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Smart classroom preferences and information literacy among college students

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In recent years, smart classrooms have been widely constructed in colleges and universities. To help the design of student-centred smart classroom in compliance with students' information literacy levels and enable all students to adapt to the smart classroom smoothly, this study utilised a quantitative method to investigate the information literacy and preferences for smart classroom learning environments (PSCLE) of 873 Chinese college students. The results indicated statistically significant effects of college students' information literacy on the eight dimensions of students' PSCLE (student negotiation, inquiry learning, reflective thinking, usefulness, ease of use, multiple sources, connectedness, functional design). In addition, three profiles could be identified regarding students' information literacy. Students with a high level of information literacy obtained significantly higher scores on four of the critical dimensions of PSCLE (student negotiation, inquiry learning, reflective thinking and functional design) than those students with medium or low levels of information literacy. Based on the results, we suggest that college students' information literacy and their PSCLE should be considered by researchers and education practitioners when designing, constructing and evaluating smart classroom learning environments.

Implications for practice or policy:

- Schools should evaluate students' information literacy and equip smart classrooms with various information communication technology devices to cater to students' varying levels of information literacy.
- Instructors or curriculum designers should develop differentiated instruction strategies and activities for students, in alignment with different levels of information literacy.
- Institutions and organisations should reconsider evaluation criteria for smart classrooms and incorporate the improvement of students' information literacy as an important indicator.

Keywords: smart classroom, information literacy, college students, preference, learning environment

Introduction

The term *smart classroom* refers to a physical classroom that integrates technology solutions such as network access, interactive whiteboards, multimedia devices and virtual learning platforms (B. Li et al., 2015). Such a learning environment provides unique opportunities for students to search, acquire, analyse and apply digital learning resources and tools in self-regulated learning, cooperative learning and inquiry learning activities (Y. Zhang et al., 2019). Given the many advantages offered by smart classrooms, many countries, of which China is one, are investing significantly in building smart classrooms, with the aim of enhancing students' learning through advanced information and communication technology (ICT) infrastructure and promoting students' academic performance (Temdee, 2021). However, despite these efforts, evidence has shown that the effects of smart classrooms on promoting students' learning, through advanced ICT and improving academic performance, have not met the latter expectations (Mao et al., 2018). In particular, researchers have criticised the fact that smart classroom learning environments invest large amounts of money in order to construct the most advanced facilities, without considering student perspectives (K. Li et al., 2016; K. C. Li & Wong, 2021; Ze & Fu, 2020). Previous studies have indicated that students' preference for learning environments, that is perceptions of a specific learning environment, could affect their learning outcomes (Chuang & Tsai, 2005; Fraser, 1998; Lu et al., 2021).

Students' preferences for a smart classroom learning environment (PSCLE) refers to students' attitude or latent tendency towards specific technology tools and digital learning resources in a smart classroom learning environment (X. Zhang et al., 2020), which has been identified as an important channel for understanding the usefulness and function of smart classrooms from the user perspective (MacLeod et al., 2018). Researchers have investigated students' PSCLE to improve the effectiveness of the smart classroom learning environment (MacLeod et al., 2018; Yang et al., 2018). Although one study examined how students' gender, education level and technological self-efficacy may affect their PSCLE (Y. Li et al., 2019), there have been few investigations into the effects of students' information literacy on their PSCLE.

Prior studies have shown that students' information literacy can be a major factor influencing students' learning in a smart classroom environment (Mao et al., 2018; Ze & Fu, 2020). For instance, Ghavifekr and Rosdy (2015) reported that low levels of student and teacher information literacy caused interruptions in the teaching and learning process. Koper's (2014) study highlighted students' complaints that the equipment and online platforms in smart classrooms were too complicated to operate in a user-friendly way. Similarly, the findings of another study indicated that students are unable to acquire and share digital learning resources in smart classrooms because of their insufficient ICT knowledge and skills (Yang et al., 2018). It is therefore essential that education administers, researchers and practitioners consider the impact of students' information literacy on their PSCLE when designing and constructing smart classrooms.

Thus far, the impact of students' information literacy on their PSCLE has been understudied. Therefore, the present study aimed to explore the relationship between students' information literacy and their PSCLE. Specifically, this study aimed to explore the following two questions:

- Research question 1: Do relationships exist between students' information literacy and their PSCLE? If so, to what extent does information literacy predict PSCLE?
- Research question 2: Are there any differences in students' PSCLE across different information literacy levels?

By analysing the relationship between students' PSCLE and their level of information literacy, we hope that this paper can provide useful insights for researchers and education practitioners to design student-centred smart classroom learning environments in compliance with students' information literacy levels, with the ultimate aim of enabling all students to adapt smoothly to smart classroom learning environments.

Theoretical framework

Students' information literacy

Since the term *information literacy* was coined in 1974 by Zurkowski, the definition has evolved alongside the development of information technology. By the end of the 1980s, the ability to search and use information efficiently was identified as a critical element of information literacy (Behrens, 1994). With the emergence and application of computers and the Internet, the connotation of information literacy has gradually shifted from emphasising the ability to retrieve information to addressing the discovery, organisation, use and evaluation of information (Macefield, 2009). For instance, Catts and Lau (2008) defined information literacy as "the ability to recognize information needs, locate and evaluate the quality of information, store and retrieve information, make effective and ethical use of information and apply information to create and communicate knowledge" (p. 12). Similarly, the Association of College and Research Libraries popularised the definition of information literacy, describing it as "a set of comprehensive 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" (2016, p. 8).

At present, with the widespread application of new information technology (such as big data, virtual reality and artificial intelligence), critical thinking, information creation and problem-solving skills have widely come to the fore in academic fields. For example, the Organisation for Economic Cooperation and Development document, *Upgrading the ICT Questionnaire Items in PISA 2021*, states that information literacy encompasses not only the ability to use information technology to access, evaluate, manage, share, communicate, transform and create information but also the ability to use information technology to solve problems creatively and in a responsible manner (Lorenceau et al., 2019). In addition, some countries and international organisations have come to consider computational thinking as a critical domain of information literacy. For example, according to H. S. Kim et al. (2019), Korea has developed a new assessment framework of information literacy that includes problem-solving strategies, computational thinking, information organisation and creation. In addition, the 2018 international computer and information literacy level study (Fraillon et al., 2020) regarded programming skills and computational thinking as important components of information literacy assessments.

In light of the above and based on an extensive literature review as well as previous research (Zhu et al., 2019; Zhu et al., 2020), we identified four key dimensions of information literacy for the purposes of the current study: information awareness and attitude, information knowledge and skills, information thinking and behaviour and information social responsibility. Information awareness and attitude refers to one's sensitivity to the information and judgement of information, as well as the awareness of issues surrounding information privacy and security. Information knowledge and skills refers to an individual's understanding and mastery of information science knowledge and the use of common software or tools to complete digital tasks. Information thinking and behaviour refers to a series of thinking activities carried out by individuals as they engage in problem-solving in the field of computer science, as well as the ability and tendency to make use of information technology. Information social responsibility here refers to an individual's responsibilities in terms of the ethics, laws and regulations of the information society.

Students' PSCLE

Preference has been identified as a latent tendency to consider something desirable or undesirable (Zajonc, 1980; Zajonc & Markus, 1982). In a smart classroom learning environment, research has found that students develop their preference for learning activities, learning resources and hardware and software equipment, after they have first experienced these in the learning environment (X. Zhang et al., 2020). In this context, researchers have developed questionnaires to investigate learners' PSCLE, with the aim of improving the condition of the smart classroom learning environment and provide an enhanced potential for the optimisation of learning experiences (Fraser, 1998). For example, Yang et al. (2018) developed five dimensions pertaining to resources, environment, enhancement, management and presentation to measure primary and middle school students' perceptions of the smart classroom learning environment. B. Li et al. (2015) used 11- to 15-year-old learners' data to develop and validate a 10-scale smart classroom inventory, considering physical design, flexibility and technology usage. Yang and Huang (2015) proposed a framework of 10 dimensions for evaluating technology-rich classroom environments from a pedagogical perspective, considering the optimum level for sharing learning content, managing classroom layout and instructional materials and accessing digital resources.

In addition, MacLeod et al. (2018) designed an instrument for measuring students' PSCLE in higher education, which consisted of eight dimensions: student negotiation, inquiry learning, reflective thinking, perceived usefulness, ease of use, multiple sources, connectedness and functional design. The instrument measures students' preferences with regard to the cognitive, metacognitive, technical, content, social and physical aspects of the smart classroom. The student negotiation and inquiry learning dimensions were designed to assess the cognitive environmental aspects of the smart classroom; the reflective thinking dimension was developed to evaluate the metacognitive aspects of the smart classroom; the ease of use and perceived usefulness dimensions were developed to assess the technical aspects of the smart classroom; the multiple sources dimension was designed to assess the content feature of smart classrooms; the connectedness dimension was developed to measure the social aspects of the smart classroom and the functional design dimension was designed to evaluate the physical features of the space of the smart classroom learning environment. Thus, for the purposes of the current study, we used MacLeod et al.'s eight dimensions to investigate college students' PSCLE, as well as the relationship between students' PSCLE and their information literacy.

Research model and hypotheses

This study aimed to examine the relationship between the different dimensions of students' PSCLE (student negotiation, inquiry learning, reflective thinking, perceived usefulness, ease of use, multiple sources, connectedness, functional design) and their information literacy. As shown in Figure 1 depicting our research model, students' information literacy was here taken to be an independent variable, while the eight dimensions of their PSCLE were dependent variables. The following section summarises the literature that informed the development of our hypotheses concerning the relationship between the dependent and independent variables of this study.

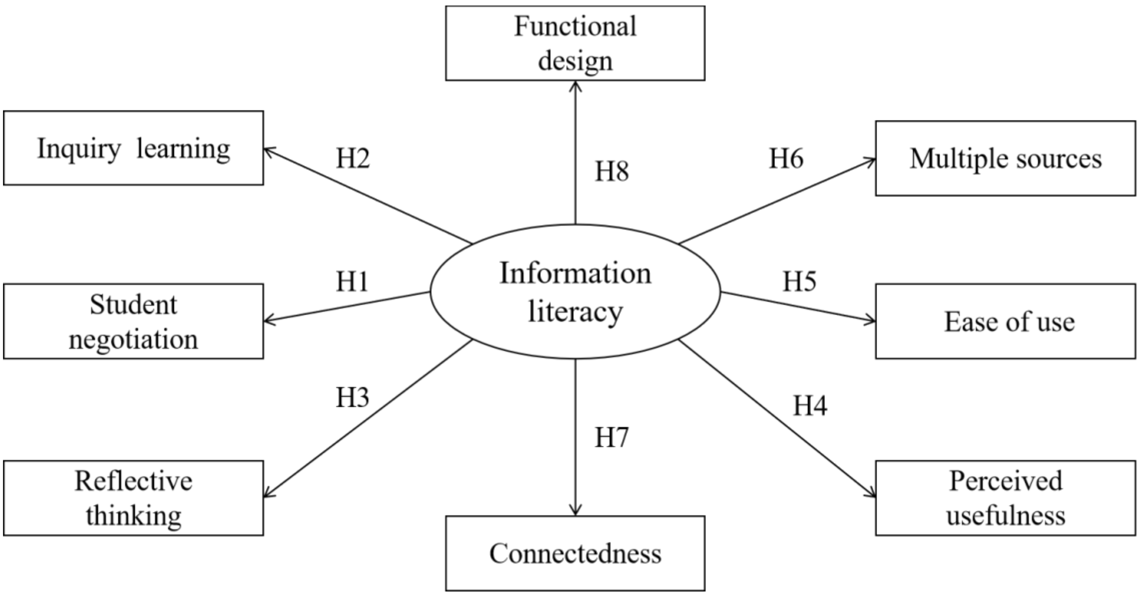

Figure 1. Research model

Student negotiation

Student negotiation refers to the extent to which students have opportunities to explain and modify their ideas with others in smart learning environments (Chuang & Tsai, 2005). This is a critical learning process as it requires students to justify their ideas and consider others' viewpoints (Taylor et al., 1997). In the context of negotiated learning, students need to interact and discuss with others and use other students' resources appropriately and efficiently in order to optimise their learning process (Yuksel, 2010).

Ting (2015) reported that students' information literacy can be enhanced and developed by designing negotiated learning activities. In negotiated learning, students interact with teachers and peers in deciding and selecting learning resources and materials. Such an interaction process involves students' ability to make efficient use of digital resources, which is related to their information literacy. The findings of Tang and Chaw's (2016) study demonstrated that students who have a high level of information literacy can adapt well to the negotiated learning environment, as they find it easy to share learning resources and systems tools with peers and to negotiate the content they want to learn with teachers.

In light of this, we propose that students' preference for negotiation learning may be positively related to their level of information literacy. Specifically, we hypothesised the following:

> H1: Students' level of information literacy is positively related to their degree of preference toward negotiated learning.

Inquiry learning

Inquiry learning has been described as a process of discovering new knowledge by conducting experiments and making observations (Maor & Fraser, 1996). Inquiry learning emphasises active participation and learners' responsibility for discovering unknown knowledge (Pedaste et al., 2015). For example, Harlen (2013) stated that inquiry learning allows students to understand natural phenomena and the world by using their cognitive and physical skills.

The literature indicates that inquiry learning activities in a web-based or digital environment are effective in developing students' information literacy (Fu & Pow, 2011; Kuiper et al., 2009; Owston et al., 2009). For example, Pow and Jun (2012) conducted an experimental study with a class of secondary school students to explore the effectiveness of cooperative inquiry learning activities in developing students' information literacy. The results indicated that collaborative inquiry learning activities helped students engage in information literacy practices and improve their information literacy levels. In addition, Chu et al.'s (2011) found inquiry and collaborative learning approaches have a positive impact on the development of primary school students' information literacy. In addition, Gasque's (2016) study presented a literature review on issues related to inquiry learning curricula to develop students' information literacy. The results suggested that inquiry-based learning allows for better integration of information literacy content, providing more meaningful learning by encouraging reflection, active participation and learning among others.

Given this understanding and based on the related literature, we propose that college students' preference for inquiry learning may be positively associated with their level of information literacy. Our hypothesis was as follows:

> H2: Students' level of information literacy is positively related to their degree of preference toward inquiry learning.

Reflective thinking

Reflective thinking refers to the active, repeated and deep re-conceptualisation of existing conclusions, perceptions, or ideas; an essential process for gaining a deep understanding of the given body of knowledge (Biggs, 1993; Kurt, 2018; Maor & Fraser, 1996).

Reflective thinking has been identified as a critical element of information literacy. For example, Vezzosi (2004) claimed that information literacy is crucial in empowering individuals' critical thinking skills. Specifically, he stated that the information search process requires individuals to identify their information need, select suitable information sources, evaluate findings, organise information and construct new knowledge, so that the abilities of interpretation, analysis, synthesis and evaluation, which are the typical features of reflective thinking, can be fostered. Similarly, Hobbs et al. (2015) stated that information literacy consists of acquiring information, analysing and evaluating information, synthesising existing information and creating new knowledge and reflecting on these information activities. Pérez and Murray (2010) proposed a model of information literacy encompassing knowledge, skills, attitude, reflective thinking, intention and generativity, in which knowledge, skills and attitudes affect generativity via reflection and intention.

In accordance with this, we propose that college students' preference for reflective thinking in smart classrooms may be positively related to their level of information literacy. More specifically, we hypothesised the following:

> H3: Students' level of information literacy is positively related to their degree of preference toward reflective thinking.

Perceived usefulness and perceived ease of use

Researchers have employed the technology acceptance model to explain and predict users' acceptance of new information technology and have suggested that users' intention to adopt a particular technology is directly related to the perceived usefulness and perceived ease of use of that technology (Davis et al., 1989; Rose & Fogarty, 2006). Perceived usefulness refers to the degree to which individuals believe that using technology would enhance their productivity, while perceived ease of use captures individuals' belief pertaining to the extent to which using technology would be free from effort (Teo, 2011, 2013).

Prior studies have consistently reported that a user's information literacy is positively related to their adoption of new technology (Hasan, 2003; Hasan & Ahmed, 2010; Potosky, 2002). For example, Scherer et al. (2015) utilised the national survey data of 1190 Norwegian teachers to examine the impact of teachers' perceived usefulness of ICT, reporting that users' perceived usefulness was a crucial determinant for integrating ICT in classrooms. Mac Callum et al.'s (2014) study employed a technology adoption model to measure students' and educators' intention to adopt mobile learning, with the result demonstrating that information literacy had an indirect effect on mobile learning adoption via perceived usefulness and perceived ease of use.

Building on these prior studies, we propose that students' preference for perceived usefulness and perceived ease of use of smart classrooms may be positively related to their level of information literacy and put forward the following two hypotheses:

> H4: Students' level of information literacy is positively related to their degree of preference toward perceived usefulness.
>
> H5: Students' level of information literacy is positively related to their degree of preference toward ease of use.

Multiple sources

Tsai et al (2012) developed a multiple sources dimension to measure perceptions of the extent to which students prefer that smart classroom learning environments contain various relevant and multiple information sources. Ukachi (2015) conducted a survey to investigate undergraduate students' information literacy skills status and their use of electronic resources provided in libraries such as e-books, CD-ROM databases, e-journals, multimedia resources and online databases. The findings revealed that the level of students' information literacy skills significantly affected their use of electronic resources. Similarly, Toyo (2017) reported that students with higher levels of information literacy demonstrated better performance in finding and utilising electronic resources via the Internet. Another study found that individuals with a high level of information literacy may be able to easily access and navigate a learning management system (Chai et al., 2011).

Given these findings, we hypothesised that students' preference for multiple sources in the smart classroom may be positively related to their level of information literacy, as follows:

> H6: Students' level of information literacy is positively related to their degree of preference toward multiple sources.

Connectedness

Connectedness denotes a strong bond within peer groups that encourages people to openly express themselves and participate in communication with others (Allen et al., 2008). Student-to-student connectedness has been defined as "student-to-student perceptions of a supportive and cooperative communication environment in the classroom" (Dwyer et al., 2004, p. 267).

Considering the notion of connectedness in the context of the current research, the literature indicates that students' social connectedness with ICT is associated with students' information literacy, to some extent. For example, the results of Alkan and Meinck's (2016) study revealed a strong relationship between students' information literacy proficiency levels and the frequency of their use of electronic devices for social communication. More specifically, students who frequently used the Internet to participate in social network communication (i.e., at least once a week) scored higher on an information literacy test than those who used ICT for the same purpose less than once a week. Similarly, Christoph et al. (2015) applied a latent mediation analysis of 445 German secondary school students' data and found that adolescents' ICT competence positively and significantly predicted their ICT-related social engagement. The findings of Areepattamannil and Khine's (2017) study further demonstrated that adolescents' basic ICT skills, such as the ability to use ICT for recreational purposes and the use of specific ICT applications, were significantly positively related to adolescents' frequency of ICT use for social communication.

In light of this understanding, we propose that students' preference for connectedness in the smart classroom may be positively related to their information literacy. More specifically, we hypothesised the following:

> H7: Students' level of information literacy is positively related to their degree of preference toward connectedness.

Functional design

Functional design refers to the physical environmental conditions of smart classrooms (MacLeod et al., 2018). Functional design includes the classroom space, lighting, classroom colour, furniture arrangements and individual ICT equipment that is included to support students' communication and interaction (B. Li et al., 2015). Compared to traditional classrooms, smart classrooms are designed to provide a wide range of computer, media, projection and communication equipment, as well as being a flexible classroom space that can support students' learning better than traditional spaces (Niemeyer, 2003).

H. S. Kim et al. (2014) reported that a higher distribution rate of ICT equipment in Korean elementary schools had a significant effect on students' information literacy. Similarly, S. Kim (2016) conducted an experimental study with 112 elementary school students to investigate the effects of flipped learning on their information literacy. The results suggested that flipped learning with smart devices was useful for facilitating information literacy in a smart learning environment. In addition, Warschauer (2007) has argued that one-to-one laptops with wireless Internet connections are invaluable tools for promoting students' information literacy. The findings suggested that students in classrooms with laptops have more opportunities to gather and analyse various types of information.

Given this importance assigned to functional design, we hypothesised that students' preference for functional design in the smart classroom may be positively related to their information literacy, as follows:

> H8: Students' level of information literacy is positively related to their degree of preference toward functional design.

Methodology

Participants

To investigate the research questions, this study gathered data of 873 second-year college students at a normal college (i.e., a college that focuses on teacher education), located in the north of China. It used the purposive sampling method, a technique for choosing representative participants from a population (Etikan et al., 2016). The college and participants were purposely selected for the following two reasons. First, the college was chosen because it attaches great importance to the application of information technology in education and has built a considerable number of smart classrooms. All instructors in this college have been provided with training opportunities to learn how to use smart classroom technologies and encouraged to conduct their instructional practices in smart classrooms across a wide variety of disciplines. Second, in order to collect data in terms of students' actual perceptions toward smart learning environments, the participants were required to have an ongoing learning experience in a smart classroom environment for 1 year. As such, second-year students of this college were chosen as the participants.

Among the participants, there were 622 female students and 251 male students. The female-to-male composition was approximately 3:1, which is a representative gender ratio of the university's demographic composition and very typical for normal university populations. All students were informed of the purpose of this research and knew that their responses would not influence their course grades. Participation in this study was anonymous and voluntary. All participants of this study were aged 19–20 years old with different academic backgrounds. A description of the sample is given in Table 1.

Table 1
Demographic composition of the sample (N = 873)

Participants	*N*	%
Academic major		
Electronic information engineering	115	13.17
Marketing management	138	15.81
Clinical medicine and nursing	379	43.41
Preschool education	33	3.78
Tourist management	41	4.70
Urban and rural planning	32	3.67
Mathematics and applied mathematics	69	7.90
Chemistry	45	5.15
Other	21	2.41
Gender		
Male	251	28.75
Female	622	71.25

Instrumentation

All participants were required to complete a questionnaire comprised of two sections: (a) the PSCLE survey, which was adopted from the study of MacLeod et al. (2018) and (b) an online information literacy test developed by Zhu et al. (2020), applied to assess the students' information literacy level.

The PSCLE consisted of eight dimensions and 40 items (5 items for each dimension). All items were measured on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The Cronbach's alpha for all scales ranged from 0.88 to 0.94, indicating this instrument's high degree of reliability for assessing college students' PSCLE.

Table 2
Sample items on students' information literacy test

Dimension	Sample items
Information awareness and attitude	If you were learning about reptiles, which of the following questions would give you more information? A. What is the difference between reptiles and other animals? B. What is an aquatic animal? C. How do animals depend on plants for survival? D. What animal is extinct?
Information knowledge and skills	What is the order of events when a computer processes information? A. Output, processing, storage, input B. Input, processing, storage, output C. Output, processing, storage, input D. Processing, storage, input, output
Information thinking and behaviour	You have found a good website on astronomical science. What is the best method to facilitate frequent browsing of new content on the website in the future? A. Add the URL to your favourite pages B. Copy the URL into a Word document C. Copy all the content on the webpage into a Word document D. Save the entire webpage to the folder on your hard drive
Information social responsibility	Which of the following statements is correct? A. Compiling and disseminating computer viruses is a criminal act. B. There are no restrictions on publishing articles in virtual communities. C. Adding an anti-piracy virus to your own commercial software is legal. D. It is not illegal to use hacking software to attack private websites.

The information literacy test had four dimensions: information awareness and attitude (12 items), information knowledge and skills (16 items), information thinking and behaviour (6 items) and information social responsibility (6 items). All the items were multiple choice with four answers and participants were asked to choose one as the best answer. Table 2 shows the sample items for each dimension.

Data collection and analysis procedure

With the assistance of the College Academic Affairs Office, the data were collected at the end of the 2019 fall academic semester. Before the survey was implemented, teachers of each department invited students via instant messaging tools such as Tencent QQ and WeChat to complete the online survey. The survey was open for 2 weeks.

In order to examine the relationship between college students' PSCLE and their information literacy, a quantitative method was utilised in this study. The data were screened and then imported into SPSS 25.0 for statistical analysis. Descriptive statistics were employed to demonstrate the overall level of students' information literacy and their PSCLE. Following this, we conducted Spearman's correlation tests and regression analyses to explore the correlation coefficients between students' information literacy and their PSCLE. To explore the different profiles of students based on their level of information literacy, K-means clustering analysis was conducted using the R programming language. K-means clustering method is a typical, unsupervised clustering method aimed at classifying observations into k clusters according to their similarities to create homogeneous subgroups (Pham et al., 2005; Steinley, 2006). In the follow-up phase of the study, a series of one-way ANOVA and Bonferroni correction tests were conducted to compare the differences between students' PSCLE across the various information literacy levels.

Results

College students' PSCLE and information literacy

An overview of the participants' (N = 873) means scores and standard deviations for students' PSCLE is detailed in Table 3. The average value of college students' overall PSCLE was 3.87. The technical features (ease of use, perceived usefulness) obtained the highest mean scores. Meanwhile, the social features (connectedness), physical environmental features (functional design) and the content features (multiple sources) obtained 3.99, 3.96 and 3.90 respectively. For their part, the cognitive and metacognitive features such as student negotiation, inquiry learning and reflective thinking obtained the lowest scores.

Table 3
Descriptive statistics of students' PSCLE

Dimensions	*M* (scoring rate)	*SD*
PSCLE	3.87	0.61
Student negotiation	3.54	0.61
Inquiry learning	3.72	0.59
Reflective thinking	3.80	0.60
Ease of use	4.01	0.64
Perceived usefulness	4.04	0.64
Multiple sources	3.90	0.62
Connectedness	3.99	0.65
Functional design	3.96	0.61

The descriptive statistics pertaining to students' information literacy are shown in Table 4. Here, the overall mean score is shown to be 68.04 (the total score is 100), with a standard deviation of 11.06. Other dimensions of information literacy, namely, information awareness and attitude, information knowledge and skills, information thinking and behaviour and information social responsibility scored 22.03, 9.67, 15.01 and 21.34 respectively. Students received the highest scoring rate in information social responsibility (86.75%) and the lowest in information thinking and behaviour (51.94%).

Table 4
Descriptive statistics of students' information literacy

Dimensions	*M* (scoring rate)	*SD*
Students' information literacy	68.04 (68.04%)	11.06
Information awareness and attitude	22.03 (74.68%)	3.95
Information knowledge and skills	9.67 (56.88%)	2.49
Information thinking and behaviour	15.01 (51.94%)	4.02
Information social responsibility	21.34 (86.75%)	5.50

Relationship between PSCLE and information literacy

To answer research question 1, correlation analyses were conducted to investigate the relationship between students' information literacy and the identified dimensions of PSCLE. As shown in Table 5, all eight dimensions of PSCLE emerged as significantly correlated to the four dimensions of information literacy.

Table 5
Correlational analysis of PSCLE and information literacy

Dimensions	SN	IL	RT	MS	EU	PU	C	FD
Information awareness and attitude	0.09**	0.08*	0.08*	0.12**	0.11**	0.13**	0.13**	0.12**
Information knowledge and skills	0.12**	0.14**	0.13**	0.15**	0.19**	0.19**	0.20**	0.20**
Information thinking and behaviour	0.20**	0.24**	0.19**	0.19**	0.13**	0.18**	0.13**	0.18**
Information social responsibility	0.27**	0.29**	0.25**	0.33**	0.34**	0.37**	0.37**	0.36**

Note. * $p < 0.05$, ** $p < 0.01$, SN = student negotiation, IL = inquiry learning, RT = reflective thinking, EU = ease of use, PU = perceived usefulness, MS = multiple sources, C = connectedness, FD = functional design.

Based on the confirmation yielded by these findings that PSCLE was associated with students' information literacy, a series of linear regressions were then conducted to analyse the relationship between the dependent variables (inquiry learning, student negotiation, reflective thinking, perceived usefulness, ease of use, multiple sources, connectedness, functional design) and the independent variable (information literacy). As can be seen in Table 6, students' information literacy significantly and positively predicted the eight dimensions of PSCLE, supporting all eight hypotheses.

Table 6
Linear regression analyses

Hypothesis	β	*F*	R^2_{adj}	Results
H1. IL -> Student negotiation	0.26***	65.33	0.07	Supported
H2. IL -> Inquiry learning	0.27***	79.31	0.08	Supported
H3. IL -> Reflective thinking	0.25***	58.22	0.06	Supported
H4. IL -> Perceived usefulness	0.34***	112.56	0.11	Supported
H5. IL -> Ease of use	0.28***	84.51	0.08	Supported
H6. IL -> Multiple sources	0.29***	143.89	0.08	Supported
H7. IL -> Connectedness	0.32***	100.41	0.10	Supported
H8. IL -> Functional design	0.34***	110.62	0.09	Supported

Note. IL = information literacy, β = standardised Beta; R^2_{adj} = Adjusted $R^{2;}$ *** $p < 0.001$.

PSCLE differences across students with different levels of information literacy

Research question 2 aimed to investigate the differences between students' PSCLE across different levels of information literacy. K-means cluster analysis was performed on the data for the dimensions of students' information literacy (information awareness and attitude, information knowledge and skills, information thinking and behaviour and information social responsibility). As shown in Figure 2, when the elbow curve falls at 3, the within-cluster sum of squares continues to decline before decreasing very slowly. There are then indications that clustering the data into three clusters gives the best clustering output (Yuan & Yang, 2019).

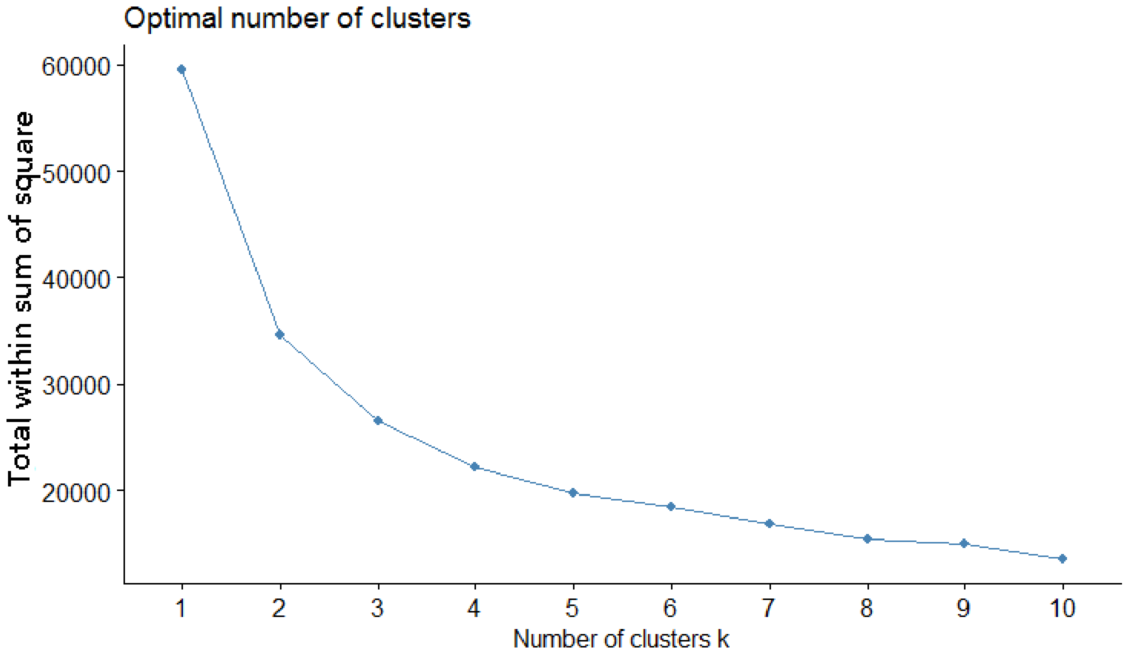

Figure 2. Estimating the number of clusters

To further validate these findings, a series of one-way ANOVA at a level of 5% significance was conducted to determine if the clusters were statistically different. The results of the ANOVA analysis show that the three clusters are statistically different across the four variables. The results of the K-means clustering on students' information literacy are shown in Table 7 and Figure 3 offers a graphical representation.

The results of the K-means cluster analysis show that three different groups of students with different information literacy can be identified. Cluster 1 is the largest group, dominated by students with a high level of information literacy. The cluster contains 49.83% (n = 435) of the entire sample. Students within this cluster achieved significantly higher scores for information literacy and the four dimensions than those in Cluster 2 and Cluster 3. Cluster 2, which includes students with a medium level of information literacy, accounts for 38.26% (n = 334) of the total. In Cluster 2, the students' scores for information literacy, information awareness and attitude, information knowledge and skills and information social responsibility were significantly higher than those in Cluster 3. However, their scores for information thinking and behaviour were not significantly higher than those in Cluster 3.

Cluster 3 contained individuals with low levels of information literacy. These accounted for 11.91% (n = 104) of the sample. In Cluster 3, the mean value of students' information literacy and the sub-dimensions of information literacy (information awareness and attitude, information knowledge and skills, information social responsibility) were significantly lower than the mean values of the other two clusters.

Table 7
Student groups based on their levels of information literacy

Dimensions	Cluster 1 (n = 435) High level	Cluster 3 (n = 334) Medium level	Cluster3 (n = 104) Low level	F
	M (SD)	M (SD)	M (SD)	
Information literacy	75.28 (5.19)	65.61 (5.53)	45.51 (8.36)	1161.64*** (1) > (2) > (3)
Information awareness and attitude	23.59 (3.38)	20.95 (3.43)	18.97 (4.76)	93.94*** (1) > (2) > (3)
Information knowledge and skills	10.32 (2.08)	9.85 (2.78)	6.33 (2.11)	145.02*** (1) > (2) > (3)
Information thinking and behaviour	17.95 (2.56)	11.98 (2.52)	12.42 (3.91)	500.67*** (1) > (3); (1) > (2)
Information social responsibility	23.43 (1.81)	22.84 (2.26)	7.80 (3.87)	2026.92*** (1) > (2) > (3)

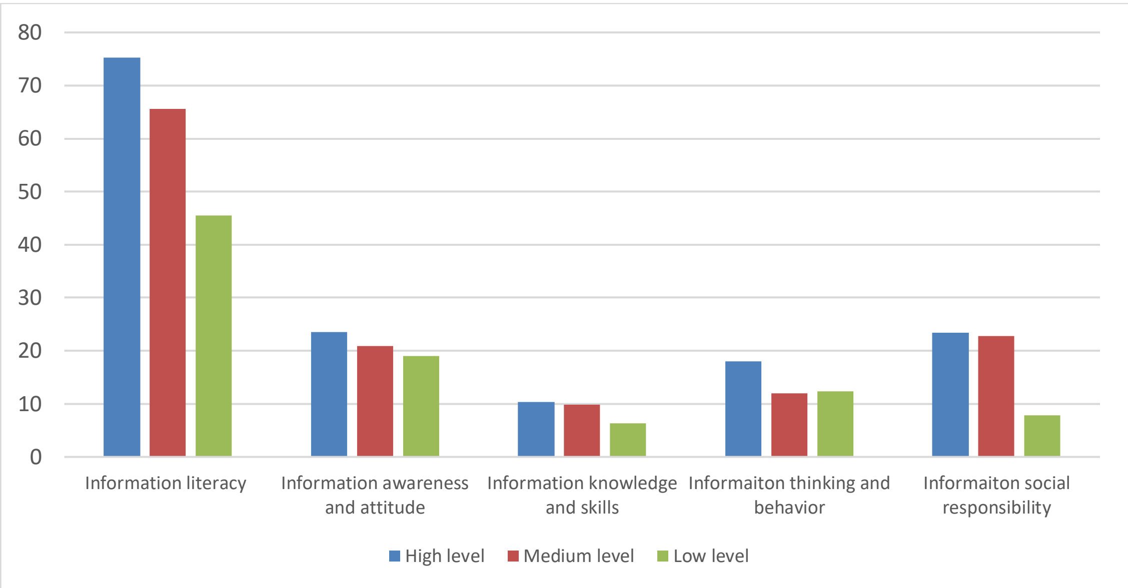

Figure 3. Level of development in students' information literacy

Based on the cluster analysis of the students' levels of information literacy, we analysed the relationship between students' information literacy and their PSCLE. Table 8 shows the comparison of students' PSCLE across these three groups based on their information literacy levels, and Figure 4 represents the distribution of students' PSCLE across the three information literacy clusters. Post-hoc comparisons (Bonferroni correction test, $p < 0.05$) revealed that students with a high level of information literacy obtained significantly higher scores on the four critical dimensions of PSCLE (student negotiation, inquiry learning, reflective thinking and functional design) than the students with medium or low levels of information literacy. However, students with a high level of information literacy did not achieve significantly higher scores than those with medium or low levels of information literacy for the other four dimensions of PSCLE (perceived usefulness, ease of use, multiple sources and connectedness).

Table 8
Students' PSCLE compared with their information literacy

Dimensions of students' PSCLE	Cluster of students' IL	*N*	*M*	*SD*	*F*	Post hoc
Student negotiation	Cluster 1	435	3.65	0.58	35.91***	Cluster 3 < Cluster 2 < Cluster 1
	Cluster 2	334	3.54	0.53		
	Cluster 3	104	3.11	0.75		
Inquiry learning	Cluster 1	435	3.85	0.57	45.30***	Cluster 3 < Cluster 2 < Cluster 1
	Cluster 2	334	3.69	0.52		
	Cluster 3	104	3.28	0.64		
Reflective thinking	Cluster 1	435	3.92	0.59	33.56***	Cluster 3 < Cluster 2 < Cluster 1
	Cluster 2	334	3.79	0.54		
	Cluster 3	104	3.40	0.67		
Perceived usefulness	Cluster 1	435	4.17	0.58	63.10***	Cluster 3 < Cluster 2 Cluster 3 < Cluster 1
	Cluster 2	334	4.07	0.60		
	Cluster 3	104	3.44	0.68		
Ease of use	Cluster 1	435	4.09	0.60	49.14***	Cluster 3 < Cluster 2 Cluster 3 < Cluster 1
	Cluster 2	334	4.07	0.60		
	Cluster 3	104	3.45	0.68		
Multiple sources	Cluster 1	435	4.02	0.57	53.23***	Cluster 3 < Cluster 2 Cluster 3 < Cluster 1
	Cluster 2	334	3.92	0.59		
	Cluster 3	104	3.36	0.67		
Connectedness	Cluster 1	435	4.10	0.59	61.43***	Cluster 3 < Cluster 2 Cluster 3 < Cluster 1
	Cluster 2	334	4.05	0.59		
	Cluster 3	104	3.38	0.74		
Functional design	Cluster 1	435	4.10	0.57	61.04***	Cluster 3 < Cluster 2 < Cluster 1
	Cluster 2	334	3.97	0.54		
	Cluster 3	104	3.41	0.63		

Note. ***$p < 0.001$, **$p < 0.005$, *$p < 0.05$, IL = information literacy.

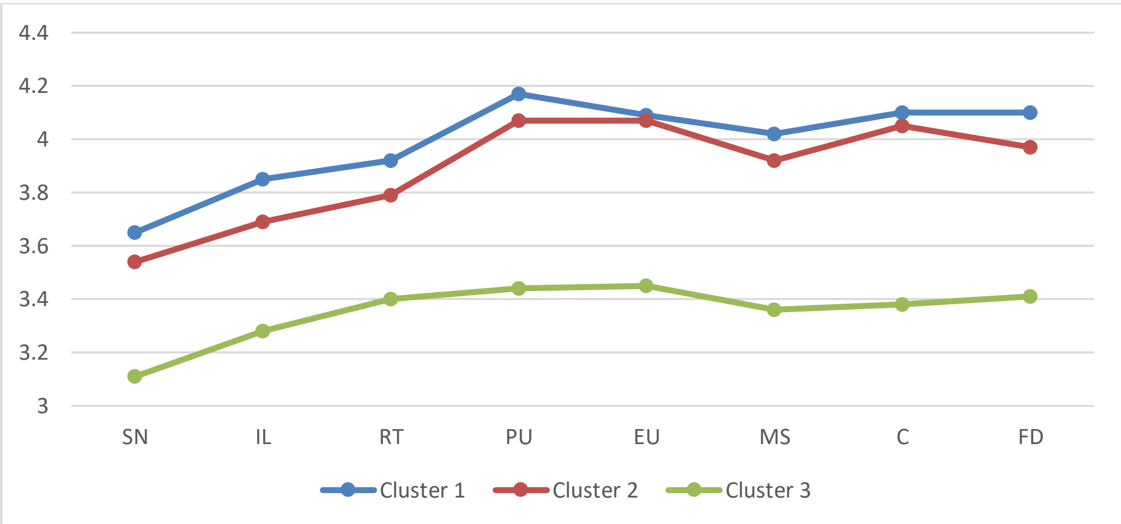

Figure 4. Students' PSCLE compared with their information literacy clusters
Note. SN = student negotiation, IL = inquiry learning, RT = reflective thinking, PU = perceived usefulness, EU = ease of use, MS = multiple sources, C = connectedness, FD = functional design.

Discussion and conclusion

The primary purpose of this study was to explore the relationship between students' PSCLE and their level of information literacy. The results support all proposed hypotheses. In summary, students' information literacy was found to significantly predict PSCLE, deconstructing this into specific preferences in relation to student negotiation, inquiry learning, reflective thinking, ease of use, perceived usefulness, multiple sources, connectedness and functional design. K-means cluster analysis showed that three different groups of students could be identified with different levels of information literacy. Cluster 1 consisted of students who had a higher level of information literacy and who scored highly in the four subdimensions. Cluster 2 comprised students who had a medium level of information literacy, information awareness and attitude, information knowledge and skills and information responsibility compared to those in Cluster 3 (though they did not have a higher level of information thinking and behaviour). Cluster 3 contains those students who had lower levels of information literacy and who scored less well in the various subdimensions than the students in Cluster 1 and Cluster 2. After these clusters were identified, students' different PSCLE were assessed based on their different information literacy levels. The results indicated that students' PSCLE varied with their different levels of information literacy.

Specifically, students with high levels of information literacy obtained significantly higher scores for the following areas in their PSCLE: student negotiation, inquiry learning, reflective thinking and functional design. In other words, students with higher levels of information literacy seem to have demanded more on the higher-order thinking features of smart classrooms (such as student negotiation, inquiry learning and reflective thinking). They also showed great appreciation for the physical aspects of the smart classroom (functional design) (Mac Callum et al., 2014; Scherer et al., 2015). With respect to the other dimensions of the PSCLE (perceived usefulness, ease of use, multiple sources and connectedness), students with high and medium levels of information literacy scored significantly higher than students with low levels of information literacy. They showed a relatively strong desire for interaction and cooperation among students and they were more likely to perceive the simplicity and usefulness of technology. They also tended to favour utilising technology to explore various ways to enhance their learning (Cheung & Wang, 2021). The findings echo the results of the study conducted by Y. Li et al. (2019), which indicated that college students' technology self-efficacy had a significant effect on their PSCLE. In other words, students with higher levels of technology self-efficacy appeared to demonstrate significantly higher levels of preference for critical features of the smart classroom (student negotiation, inquiry learning, reflective thinking, usefulness, ease of use, multiple sources, connectedness, functional design).

Compared to students with higher levels of information literacy, our study indicates that students with lower levels of information literacy were less likely to prefer cognitive and metacognitive features (student negotiation, inquiry learning and reflective thinking). They were also less eager to engage in the exploratory learning and critical reflection opportunities provided by smart classroom learning environments. They did not believe that information technologies were useful or easy to use, they perceived little connectedness among peers and did not tend to favour searching for various information resources by using technology in the smart classroom (Areepattamannil & Khine, 2017; Toyo, 2017). This shows that students' information literacy is a very important demographic factor that affects their PSCLE.

The findings of this study contribute to key theoretical and practical implications for the field of education. Theoretically, the findings of this research provide new insights for understanding and interpreting students' PSCLE. That is, the results suggest that students' information literacy is a critical factor that might control the display of students' PSCLE. From a practitioners' perspective, these findings strongly suggest that the differences in students' information literacy should be fully taken into account when designing, constructing and evaluating a smart classroom learning environment. In order to develop more appropriate smart classroom learning environments, we put forward the following recommendations.

First, in the process of designing smart classroom learning environments, schools should evaluate students' information literacy levels and identify those students with poor information literacy. Then, school administrators should pay close attention to students' difficulties in using ICT devices in smart classrooms, for example by gathering student feedback on the optimisation of software and hardware. Specifically, school administrators should invite students with varied levels of information literacy as partners while designing a smart classroom learning environment (Gros, 2016; Zou et al., 2021). At the same time, schools should provide technical support for students in terms of using hardware and software, such as making operation guidelines freely and easily available, establishing information technology service platforms with professional staff dedicated to providing technical services, so that students can concentrate on learning rather than solving technical issues (Zhan et al., 2021). In addition, it is also highly desirable that smart classroom learning environments fulfill the requirements of learners with differential competencies, learning styles and interests (Gros, 2016; Li & Wong, 2021). Thus, instructors and school administrators should equip classrooms with various ICT devices in an attempt to cater to students' varying levels of information literacy. If educators intend to develop technology-based learning environments for students with higher levels of information literacy, more advanced technologies and tools could be utilised to create more opportunities for students to negotiate ideas and reflect on their learning (Z. Zhang et al., 2020).

Second, the findings derived from this study also support the claim that students with high and medium levels of information literacy tend to attain significantly higher scores on the scales of student negotiation, inquiry learning, reflective thinking and functional design than those with low levels of information literacy. The implication here is that teachers or curriculum designers should develop differentiated instruction strategies and activities for students, in alignment with different levels of information literacy. For instance, for students with high levels of information literacy, teachers should increase their use of inquiry-based learning and critical or reflective learning tasks. They should create more opportunities for students to negotiate ideas, explore a variety of information and enhance their reflective and epistemological thinking. In particular, education administrators can incorporate social media platforms in smart classrooms with the aim of promoting students' engagement, critical thinking and negotiated learning via interaction (Barfi et al., 2021; Hwang et al., 2017; Oliveira & Corrin, 2021). Conversely, for students with poor information literacy, teachers should not only encourage them to access digital resources and interact with learning systems but also actively provide them with necessary learning guidance and supportive tools, especially during the process of inquiry learning (Zhan et al., 2021). Furthermore, school administrators should help those students with poor information literacy by providing regular training in technological skills. This would help students to adapt to smart classroom learning environments.

Third, it is necessary to reconstruct the evaluation criteria of smart classrooms and incorporate the improvement of students' information literacy as an important indicator. The ultimate goals of building smart classrooms are to guide students to become self-directed learners and help students acquire 21st-century competencies, such as information literacy (Cheung & Wang, 2021). Consequently, relevant institutions and organisations should develop assessment standards for the effectiveness of smart learning environments, which not only include relevant content of technological solutions but also focus on the development of students' information literacy. Moreover, researchers and education practitioners should investigate the effect of smart classrooms on improving students' information literacy by conducting quasi-experiments after students experienced the smart classroom learning environment (Jiang et al., 2021) and the results could also be used as an important reference of the evaluation criteria for smart classrooms.

The current study has a few limitations that need to be recognised. First, due to time and accessibility constraints, the participants were recruited from a single college located in the north of China. Additional studies need to be carried out in other colleges to generalise the findings to a broader scope. Second, it should be recognised that the data collection on students' PSCLE was conducted using a quantitative, self-report method; future research may benefit from providing deeper knowledge through experimental studies and behavioural analysis.

To conclude, the smart classroom learning environment is a personalised learning environment that contains multiple advanced technologies, tools and resources. A key challenge is ensuring that students with different levels of information literacy can adapt well to these environments. The critical contribution of the present study is the identification of the relationship between students' information literacy and their PSCLE, which provides new evidence for better understanding the differences in students' preferences toward the smart classroom learning environment. The key implication of this study is that researchers and practitioners should take students' information literacy into full consideration when designing, constructing and evaluating a smart classroom environment, with the aim of enhancing students' effective learning.

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Data availability statement

The data in this study may be obtained by contacting the authors via email.

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