Smart campus: a user case study in Hong Kong

Yuchen Zhang\(^1\), Zhao Yang Dong\(^2\), Christine Yip\(^1\), Sharon Swift\(^1\)
\(^1\)School of Electrical Engineering and Telecommunications, and UNSW Digital Grid Futures Institute, The University of New South Wales, Sydney, Australia
\(^2\)E-mail: mnhighthang@gmail.com

Abstract: Smart campus, as a high-end form of a smart education system and a mini-sscopic version of a smart city, has received increasing research and attention globally. The existing smart campus concepts are mostly technology-driven, which simply introduces interconnection from a technological perspective to serve its residents but not necessarily adhering to the needs and interests of stakeholders in such a community. To fill this gap, this study presents a human-centred approach for smart campus design and development, where a user case survey study is undertaken in Hong Kong primary and secondary schools. The overall aim of the survey is to accurately and timely capture and understand the perspectives of school stakeholders on education applications in the context of the smart campus. The findings from survey analysis are presented, with insights and suggestions for future smart campus development provided. The findings in this study are also expected to result in a benchmark reference of the smart campus concept for international educational providers, government, and technology companies that will deliver smart solutions.

1 Introduction

Many places in the world are undergoing tremendous revolution towards smart cities, where citizen’s daily life is increasingly penetrated with ‘smart’ things, ranging from small devices, such as smart watches, smartphones, and smart meters, to large systems, such as smart homes, smart buildings, and smart grids [1, 2]. Among them, a smart campus, as a high-end form of a smart education system and also a mini-sscopic version of a smart city, connects the components and users through the common information-based platform to intellectualise learning, teaching, research, management, and campus life.

In recent years, the smart campus has received increasing research and attention globally, and there are extensive literatures focusing on defining and envisaging smart campus. For example, a vision on an intelligent campus is provided in [3]. The relationship between smart learning and smart city is investigated in [4]. A smart university taxonomy is identified in [5] with its main features, components, technologies, and systems. A technological smart campus architecture is proposed in [6] to provide both basic and value-added smart services. The realisation of a smart campus in a large-scale university is presented in [7]. It is observed that most of the state-of-the-art smart campus concepts are technology-driven, which simply introduces interconnection from a technological perspective to serve its residents but not necessarily addressing the needs and interests of stakeholders in such community.

The survey serves as an effective and efficient tool for subjective information collection and analysis, which has been widely adopted to guide future smart campus development around the world. For example, in [8], a questionnaire survey is conducted on university principals and senior assistants in Malaysia to investigate the impact of information and communication technology (ICT) on smart school management. A survey is conducted in [9] to investigate the factors and driving mechanism of learner’s technology engagement towards ubiquitous game-based learning in the smart campus context. A survey at 13 Dutch universities is conducted in [10] to explore the use of smart campus tools to improve space use on campus. The factors of teachers’ acceptance and concerns on using smart mobile devices in their lessons are investigated in [11] through a user-case survey in South Korea. In [12], a questionnaire survey aiming at understanding the stakeholders’ perceptions of various smart campus applications is taken at the American University of Sharjah, UAE. The survey studies in the above literature focus on specific smart campus functions, such as school management, mobile-based learning, ubiquitous game-based learning, campus space use etc., but lack an integral view on smart campus design and development.

Some campus-level survey studies have also been implemented recently. For instance, the survey study in [13] examines the impact of the iCampus pillars on schools’ key performance indicators and investigates the schools’ plans for implementing iCampus solutions. In [14], a survey study is conducted at Czech Technical University in Prague and Thammasat University in Thailand to learn about students’ preferences and perceptions on the smart campus concept. User surveys at a public university in the United Kingdom are employed in [15] to gain insight into the possible role of user experiences and data in making a smart campus. Overall, these survey-based projects mainly focus on gathering information about technological progress to guide future campus development.

In the literature, there are many technologies deployed in smart campus, such as internet of things (IoT) [16], cloud computing [17], augmented reality (AR) [18, 19], and artificial intelligence (AI) [20–22], and even the latest 5G technology [23], and most survey-based research presumes that smart campuses are technology-driven systems. In fact, in a smart learning environment, although technology must play an important role, the human involved is found to be the heart of such an environment [24]. Therefore, there is a research gap that such technological innovation does not necessarily transfer into benefits to enhance user experience and learning outcomes for a smart campus unless those technologies are carefully selected and integrated into the smart campus system from users’ perspective.

To fill this gap, we are inspired by the human-centred design (HCD) concept [25, 26] that is widely used for technological product development in the early phase [27]. HCD is also considered suitable in smart campus design and development for the following reasons: (i) smart campus involves dense interplay between new technologies and humans; and (ii) smart campus is still at its conceptual stage and there is still much space for its design improvement. HCD is an iterative process involving the understanding of stakeholders’ context, identification of
stakeholders’ requirements, designing and development of solutions, and evaluation of the outcome against stakeholders’ requirements. This iteration process continues until the evaluation results are satisfactory. It integrates the use of a mixture of investigative tools (e.g. surveys) and generative methods (e.g. brainstorming) to realise a pervasive approach that can not only develop an understanding of stakeholders’ needs but also help achieve a seamless adaption of technology in stakeholders’ campus life.

Serving as an essential step in the HCD of smart campus, a user-case survey is provided in this paper to study the practical stakeholders’ needs of smart technologies in primary and secondary schools. This survey is undertaken in Hong Kong (HK), which is a modern metropolitan city of innovation and infrastructure ready for smart campus role out. The overall aim of the survey is to capture and understand the perspectives of school stakeholders on learning and education applications in the context of the HK smart campus. This paper presents the findings from survey analysis and provides insights and suggestions for future smart campus development in HK. The findings in the survey are expected to result in a benchmark reference of the smart campus concept for international educational providers, government, and technology companies that will deliver smart solutions. The main contributions of this paper are summarised as follows:

(i) Unlike the technology-driven smart campus concept in the literature, the survey in this paper adheres to the HCD concept using a pervasive approach. It helps understand how technologies have been working properly on stakeholders and what technologies could be applied in alternative ways to achieve better user experience in a smart campus.

(ii) Most data collection in the literature merely targets on tertiary education, whereas few of them on the primary or secondary education institutes. Since primary and secondary education formulates the foundation for children and teenagers, it is also essential to collect and study the smartness needs of these schools. The user-case survey in this paper is conducted on HK primary and secondary schools, which helps expand and generalise the smart campus concept into different education levels.

(iii) The recommendations provided in this paper are centric on social and human components, which contribute to a real guide for effective smart campus development and serves as a valuable case to figure out the motivation and guideline for continuing international research in this area in the next stage.

The rest of the paper is organised as follows. The HCD of the smart campus is briefly introduced in Section 2; the current technology deployment in HK education system is investigated in Section 3; the user-case survey is presented in Sections 4, 5, and 6, respectively, for survey methods, results, and recommendations; and Section 7 concludes the paper.

2 Concept of human-centred smart campus

In recent years, the smart campus has attracted worldwide attention, and there are extensive literatures focusing on defining and envisaging smart campus. However, most smart campus concepts are technology-driven, and the main stakeholders of education including teachers, students, principals, and parents are not necessarily the focus. As reflected by the HCD concept, we need to re-examine the role of technology in the smart campus revolution and make sure the provision of intelligent services is centred on human factors. The smartness of the future campus tends to shift from technology-led to learner-centric and further into human-centric, highlighting the educational needs of all the people involved in the education system.

In our previous work [28], we highlighted the HCD of smart campus and defined smart campus as an educational environment that is penetrated with enabling technologies for learning-oriented services to enhance educational performance while meeting stakeholders’ interests, with broad interactions with other interdisciplinary domains in the smart city context.

From an integral point of view, a smart campus is an educational institution involving various stakeholders. The main stakeholders of smart campuses typically include students, teachers, parents, and school management teams, which all take different roles. Based on their different needs and contributions, the stakeholders’ expectations on campus smartness will also be deviated [3]. To integrate the HCD concept in smart campus development requires the service providers to capture and understand the stakeholders’ needs and interests in an accurate, timely, and coordinated manner, which motivates the user-case survey study in this paper.

3 Technology deployment in HK education system

HK has shown strong technological deployment ready for the smart transition. In the 21st century, the HK government and enterprises are utilising the power of information technology (IT) to strengthen and facilitate smart city development [1, 2]. The Digital 21 Strategy released in 1998 sets out the blueprint for the overall development of HK’s information and communications technology, which leads the government, society, business, industry, and academia to work together to achieve the goal of moving HK to the forefront of global IT development. Since then, to be in line with the ever-changing technological development and social needs, this strategy has been revised four times, respectively, in 2001, 2004, 2008, and 2014 [29]. HK has so far made considerable progress in its digitalisation. For instance, according to IMD World Competitiveness Yearbook [30], HK achieved the first rank in technology infrastructure in 2012 and 2013. The internet connection speed, broadband, and mobile phone penetration rates in HK (85% and 231%, respectively) are also among the highest in the world. The newest Digital 21 Strategy promotes the theme of ‘Smart HK, Smart Living’ to create a vibrant information environment for HK.

With the widespread IT deployment and development, the HK education system has also experienced a significant revolution in recent years to maximise its benefits. The HK government has invested over $10 billion in IT in education (ITEd) and other e-learning initiatives since the 1998/99 school year. The three strategies on ITEd implemented have made significant progress in schools’ IT infrastructure, e-learning resources, teachers’ professional capacity, and students’ digital literacy. Building on the previous advantages and experience of strategies on ITEd, the HK Education Bureau launched the newest Fourth Strategy on ITEd (ITE4) in 2014/15, which is formulated to unleash the learning power of all students through realising the potential of IT in enhancing interactive learning and teaching experiences. ITE4 has a profound impact on the overall development of school education, as well as emphasises the technological readiness of HK to start a smart campus revolution. The strategy states that with the popularity of mobile devices (e.g. smartphones and tablets) and the rich web information in future smart campuses, students can study without the restriction of time and space, meaning the teaching/learning is not limited to classrooms or restricted by class schedules and designated textbooks. Learning tends to be more autonomous, collaborative, and humane. As a key field in HK smart city plan, the construction of smart campuses has attracted great attention from governments and enterprises. High IT penetration in HK primary and secondary schools has been achieved over the last two decades and actually has made significant progress in schools’ IT infrastructure, e-learning resources, teachers’ professional capacity, and students’ digital literacy. This means the enhanced technology in the HK education sector has laid the foundation for the next generation of smart campus.

Although the HK government and relevant associations have made a significant investment in the education sector to strengthen the use of ICT in teaching and learning, schools in HK still have technological limitations with regard to the transition from digitalised education to smart education. The limitations can be summarised in the following areas:
(i) Lack of a sophisticated framework or plan of how to construct a sustainable human-centred smart campus.
(ii) Limited emerging technologies (e.g. IoT and AI) to support campus smartness.
(iii) Difficulties for most elder teachers and non-science, technology, engineering and mathematics (non-STEM) teachers to equip with the knowledge and skills required to handle the new technologies and pedagogies.
(iv) Concerns on cybersecurity and privacy.

Given the current technological advancement and limitation in HK education system, it is expected the further collaborations among the government, education bureau, school sponsoring bodies, individual schools and relevant departments to make the fulfilment of stakeholders’ needs and realise the further potential of smart technologies, to achieve greater success in quality HK education.

4 Survey methods

The survey is performed through an offline invitation and an online questionnaire-based survey. This section presents the respondent statistics and the design method of the survey.

4.1 Respondent statistics

A total of 34 primary and secondary schools in HK were invited to join the survey. The participating schools come from different well-established SSBs, indicating the survey is broadly distributed to HK schools to minimise biases in the survey results.

The user group of the survey focuses on the academic staff and parents of primary and secondary schools in HK. For each participating school in HK, the principal, five teachers, and five parents were invited by the school (totally 11 participants) to complete the survey. As a result, the user groups of this survey include principals, STEM teachers, non-STEM teachers, and parents, all of which are the key stakeholders of the smart campus.

The primary and secondary schools in HK are mainly divided into four types based on their funding sources. They are government schools, aided schools, directed subsidy scheme (DSS) schools, and private schools. A brief introduction of each school type is provided below:

- Government schools are funded by the government and directly managed by the HK Education Bureau. All the teaching staff of government schools are all civil servants. All government schools have no religious background, and most of them are co-educational.
- Aided schools, also known as ‘subsidised schools’, are non-profit organisations receiving government subsidies to provide free education. The vast majority of education funding of aided schools comes from the government, while management is the responsibility of the school’s board of directors. Most schools in HK fall into this category, accounting for >70% of all schools.
- DSS schools are entitled to government subsidies based on the number of eligible students in the school, but tuition fees may still be charged. Compared with government and aided schools, DSS schools have relatively high autonomy and can customise their courses and admission requirements.
- Private schools are self-funded and run by school sponsoring organisation and managed by the school board. Private schools do not receive government subsidies and tuition fees are relatively high. Private schools may determine their own enrolment policies.

These four types of schools account for >90% of HK primary and secondary schools, which ensures a reliable coverage of the school funding types in HK. The distributions of each school funding type in HK and the invited schools are shown in Fig. 1. It can be seen that the proportion of each type in the invited schools is consistent with their actual distribution in HK, which avoids producing significant statistical biases in the survey results.

4.2 Design method

The quantitative method by web-based questionnaire surveys was used for data collection. Also, as reported in [31], the differences between the reliability of web-based surveys and traditional paper-based surveys are insignificant. However, due to the convenience in handling multiple questionnaires and processing data, a web-based approach was performed on Qualtrics platform [32].

The questionnaire consists of 49 questions, where some of the questions are separately designed for school staff and parents due to their deviated experience and roles in smart campus operation and development. Among the 49 questions, 44 and 40 questions were exposed to school staff and parents, respectively. The questions are in various forms, including ‘single selection’, ‘multiple selection, ‘ranking questions’, ‘Likert scale’, and ‘scenario-based questions’. An ‘others, please specify’ option is provided for most ‘single selection’ and ‘multiple selection’ questions to collect open-ended data as supplementary to those questions. A ‘Do not know’ option was also provided for most questions to eliminate random guess from respondents.

System data cleaning and manual data polishing were performed to detect and correct any corrupted, incorrect, and invalid data entries. For example, for the ‘other – please specify’ option, if the textual response actually duplicates any other option already provided in the question, manual data entry correction is required.

This questionnaire-based survey mainly involves quantitative data, so various statistical methods were adopted in its data analysis. The collected data collected was analysed based on user groups (i.e. principals, STEM teachers, non-STEM teachers, and parents), school education levels (i.e. primary schools and secondary schools), and school funding types (i.e. government schools, aided schools, DSS schools, and private schools). The questions were separately designed from the following aspects to frame up a human-centred smart campus:

- Demography
- Knowledge on smart campus
- Current school smartness
- Stakeholder expectation and school fulfilment
- Acceptance of smart learning technologies (SLTs)
- Cybersecurity and privacy

Different descriptive statistics were computed according to different question types. For single-selection questions, counts and percentages were computed; for multiple-selection questions, counts, percentages, and counts to respondent ratio (CTRR), were calculated; for closed-end questions, arithmetic means were computed as the score to quantify the tendency; and for ranking questions, means were calculated as the ranking index of each item to be ranked. Based on the above statistical quantities, Krsksas–Wallis tests [33] were performed to investigate the significance in the data, and Spearman tests [34] were also performed to mine the correlation significance between respondents’ knowledge level and their attitudes towards smart campus. Kruskal–Wallis test and Spearman test were chosen for the significance test because they are non-parametric test methods that can suit any unknown data distribution.
Overall, the demographic information indicates the reliability of the collected data, and to a large extent, the findings from the data should reflect the real circumstances in HK primary and secondary education sectors.

5.2 Knowledge on smart campus

Understanding stakeholders’ knowledge level on a smart campus is important as it affects their perceptions and attitudes on the smart revolution in education. Such knowledge can be interpreted as how familiar the respondents are with the smart campus, and four knowledge levels are defined for the respondents to choose from. They are ‘1 – never heard of it’, ‘2 – general knowledge (e.g. read about it online, heard about it on the news etc.)’, ‘3 – have done some research on smart campus’, and ‘4 – have engaged with the implementation of some smart functions on your campus’. By assigning a numerical value to each knowledge level, the qualitative information about respondents’ knowledge can be analysed in a quantitative way, where a higher value represents more knowledgeable. The overall distribution of the response is shown in Fig. 3. Most respondents selected levels 1 and 2 and the mean knowledge level is 2.12, which indicates the lack of knowledge on smart campus among stakeholders. This pushes the need of reinforcing training and advocacy of smart campus in HK.

To further investigate the respondents’ knowledge among different demographic indices, the distribution with respect to user groups, school education level, and school funding types is collected, with statistical results presented in Table 1. In terms of stakeholders, principals are more knowledgeable on smart campus than the other three groups, which is reasonable as the leadership role of principals requires them to be more forward-looking on cutting-edge concepts. Moreover, STEM education encourages the fusion of emerging technologies and pedagogies. The higher knowledge of STEM teachers implies the potential interplay between STEM education and future smart revolution. In terms of school education levels, staff and parents of secondary schools are generally more knowledgeable than those from primary schools, which encourages smart campus promotion in primary schools. In terms of school funding types, DSS schools and private schools show significantly higher knowledge on smart campus than government schools and aided schools, which shows a positive correlation between government funding flow and users’ understanding of smart campus.

5.3 Current school smartness

Provided the high penetration of ICT in the HK education sector, a certain level of smartness has been achieved in some HK schools. This part of the survey collects the current situation of smart function deployment in HK primary and secondary schools, to provide a database to indicate the sufficiency in supporting smart campus development. In the survey, the smart features in school are divided into five categories: smart sensing infrastructure (SSI), smart environment and resource management (SERM), energy sustainability (ES), SLTs, and smart pedagogies (SPs). For each category, multiple items are listed in the form of multiple selection questions for the respondents to answer.

The scope of each category is as follows. Sensing infrastructure serves as the basis for IoT-based smart functions in a smart campus. By deploying sensors to monitor campus environment and personnel in real-time, the context-aware feature of smart campus can be achieved. This category involves the various sensing technologies as the items, such as card reader, quick response (QR) code, video surveillance, facial recognition, environment sensing etc. SERM refers to the remote and efficient management of the space, physical environment, energy, and waste in the context of the smart campus, which helps maintain a comfortable and convenient campus environment for stakeholders. Owing to the recent concerns on the change in climate and the lack of fossil fuels, ES is a significant objective in smart campus development. In this category, the different sustainable energy resources, such as solar energy and wind energy, used to operate the campus are surveyed. SLTs include emerging technologies to improve teaching...
Table 2 CTRR of school smartness with respect to different stakeholders

|                  | Principal | STEM | Non-STEM | Parent |
|------------------|-----------|------|----------|--------|
| SSI              | 2.75      | 2.64 | 2.33     | 1.18   |
| SERM             | 1.33      | 1.12 | 0.63     | 0.58   |
| ES               | 1.08      | 0.80 | 0.53     | 0.42   |
| SLT              | 4.33      | 3.84 | 2.98     | 1.12   |
| SP               | 2.17      | 1.88 | 1.73     | 0.72   |

Table 3 CTRR of school smartness with respect to different school education levels

|                    | Primary | Secondary |
|--------------------|---------|-----------|
| SSI                | 1.40    | 2.39      |
| SERM               | 0.66    | 0.87      |
| ES                 | 0.34    | 0.79      |
| SLT                | 1.84    | 3.12      |
| SP                 | 1.18    | 1.54      |

Table 4 CTRR of school smartness with respect to different school funding types

|                  | Government | Aided | DSS | Private |
|------------------|------------|-------|-----|---------|
| SSI              | 1.46       | 1.52  | 3.12| 3.00    |
| SERM             | 0.87       | 0.66  | 1.02| 0.75    |
| ES               | 0.33       | 0.33  | 1.16| 1.5     |
| SLT              | 1.41       | 2.42  | 3.96| 2.75    |
| SP               | 1.08       | 1.36  | 1.84| 1.5     |

Fig. 4 Stakeholders’ expectation versus school fulfilment
(a) School staff expectation versus school fulfilment, (b) Parent expectation versus school fulfilment

and learning. They are learning-oriented and are essential in achieving the smartness in schools. Some examples are AR, virtual reality (VR), cloud computing, and AI. Along with the rapid technological development, innovative pedagogical approaches, namely SPs, have also been developed recently to enhance the learning experience for students. In this smart pedagogy category, some typical examples are personalised learning that can meet the interests of each individual student, remote learning that enables the ubiquitous learning ability of students and collaborative learning that encourages incorporation and inspiration among students, teachers, and schools.

The overall survey results on current school smartness show a low percentage of ‘none of the above’ response, which indicates a good level of smartness in HK schools. In the sensing infrastructure category, higher popularity is shown on conventional sensing facilities, such as card readers and QR codes, whereas responses on AI-based items, such as facial recognition and voice recognition, are much lower. In the smart learning technology category, sufficient technology deployment in HK is shown to support online/remote learning. By contrast, AR/VR technologies are deployed just at a moderate level, and AI-based learning is still in its infancy among HK schools. In the smart pedagogy category, the survey result indicates that the advanced pedagogical approaches have been generalised into the majority of HK schools. However, the applied pedagogies are mainly real-time student monitoring and collaborative learning, but lacks attempts on e-learning and personalised learning.

To facilitate the conditional analysis in each category, the CTRR for each demographic index is calculated, and the results are shown in Tables 2–4. CTRR refers to the average number of items (except the ‘none of the above’ item) selected by the respondents in each category, which indicates the development level of school smartness. It can be seen that the CTRR values in all categories show similar trends. In Table 2, the CTRR of principals and STEM teachers are higher than non-STEM teachers and parents, which means principals and STEM teachers can perceive more smart functions than non-STEM teachers and parents although they are from the same school with the identical level of smartness. This phenomenon could be explained by a better understanding of principals and STEM teachers on smart campus as shown in Table 1. In Table 3, secondary schools show much higher CTRR than primary schools, which indicates the uneven smart deployment in different education levels. In Table 4, the CTRR of DSS schools and private schools are higher than government schools and aided schools. This result again verifies the correlation between government funding and smart development in education.

5.4 Stakeholder expectation and school fulfilment

Adhering to HCD, the stakeholders’ needs on school teaching/ learning should be collected to guide future smart campus development. In this survey, a set of ranking items are provided to the stakeholders to express their priority in school teaching/learning. Two ranking questions are designed for each respondent. On the one hand, the first question is asking the respondents to rank the items from the most to the least important in teaching/learning. This question focuses on collecting stakeholders’ perceived needs in smart learning. On the other hand, the second question is asking respondents to rank the items from the best to the worst managed by the school. This question aims to test schools’ fulfilment of stakeholders’ needs.

Owing to the deviated roles and responsibilities, the expectation of school staff (i.e. principals, STEM teachers, and non-STEM teachers) and parents on the school teaching/learning items are evaluated separately, and the results are shown in Figs. 4a and b, respectively. The items listed on the right-hand side table are provided for ranking. For each item, the mean rank value is computed as the score to evaluate its importance perceived by stakeholders. A smaller score value means the item is more important or better managed. The overall scores of each item in the two questions are aggregated into a scatter plot. The score in the horizontal axis represents the stakeholders’ expectations on the teaching/learning items, whereas the vertical axis represents the school fulfilment level on their needs. The red diagonal line indicates the school perfectly fulfils the expectation of stakeholders. The points above (or below) this line means the school’s management on those items is lacking behind (or exceeding) stakeholders’ needs.

As shown in Figs. 4a and b, the ‘understanding learning needs’ are identified by the stakeholders as the most important item in school teaching/learning, whereas the ‘sustainability’ is ranked as the least important. The items are distributed close to the red diagonal line, showing the current schools’ management on school teaching/learning closely aligns with the expectation from different stakeholders in general. Nevertheless, by comparing Figs. 4a and b, it can be seen that the items in Fig. 4b are located closer to the red diagonal line than in Fig. 4a, which indicates the current school management is slightly better at adhering to parents’ needs rather than the teachers’ needs.
A smart campus can be seen as a cyber-physical–technologies to be deployed is also important in smart campus school funding types. By doing so, the technology and service providers can interacted under an interdisciplinary framework. In the smart campus context, maintaining stakeholders’ positive attitudes on school operation. Hearing user’s voices is always important before the launch of new social system where stakeholders and technologies have closely space for school improvement in some aspects, such as maintaining teacher-student relationship, understanding students’ learning needs, and maintaining teacher and student mental health and wellbeing, to fulfil the school staff’s expectations.

In this survey, a Likert scale question is designed to collect and compare stakeholders’ acceptance of various SLTs. The SLTs asked in these questions include cloud-based learning, collaborative learning, mobile-based learning, AR/VR-based learning, and IoT-based learning. For each technology, the question includes a statement with seven acceptance levels for the respondents to choose from. The statement is in the form of ‘I am comfortable with XXX technology being used at my school’. The seven acceptance levels in the options are ‘1 – strongly agree’, ‘2 – agree’, ‘3 – somewhat agree’, ‘4 – neither agree nor disagree’, ‘5 – somewhat disagree’, ‘6 – disagree’, ‘7 – strongly disagree’. The values 1–7 assigned to each acceptance level are used for quantitative analysis, where significance tests and correlation tests are performed to extract findings from the responses.

The analysis is performed based on the acceptance score, which is the mean acceptance level among respondents. A lower score value means higher acceptance from the respondents. The analysis is conducted in different user groups, different school education levels, and different school funding types. The statistical results are shown in Tables 5–8.

In Table 5, an overall acceptance score of 2.24 (much smaller than 4) is provided by the respondents, which shows their positive attitudes towards SLTs in general. By comparing among the different technologies, respondents show significant averse on mobile-based learning and AR/VR-based learning. The main concern on mobile-based learning is that although mobile devices can provide a ubiquitous environment for learning, students can also be distracted by the many attractive alternatives on mobile devices, such as games, social media etc.

In Table 6, principals and STEM teachers show higher overall acceptance of SLTs than non-STEM teachers and parents. STEM teachers even show significantly higher acceptance of cloud-based learning and collaborative learning. This high acceptance from STEM teachers is mainly because these two techniques have been widely employed in STEM education in recent years and received very positive feedback.

In Table 7, respondents from primary and secondary schools show similar attitudes towards SLTs. However, as analysed in Section 5.3, the current smartness of primary schools lacks behind secondary schools in HK. This requires equal smart deployment among primary and secondary schools due to the balanced needs of their stakeholders.

In Table 8, no significance was detected among different school funding types, meaning the different types of schools show similar acceptance on new learning technologies although they receive different levels of funding and their current school smartness levels are uneven.

Table 5: Acceptance score on different SLTs

| Technology | Cloud | Collaborative | Mobile |
|------------|-------|---------------|--------|
| score      | 2.48  | 2.48          | 4.10   |

Table 6: Acceptance score on SLTs with respect to different stakeholders

|                        | Principal | STEM | Non-STEM | Parent |
|------------------------|-----------|------|----------|--------|
| cloud                  | 2.42      | 2.08 | 2.53     | 2.78   |
| collaborative          | 2.58      | 1.96 | 2.43     | 2.92   |
| mobile                 | 3.75      | 3.7  | 4.25     | 4.42   |
| AR/VR                  | 3.00      | 3.18 | 3.05     | 2.92   |
| IoT                    | 2.67      | 2.94 | 3.08     | 2.88   |

Table 7: Acceptance score on SLTs with respect to different school education levels

|                      | Primary | Secondary |
|----------------------|---------|-----------|
| cloud                | 2.56    | 2.38      |
| collaborative        | 2.73    | 2.32      |
| mobile               | 4.06    | 4.13      |
| AR/VR                | 3.08    | 2.99      |
| IoT                  | 2.98    | 2.89      |

Table 8: Acceptance score on SLTs with respect to different school funding types

| Funding Types | Government | Aided | DSS | Private |
|---------------|------------|-------|-----|---------|
| cloud         | 2.33       | 2.57  | 2.47| 2.64    |
| collaborative | 2.51       | 2.57  | 2.37| 2.75    |
| mobile        | 3.92       | 4.01  | 4.51| 4.50    |
| AR/VR         | 2.79       | 3.21  | 3.12| 2.50    |
| IoT           | 2.90       | 2.88  | 3.08| 3.00    |

than the school staff’s needs. As indicated in Fig. 4a, there is still space for school improvement in some aspects, such as maintaining teacher-student relationship, understanding students’ learning needs, and maintaining teacher and student mental health and wellbeing, to fulfil the school staff’s expectations.

5.5 Acceptance of SLTs

Hearing user’s voices is always important before the launch of new products. By doing so, the technology and service providers can know the users’ perceived benefits and concerns on the product. Likewise, investigating stakeholders’ attitude on emerging technologies to be deployed is also important in smart campus development. A smart campus can be seen as a cyber-physical-social system where stakeholders and technologies have closely interacted under an interdisciplinary framework. In the smart campus context, maintaining stakeholders’ positive attitudes on new technologies is crucial in achieving effective and efficient school operation.

In this survey, a Likert scale question is designed to collect and compare stakeholders’ acceptance of various SLTs. The SLTs asked in these questions include cloud-based learning, collaborative learning, mobile-based learning, AR/VR-based learning, and IoT-based learning. For each technology, the question includes a statement with seven acceptance levels for the respondents to choose from. The statement is in the form of ‘I am comfortable with XXX technology being used at my school’. The seven acceptance levels in the options are ‘1 – strongly agree’, ‘2 – agree’, ‘3 – somewhat agree’, ‘4 – neither agree nor disagree’, ‘5 – somewhat disagree’, ‘6 – disagree’, ‘7 – strongly disagree’. The values 1–7 assigned to each acceptance level are used for quantitative analysis, where significance tests and correlation tests are performed to extract findings from the responses.

The analysis is performed based on the acceptance score, which is the mean acceptance level among respondents. A lower score value means higher acceptance from the respondents. The analysis is conducted in different user groups, different school education levels, and different school funding types. The statistical results are shown in Tables 5–8.

In Table 5, an overall acceptance score of 2.24 (much smaller than 4) is provided by the respondents, which shows their positive attitudes towards SLTs in general. By comparing among the different technologies, respondents show significant averse on mobile-based learning and AR/VR-based learning. The main concern on mobile-based learning is that although mobile devices can provide a ubiquitous environment for learning, students can also be distracted by the many attractive alternatives on mobile devices, such as games, social media etc.

In Table 6, principals and STEM teachers show higher overall acceptance of SLTs than non-STEM teachers and parents. STEM teachers even show significantly higher acceptance of cloud-based learning and collaborative learning. This high acceptance from STEM teachers is mainly because these two techniques have been widely employed in STEM education in recent years and received very positive feedback.

In Table 7, respondents from primary and secondary schools show similar attitudes towards SLTs. However, as analysed in Section 5.3, the current smartness of primary schools lacks behind secondary schools in HK. This requires equal smart deployment among primary and secondary schools due to the balanced needs of their stakeholders.

In Table 8, no significance was detected among different school funding types, meaning the different types of schools show similar acceptance on new learning technologies although they receive different levels of funding and their current school smartness levels are uneven.

5.6 Cybersecurity and privacy

Cybersecurity and data privacy are always critical concerns when dealing with cyber systems and sensitive human-related data. These systems and data must be handled according to the legal/regulatory requirements. As the realisation of campus smartness highly relies on the availability of high-dimensional data, in particular, personal data with subjective opinion, protecting the data for students and staff would be a challenge in smart campus development, especially on an information platform based on emerging technologies such as cloud computing and IoT [35]. This survey area focuses on investigating stakeholders’ concern on the security and privacy issue in the context of a smart campus.

A smart campus is exposed to various cybersecurity issues. A cyber-secure campus can provide a peace-of-mind cyber environment for the students and staff when they use the online teaching/learning facilities. This means they are free to use online materials based on their needs, without worrying about the disruption of services or leakage of sensitive data. The main cybersecurity concerns on a cloud-IoT-based smart campus are related to data insecurity. For example, intruders may get access to the campus data and perform attacks because the cyber system of a campus is usually open. A solution for mitigating the attack issues could be increasing the data redundancy and protection against denial-of-service attacks [36]. The data system in a smart campus needs to meet the requirements of confidentiality, authenticity, integrity, and availability.

In this survey, a Likert scale question is again designed to collect stakeholders’ concerns on cybersecurity and privacy issues.
This Likert scale question consists of four sub-questions as below to investigate stakeholders’ opinion:

(iv) Are you comfortable with increased data collection?
(v) Do you believe your school’s cyber system can reliably protect the data?
(vi) Do you believe your school can ethically manage the data?
(vii) Do you believe the benefits of data collection outweigh its privacy risks?

By answering the above four sub-questions, the overall attitude of stakeholders on cybersecurity and privacy in smart campus can be obtained. The users’ acceptance of increased data collection is discretised into seven levels, where the smaller value indicates more positive attitude towards increased data collection (i.e. less concerns on cybersecurity and privacy). Significance tests and correlation tests are also performed on the responses. The analysis is performed based on the responses in different user groups, different school education levels, and different school funding types. The statistical results are shown in Tables 9–12.

**Table 9** Score on different sub-questions regarding cybersecurity/privacy concerns

| Question | Q1 | Q2 | Q3 | Q4 | Score |
|----------|----|----|----|----|-------|
|          |    |    |    |    | 2.35  |
|          |    |    |    |    | 2.36  |
|          |    |    |    |    | 2.19  |
|          |    |    |    |    | 2.93a |

*Kruskal–Wallis test: significant difference (p < 0.05).*

**Table 10** Score on cybersecurity and privacy sub-questions with respect to different stakeholders

| Principal STEM Non-STEM Parent | Q1  | Q2  | Q3  | Q4  | Score |
|--------------------------------|-----|-----|-----|-----|-------|
| Q1                             | 2.08| 2.18| 2.68| 2.33|
| Q2                             | 2.33| 2.44| 2.53| 2.20|
| Q3                             | 1.75| 2.18| 2.38| 2.15|
| Q4                             | 2.33| 2.60| 3.18| 3.00|

**Table 11** Score on cybersecurity and privacy sub-questions with respect to different school education levels

| Primary    | Secondary | Q1  | Q2  | Q3  | Q4  | Score |
|------------|-----------|-----|-----|-----|-----|-------|
| Q1         | 2.42      | 2.28|
| Q2         | 2.42      | 2.27|
| Q3         | 2.26      | 2.02|
| Q4         | 2.98      | 2.82|

**Table 12** Score on cybersecurity and privacy sub-questions with respect to different school funding types

| Government Aided DSS Private | Q1  | Q2  | Q3  | Q4  | Score |
|------------------------------|-----|-----|-----|-----|-------|
| Q1                           | 2.15| 2.40| 2.43| 2.75|
| Q2                           | 2.26| 2.57| 2.10| 2.25|
| Q3                           | 2.26| 2.25| 2.02| 2.00|
| Q4                           | 2.44| 2.79| 3.04| 2.00|

**Table 13** Correlation test results between acceptance on SLTs and respondents’ knowledge on smart campus

| Cloud | Collaborative | Mobile | AR/VR | IoT |
|-------|---------------|--------|-------|-----|
| p-value | 0.10 | 0.22  | 0.19  | 0.03a | 0.10 |

*Spearman test: significant correlation (p < 0.05).*

**Table 14** Correlation test results between concerns on cybersecurity/privacy and respondents’ knowledge on smart campus

| Q1 | Q2 | Q3 | Q4 |
|----|----|----|----|
| p-value | 0.003b | 0.002b | 0.0008b | 0.03a |

*Spearman test: significant correlation (p < 0.05).*

*Spearman test: significant correlation (p < 0.01).*
6 Recommendations

This survey provides statistical information to guide future development and planning of smart campus and aims to build a better understanding of the current smart campus landscape in HK. Adhering to HCD, the recommendations with regard to smart campus development will be summarised in six main areas: promotion, funding and infrastructure, curriculum and pedagogy, teacher support, privacy, and sustainability.

6.1 Promotion

The survey shows that for respondents who have a higher level of knowledge on smart campus, they tend to be more acceptable to exploit new techniques in learning. In other words, respondents’ knowledge on smart campus determines their understanding and acceptance of new technology-based learning. This finding indicates that the stakeholders tend to use the new technologies only if they have a good understanding of them. The survey revealed that HK users’ aversion to AR/VR-based learning is precise because AR/VR technology is still new to them, and the lack of knowledge or experience creates barriers between the users and the technology. Therefore, improving stakeholders’ knowledge on smart campus is shown to help accelerate the popularity of smart campus, which encourages the cultivation of stakeholders for future smart campus development. This could be achieved by increasing the promotion of smart campus and providing more opportunities for real smart experience for the public. The promotion activities could be not only on students, teachers, and other school staff but also on parents. It is necessary to seek effective measures to motivate parents to understand more about smart campuses and enhance their knowledge of the smart features available at their children’s schools.

6.2 Funding and infrastructure

The data suggest that HK government and enterprises increase funding support on the smart facility reinforcement in primary schools. The quality of early education is critical to children’s growth. Especially in the current stage of transition towards smart education, children’s early exposure to smart technology is essential to lay the foundation for their future mastery of smart functions in secondary school. Therefore, it is worth considering how to accelerate the smart infrastructure of primary school and enable students to adapt to smart technologies in learning at an earlier age. In particular, AI-based learning has been rarely adopted, so there is a pressing need to renovate the current sensing infrastructure into more AI-based mode to meet the needs of future smart campus development.

6.3 Curriculum and pedagogy

Comparing STEM subjects, the fusion of emerging technologies and pedagogies is rarely experienced on non-STEM subjects. As a result, non-STEM teachers lack knowledge and capabilities on smart technologies and show less reliance on data-driven applications. Hence, more efforts are suggested to exploring the usage of smart technologies to enhance the teaching and learning performance on non-STEM subjects.

Moreover, as AI-based learning and AR/VR-based learning are still in their infancy in HK schools, it is essential to increase the penetration of AI and AR/VR in daily school learning and management. While encouraging the implementation of remote learning and personalised learning, it would be more beneficial if the developers could establish an open-source mobile platform to provide students with a more balanced view between learning and recreation. A good mobile platform can facilitate the teachers to browse students’ interests. The open-source feature would make the mobile platform more adaptable to new technologies and pedagogies.

6.4 Teacher support

Although smart technologies enhance teaching performance, they also bring pressure and challenges to the teachers. There is definitely a need for on-going professional development for teachers. Rather than equipping teachers with the capability to use new technologies in teaching, it is more in terms of pedagogical use of new technologies in specific subjects. Moreover, the survey revealed that parents in HK have high expectations for teachers in a smart campus. The survey results indicate that teachers still have space for improvement in areas of ‘teacher–student relationships’ and ‘understanding students’ learning needs’, so more attention is expected on these aspects in future teacher training. In addition, since children’s early exposure to smart technology will bring great benefits to their future learning, primary schools require more staff training to prepare for the future smart education revolution. It is worth noting that the current school management is better at adhering to parents’ needs rather than the staff’s needs. Teachers’ demands and their mental health and wellbeing are often overlooked by the schools. Therefore, it is recommended that schools and relevant departments could help teachers withdraw from various administrative and routine tasks by using smart technologies so that sparing enough time and energy for them to focus on SPs and concentrate on their students.

6.5 Privacy

In smart campus implementation, it is important to find an effective measure to mitigate the privacy risks to make users more comfortable with data collection and more confident in the data management system. It is recommended for future smart campus research and development to focus on the following problems:

- How to model and decide the trade-off between stakeholders’ perceived benefits and their perceived privacy risk from the increased data collection in the smart campus context?
- How to optimally balance the trade-off between the benefits and privacy risk in smart campus design and operation? (i.e. how to optimally protect stakeholders’ privacy while maintaining the effectiveness of smart campus applications?)
- How to satisfy the deviated privacy needs from individual stakeholders?
- How to incorporate legal and regulatory constraints to protect stakeholders’ privacy?

With the above considerations, the recommendations could be given in both technical and political areas to achieve a privacy-aware transition from the existing campus to a smart campus. On the one hand, upon providing smart services, the teams that design, plan and implement the data-driven smart campus applications need to take the responsibility to investigate individual’s privacy concerns and provide personalised data control to protect individual data, as well as follow the legal/regulatory requirements and principles on data protection. On the other hand, the government and policymakers need to timely update the law, policies, and regulations to protect an individual’s privacy while ensuring a certain level of context awareness within the campus.

Moreover, the correlation test on the survey data suggests that an effective way to alleviate people’s concerns on cybersecurity and privacy is to improve their knowledge on smart campus. It is believed that along with the constantly reinforced promotion, training, and use of smart services, people will be getting more familiar with and giving more trust on the smart things and gradually accept them as ordinary tools to support their living, learning, and socialising activities, which progressively builds their confidence on smart campus.

6.6 Sustainability

The survey indicates that a significant portion of HK schools currently lacks facilities for smart waste management and sustainable energy. Also, ‘sustainability’ is ranked as the least important by parents and school staff. To promote the sustainable development of the smart campus, it is recommended that the
relevant departments could generalise the integration of sustainable energy and elevating citizen's environmental awareness by establishing attractive energy policies and products, e.g. feed-in tariff.

7 Conclusion

Adhering to HCD, this paper presents a user case survey conducted among HK primary and secondary schools, aiming to capture and understand the perspectives of school stakeholders on education applications in the context of the smart campus. This survey is structured to investigate six areas: demography, knowledge on smart campus, current school smartness, stakeholder expectation and school fulfillment, acceptance on SLTs, and cybersecurity and privacy. All the extracted findings indicate technological readiness in primary/secondary schools and positive attitudes of school stakeholders towards smart campus transition in HK. This includes fast developing knowledge on smart campus, adequate infrastructure and technology to support school smartness, excellent school fulfillment on stakeholders’ needs and expectations, wide acceptance on new technologies and pedagogies, and manageable concerns on cybersecurity and privacy. Targeted recommendations with regard to the areas of promotion, funding and infrastructure, curriculum and pedagogy, teacher support, privacy, and sustainability are also given to support the next stage of smart campus planning and development.

With one of the region’s well established educational systems and decades of continuous efforts in adopting the latest technologies in school education in Hong Kong, the findings and recommendations in the survey are also expected to result in a benchmark reference of the smart campus concept for international educational providers, government and technology companies that will deliver smart solutions.

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