & Gannaway, 2019) [22]. Postgraduates with Qty-KSP are greatly driven by external self-motivation and hope to obtain virtual currency or forum points through knowledge sharing (Jin et al., 2016) [51]. Their online learning process consists mainly of "spamming" (publishing many meaningless posts on online platforms) and "water paste" (meaningless reply to the discussion topic to accumulate platform points or experience values). Therefore, the online-learning process of these "information porters" is decentralized and instrumental in nature, lacking critical thinking, integration, and the reconstruction of information, thus contributing less to innovation output. It is a kind of Surface Approach (Marton & Saljo, 1976) [52]. On the contrary, the Qlty-KSP is more of a Deep Approach in the traditional learning situation. These "knowledge creators" driven by social motivation and internal self-motivation pay more attention to valuable information sharing and exchange (Wasko & Faraj, 2005) [40]. They seek the potential significance and purpose of online-learning tasks and compare the multi-party information and knowledge structure. These in-depth online-learning processes are of positive significance to improving individual's sustainable development ability and promoting the output of their innovative achievements.

5.4. Postgraduates' Online Learning Process Plays an Intermediary Role in the Impact Path of Their Information Literacy on Innovation Performance

Having a high level of information literacy and engagement in high-quality online-learning processes has gradually become an important prerequisite for postgraduates to achieve individual professional development in the digital age. Yin (2018) [34] proposed that knowledge sharing plays a mediating role between the information ability of knowledge workers and organizational innovation performance. This study further found that the Qlty-KSP plays a partial mediating role in the positive prediction of information literacy and environmental factors on innovation performance, while the Qty-KSP only has a mediation effect on the relationship between information application literacy and innovation performance. Postgraduates with high information literacy will pay more attention to the significance of information sharing rather than low-quality screen brushing. Compared

to reprinting and sharing other people's content, postgraduates with high information literacy tended to choose Qlty-KSP. They summarize the main ideas and structure from the extracted information, combine thinking, and practice to form their own knowledge and views, and then output them for sharing. Stable and efficient platform hardware support and harmonious high-level peer learning also provide an environmental basis for postgraduates' Qlty-KSP. The process of critical thinking and knowledge system reconstruction under the support of existing information literacy and environmental support will have a significantly positive impact on postgraduates' innovation behavior and innovation achievements. However, the Qlty-KSP is driven by external motivation rather than by high information literacy. The mediating effect seems to be more obvious in active high-quality users such as "internet academic celebrities" and "platform big V influencers" with strong information-application integration ability.

6. Conclusions

The meaning of sustainability in higher education has changed in the digital age. This study took place in China, which has the largest education system in the world. This study draws on a sample of 501 postgraduates from China. Based on Biggs' Presage-Process-Product model, this study examines the relationship and impact path among postgraduates' information literacy, online knowledge-sharing process, and innovation performance from a whole-process perspective. The study findings emphasize the importance of innovative capacities of postgraduates in promoting the sustainable development of higher education. This can be achieved by cultivating the information literacy of postgraduates and paying attention to the quality of online learning process. This may be an important course of action to achieve the sustainable development goal of "Quality Education" and promote the 2030 Agenda for Sustainable Development.

This study extends the Biggs' 3P learning model to the postgraduate online-learning context. In addition, this research focuses on the practical issues of sustainable development of higher education and skills development in the digital age. We suggest postgraduates' information literacy and extracurricular online learning processes as important paths for cultivating innovative talents in the digital age to achieve sustainable development. Through the findings of this study, it can be speculated that improving postgraduates' sustainable-development capabilities in the digital age, through an online-learning process that helps them develop information literacy, will foster an inclusive learning environment as well as high-quality learning outcomes. This provides a reference based on empirical data to encourage everyone to have the right to enjoy digital services fairly. This will contribute to the achievement of the SDGs, especially Goal 4, "Quality Education".

Based on the above research findings, this research suggests to (1) incorporate information literacy-related courses into postgraduates' learning scope, and develop their information literacy, especially information discrimination literacy and information application literacy; (2) encourage postgraduates to actively participate in the knowledge sharing of extracurricular learning platforms such as virtual academic communities and cultivate their digital capabilities for sustainable development in the digital age through high-quality sharing practices; and (3) build a user-friendly knowledge sharing platform for postgraduates, and provide a good environment for improving the sustainability, flexibility, and digitalization (Miceli et al., 2021) [53] of higher education.

This study used a variety of research designs to improve the internal validity and reliability, but some limitations remained. Deng, Benckendorff, Gannaway (2019) [22] explore the applicability of the Biggs 3P model from a cultural perspective. They find that the impact of learning methods on achievement varies according to students' gender and cultural background. Future research can explore the applicability of this study to students of different genders, educational backgrounds, and family backgrounds. Furthermore, the results were relatively subjective, although self-reported innovation performance is common. Future research could use relatively objective data such as the number of papers to measure innovation performance to validate our findings.

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