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Adequacy and functionality of information and communication technology infrastructure: its online learning implications

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ABSTRACT

This study investigates the adequacy and functionality of information and communication technology (ICT) infrastructure for online learning in a Philippine Higher Education Institution (PHEI), particularly in the context of Caraga State University Cabadbaran Campus (CSUCC). Faculty perceptions were gathered through surveys to assess various aspects of the infrastructure, including computer labs, internet connectivity, software applications, learning materials, and communication tools. The findings reveal that while the overall ICT infrastructure is perceived as generally functional, significant improvements are needed, particularly in internet connectivity, which was rated as inadequate and less functional. Faculty also expressed concerns about the quality and availability of online learning materials. Positive aspects were identified in video conferencing tools and backup power supply, although inconsistencies exist in the latter. The study recommends substantial investments in improving internet infrastructure and software upgrading. Additionally, it emphasizes the need to develop high-quality online learning materials and ensure compatibility and faculty training on relevant software applications. Addressing these critical areas can create a more robust and supportive ICT infrastructure for compelling online learning experiences in Higher Education Institutions (HEIs).

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1. INTRODUCTION

As technology has significantly improved, the desire for new ways to deliver education is growing, prompting changes in teaching and learning approaches. Distance education, which varies from traditional education, entails studying from home while students and teachers are physically separated. At the same time, classroom learning refers to an educational system where students and teachers work together. Electronic tools enable students to communicate with teachers, bridge the gap, and deliver instructional content via remote learning programs. Both learning approaches have some advantages and limitations [1]. This type of educational delivery has been deployed on various platforms at different levels of education, where information and communication technology (ICT) applications are crucial in the era of new technology [2]. The rapid rise of online learning in recent years has highlighted the critical role of ICT infrastructure in supporting compelling educational experiences. This is particularly true in the Philippines, where Higher Education Institutions (HEIs) increasingly embrace online learning opportunities. However, the success of online learning hinges on an

adequate and well-functioning ICT infrastructure. Therefore, it is critical to be cognizant of the importance of ICT infrastructures and the challenges that may occur when adopted in HEIs [3].

A study by Al-Ansi *et al.* [4] found that ICT-based learning offers a range of advantages, opportunities, and challenges. Internet accessibility, electricity problems, infrastructure maintenance, increasing cost of ICT devices, lack of expertise, inability to manage classrooms, and plagiarism were the high-ranked threats for learners and teachers to sustain online learning. Developing countries like the Philippines must develop new strategies and techniques to promote ICT-based learning based on innovation, socio-cultural and socio-economic aspects, and financial support.

Anchored on the technological pedagogical content knowledge (TPACK) model, there is a strong connection between the adequacy and functionality of ICT infrastructure and TPACK. Effective implementation of the TPACK framework depends on an adequate and functional ICT infrastructure [5]. This translates to dependable hardware and software, encompassing a sufficient number of well-maintained and recent models of computers, tablets, and other relevant ICT devices. These technological tools must also be pedagogically and content-aligned to directly support the intended curriculum and the teacher's chosen teaching strategies. This includes internet connectivity, specific software applications, or interactive whiteboards. Furthermore, sufficient technical support, in the form of personnel or resources, is essential to assist educators in navigating any challenges that may arise when integrating technology into the teaching-learning process.

Prior research has explored the general adequacy and functionality of ICT infrastructure. However, a more in-depth examination and analysis are needed to understand how disparities in ICT infrastructure specifically impact students' online learning experiences. Focusing on these disparities is crucial because understanding these intricate effects may lay the foundation for the development of more equitable policies for resource allocation. Such policies would ensure that all learners have equal opportunities to reap the benefits of online education. This knowledge gap served as the primary driving force for this current study. The researchers aimed to investigate the adequacy and functionality of the ICT infrastructure utilized for online learning within a Philippine Higher Education Institution (PHEI), focusing on the Caraga State University Cabadbaran Campus (CSUCC). It aims to identify areas of strength and weakness within the current ICT infrastructure by collecting information from the faculty who directly observed and used these resources. Understanding and analyzing faculty responses to these aspects is crucial as it will be the centre of developing and delivering an online learning environment. The study also examined various aspects of the ICT infrastructure, including hardware adequacy and functionality in computer laboratories and other dedicated equipment used for online learning, the availability and functionality of software applications that support online learning activities, and the quality and accessibility of online learning materials provided by the institution. Additionally, the study looks into the reliability and speed of internet connectivity, which are crucial for online learning delivery, the functionality of communication tools used for online interaction between faculty and students, and the availability and effectiveness of backup power in case of power outages. As mentioned, analyzing faculty perceptions and experiences on those elements can provide valuable insights for the HEI to improve its ICT infrastructure and create a more conducive environment for successful online learning experiences.

COVID-19 has brought a drastic shift to ICT-based learning; whether we like it or not, technology will be a part of our instruction. Mobile phones, computers, printers, scanners, photocopiers, projectors, and broadcasting technologies like televisions and radios are all part of the ICT infrastructure. According to the study by Bariu [6], most schools fail to implement online learning due to the increasing costs of computer hardware, software, and related accessories that require substantial investment in ICT infrastructure. School administrators, teachers, and students must also gain new skills and competencies to prepare for using ICT infrastructure.

HEIs must adopt active learning and virtual technologies to shift teaching strategies toward more adaptable, student-centred approaches [7]. The effectiveness of these strategies still heavily depends on students attending class in person. Despite the many instructional strategies suggested to improve students' learning, the main issue is that they need to participate. Whether or not students are motivated to use such online learning will determine how successfully the learning pedagogies are implemented [8].

The paper "online and remote learning in higher education institutes: a necessity in light of the COVID-19 pandemic" by Ali [9] confirms that even sophisticated countries cannot deliver online learning on such a huge scale. Ali [9] further emphasized that to achieve an influential online and blended learning environment, proper ICT support in infrastructure, tools, hardware, and software support systems is essential for efficient online learning delivery. This finding also highlighted the importance of ICT infrastructure as the foundation for an online learning environment.

The study of Ademiluyi [10] reports that ICT facilities are unavailable, grossly inadequate and vastly underutilized in teaching business courses in Osun State public secondary schools. The study suggested that the government and other education stakeholders offer adequate ICT infrastructure and personnel in public secondary schools to create an engaging online learning environment. Educators in an online delivery system must now make an extra effort to facilitate learning and build alternative learning modes that match the learners' needs and abilities. Furthermore, they must design and implement solutions in

light of the rapid evolution of technology, which is seen as the most critical problem for teachers and even in specific institutions. ICT infrastructure should be accessible and usable by everyone. Teachers need to undergo a series of webinars and tutorials to improve their competence in using the said ICT resources to boost their confidence to use it in a hybrid learning environment, as we all know that integrating digital technology can enhance teaching and learning for the quality of education.

The value of online learning is discussed in "an investigation into what educators think about online learning." The fundamental purpose of the article is to "examine the problems educators face." The changes they predict in online learning practices during the COVID-19 pandemic, the changes they experienced in online learning practices during the COVID-19 pandemic educational procedures in the post-COVID-19 era, as well as actions to be made in education to prevent further outbreaks." As a result, online instruction will continue to be difficult for educational institutions after COVID-19. Furthermore, good digital infrastructure for professors and students is required to improve institutions' teaching and learning [11].

Education has changed rapidly because of technology's capacity to create a proactive, easy-to-access, and all-inclusive teaching and learning environment. According to Ghavifekr *et al.* [12], the majority of teachers are aware of the benefits and utility of ICT in the classroom, and the majority of teachers acknowledged that using ICT allows them to improve their teaching by utilizing more up-to-date materials. More accurate and up-to-date Internet teaching resources and materials are handy for teachers to create more exciting and engaging lessons for students. Some studies emphasized that it is vital to build a comprehensive rationale before employing ICT infrastructure in schools and classrooms. In general, as computer technology becomes more widely available, it is critical that teachers avoid becoming engaged in the equipment and instead concentrate on the students. Educators are their primary role. Teachers must trust their imaginations to the fullest extent possible, remembering that technological advancements will continue to change how they teach. They will be able to accomplish more of their objectives as technology advances [13]. The literature and related studies above provided additional insights to the researchers about the study. The importance of ICT infrastructures in supporting online learning and the administrative support for using these infrastructures also serve as the basis of the researchers' pursuit of this study.

2. METHOD

2.1. Research design

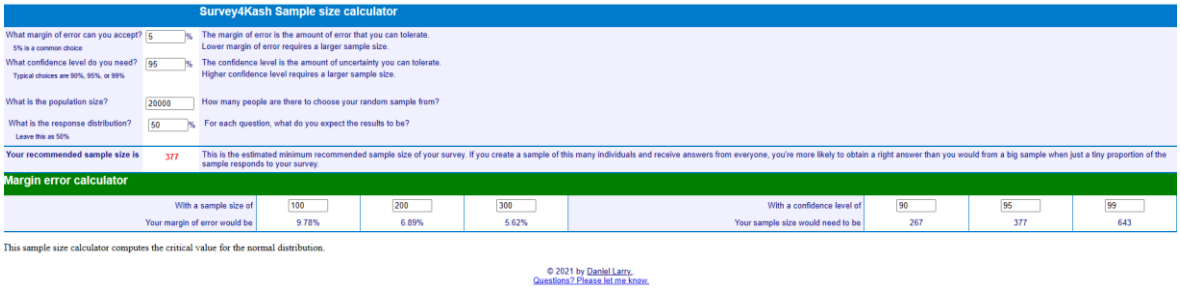
This study employed a survey research method to gather data on the adequacy and functionality of the ICT infrastructure and its implication for online learning in a chosen PHEI. The chosen HEI is the Caraga State University, where faculty observations and experiences using ICT resources were considered. Figure 1 presents the research concept of this study.

Figure 1. Conceptual framework

2.2. Participants

The target population for this study are the CSUCC faculty members with experience in online teaching. There were 100 faculty members randomly chosen to participate in this study from the total population of 134. It was ensured that they were the representative sample of the total faculty population. Sampling procedures utilize some rules of thumb that best suit specific samples. There is no harm in employing these rules if researchers can fulfil their "representativeness" assumptions. In this case, the sampling frame is easily accessible for selecting the research participants randomly. As a result, we consider using online calculators such as RaoSoft or Calculator.net [14], [15]. Figure 2 shows how the estimated minimum recommended sample size for this study was calculated using the Survey4kash sample size online calculator, which has a similar concept to Raosoft [15].

The online calculation confirms that 100 is the adequate estimated minimum sample size for this survey, which is more likely to obtain the correct data if all responses were retrieved. This is further supported by the research advisors sample size table which can be viewed online. As presented in Figure 3, a 100 samples size from a population of 134 is deemed accurate for a 95% confidence level with a margin of error of 5%.



Survey4Kash Sample size calculator

What margin of error can you accept? 5 %
5% is a common choice
The margin of error is the amount of error that you can tolerate.
Lower margin of error requires a larger sample size.

What confidence level do you need? 95 %
Typical choices are 90%, 95%, or 99%
The confidence level is the amount of uncertainty you can tolerate.
Higher confidence level requires a larger sample size.

What is the population size? 20000
How many people are there to choose your random sample from?

What is the response distribution? 50 %
Leave this as 50%
For each question, what do you expect the results to be?

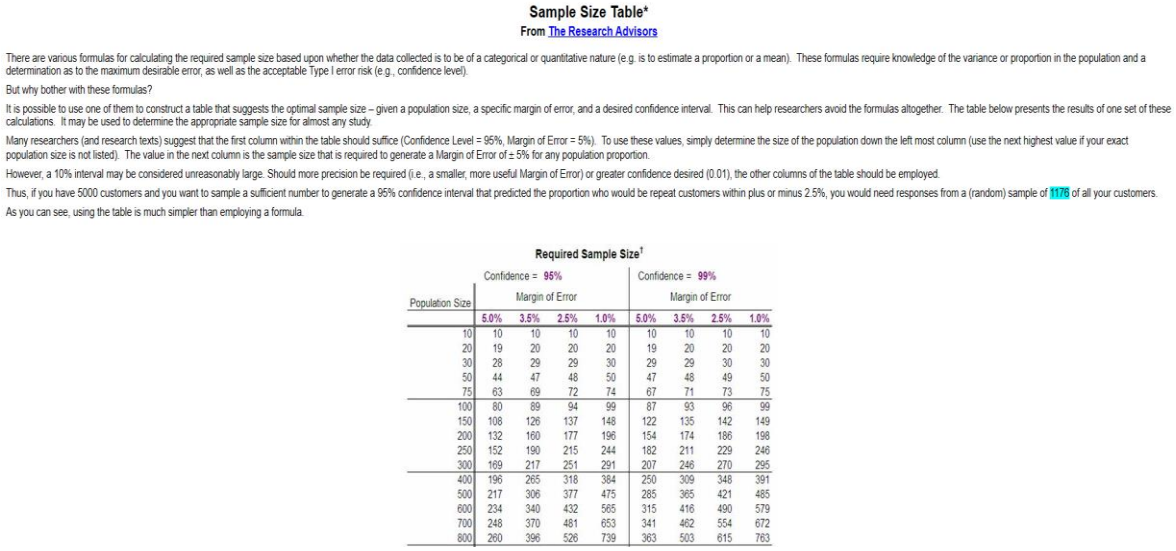
Your recommended sample size is 377
This is the estimated minimum recommended sample size of your survey. If you create a sample of this many individuals and receive answers from everyone, you're more likely to obtain a right answer than you would from a big sample when just a tiny proportion of the sample responds to your survey.

Margin error calculator

With a sample size of	100	200	300	With a confidence level of	90	95	99
Your margin of error would be	9.78%	6.89%	5.62%	Your sample size would need to be	267	377	643

This sample size calculator computes the critical value for the normal distribution.

Figure 2. Screenshot of Survey4Kash sample size calculator by Larry [16]



Sample Size Table*
From The Research Advisors

There are various formulas for calculating the required sample size based upon whether the data collected is to be of a categorical or quantitative nature (e.g. is to estimate a proportion or a mean). These formulas require knowledge of the variance or proportion in the population and a determination as to the maximum desirable error, as well as the acceptable Type I error risk (e.g., confidence level).

But why bother with these formulas?

It is possible to use one of them to construct a table that suggests the optimal sample size – given a population size, a specific margin of error, and a desired confidence interval. This can help researchers avoid the formulas altogether. The table below presents the results of one set of these calculations. It may be used to determine the appropriate sample size for almost any study.

Many researchers (and research texts) suggest that the first column within the table should suffice (Confidence Level = 95%, Margin of Error = 5%). To use these values, simply determine the size of the population down the left most column (use the next highest value if your exact population size is not listed). The value in the next column is the sample size that is required to generate a Margin of Error of ± 5% for any population proportion.

However, a 10% interval may be considered unreasonably large. Should more precision be required (i.e., a smaller, more useful Margin of Error) or greater confidence desired (0.01), the other columns of the table should be employed.

Thus, if you have 5000 customers and you want to sample a sufficient number to generate a 95% confidence interval that predicted the proportion who would be repeat customers within plus or minus 2.5%, you would need responses from a (random) sample of 1176 of all your customers.

As you can see, using the table is much simpler than employing a formula.

Required Sample Size†

Population Size	Confidence = 95% Margin of Error 5.0%	3.5%	2.5%	1.0%	Confidence = 99% Margin of Error 5.0%	3.5%	2.5%	1.0%
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	132	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	196	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763

Figure 3. Screenshot of the required sample size from research advisors [17]

2.3. Survey instrument

A self-administered survey questionnaire was developed specifically for this study. Some of the questions were adapted from the study of Doculan [18]. The questionnaire included several essential elements. First, it gathered demographic information about the faculty members, such as age, sex, civil status, years in service, and highest educational attainment. Next, it focused on the ICT infrastructure components used for online learning, specifically examining their adequacy and functionality. These questions utilized a five-point Likert scale to quantify the participants' responses. Before the questionnaire was distributed to the participants, it was presented first to the panel of experts in the field of technology education for content validity.

Pilot testing was also performed to determine the reliability of the instrument. During pilot testing, the survey instrument was tested on faculty members who were not considered participants in this study. Cronbach's Alpha was utilized as a standard measure of internal consistency reliability [19]. Reliability test results reveal two forms of Cronbach's Alpha: first is the value of 0.958, indicating a high level of reliability for the survey instrument. Second is the value of 0.961 based on standardized items, which is slightly higher than the original Alpha. This suggests that the reliability might be even stronger when the items are standardized (e.g., having a mean of 0 and a standard deviation (SD) of 1). Results also reveal that the instrument has 32 items. A more significant number of items can contribute to higher reliability. In addition, the high Cronbach's Alpha values suggest that the items within the instrument consistently measure the same underlying concept.

2.4. Data collection procedures, scoring, and quantification of data

The questionnaire was distributed electronically through email and manually through a face-to-face survey to maximize its retrieval. An informed consent statement was included, explaining the study's purpose and ensuring the participants' anonymity. Gathered data from Likert scale responses from the participants were analyzed using descriptive statistics (means, SD). A 5-point Likert scale was used to describe the extent

of ICT resource adequacy and its functionality based on the observation and experiences of the faculty members during online learning. The scoring scale and ranges are given in Table 1.

Table 1. Scoring scale, range, and interpretation used to quantify data

Scale	Score ranges	Verbal description	
		Adequacy	Functionality
5	4.50–5.00	Completely adequate	Fully functional
4	3.50–4.49	Mostly adequate	Functional
3	2.50–3.49	Slightly adequate	Somewhat functional
2	1.50–2.49	Inadequate	Less functional
1	1.00–1.49	Not existing	Not functional

2.5. Limitations

This study had inherent limitations, such as the findings not being applicable to all PHEIs due to its focus on one institution. Self-reported data through surveys is susceptible to bias based on individual perceptions and experiences. There were no classroom observations to triangulate how technology was being used [20]. Further in-depth studies may be needed to confirm the importance of an adequate and functional ICT infrastructure in HEIs nationwide to provide compelling online learning experiences.

3. RESULTS AND DISCUSSION

This section discusses the faculty's perception of the adequacy and functionality of Caraga State University's ICT infrastructures and its implications for online learning. The information collected from the participants was processed and transformed into data. The results were presented in tabular form.

3.1. Adequacy of information and communication technology infrastructure

Table 2 summarizes the faculty's responses on the adequacy of various aspects of the ICT infrastructure at CSUCC for online learning. The data were summarized using mean scores, SD, and verbal interpretations. The overall adequacy with a grand mean score of 3.43 (SD=0.63) with a verbal interpretation of "slightly adequate" indicates that the CSUCC faculty members have mixed observations and experiences about the overall suitability of the ICT infrastructure used for online learning.

Table 2. Summary of faculty's responses on the adequacy of ICT infrastructure for online learning

Parameters	Mean	SD	Verbal interpretation
Computer laboratories	3.48	0.79	Slightly adequate
The internet connection	2.41	0.87	Inadequate
Supporting infrastructure (like desktop and laptop)	3.48	0.98	Slightly adequate
Computer software application	3.49	0.93	Slightly adequate
Content/material for online learning	2.49	0.87	Inadequate
Communication tools	3.97	0.79	Mostly adequate
Alternative supply of electricity in case of interruptions	3.86	1.07	Mostly adequate
Video conferencing applications/tools (like Zoom, Google Meet, MS Teams, and Webex)	4.28	0.77	Mostly adequate
Grand mean	3.43	0.63	Slightly adequate

Faculty observations and experiences regarding the adequacy of the University's ICT infrastructure and online learning resources reveal mixed responses across various dimensions. Computer laboratories (mean=3.48) and supporting infrastructure, including desktops and laptops (mean=3.48), were considered slightly adequate, indicating they meet basic needs but may suffer from limitations such as outdated equipment, insufficient quantities, or unreliable functionality. Gupta and Hayath [21] emphasize the need for robust IT infrastructure for effective virtual learning environments, noting that inadequate resources can hinder online education implementation, affecting both students and teachers. Software applications (mean=3.49) were also found to be slightly adequate, fulfilling basic requirements but potentially lacking advanced features or facing compatibility issues. A significant concern emerged regarding the content and materials for online learning, which were rated inadequate (mean=2.49), highlighting a pressing need for improvement in this area. Internet connectivity, another critical component, was rated as inadequate (mean=2.41), reflecting issues with reliability in the Philippines, where slow or unstable connections pose significant challenges to online learning [22]. Communication tools, such as messaging platforms and

discussion forums (mean=3.97), were viewed as mostly adequate, though with room for enhancement. Resilience and support measures, like alternative electricity supplies (mean=3.86), were mostly adequate, suggesting some institutional capacity to address power outages despite variability in experiences. Video conferencing applications (mean=4.28), including Zoom and MS Teams, were also rated mostly adequate, indicating they meet faculty needs for online interaction. While certain aspects of the ICT infrastructure are sufficient, critical areas, particularly in content provision and internet connectivity, require substantial improvement to support effective online education.

The findings identify a need for significant improvement in the quality of content/material for online learning and internet connectivity to support effective online learning. A critical factor affecting students' online learning experience was technical support and ease of using the learning platform [23]. While hardware and software are perceived as slightly adequate, further investment in upgrading equipment and ensuring software compatibility might be necessary. Communication tools are functional, but the study could explore faculty preferences and identify areas for improvement. Reliable backup power is crucial for online learning continuity-the high SD in faculty ratings suggests investigating potential inconsistencies in its availability. By addressing these gaps, the University can create a more robust and supportive ICT infrastructure that facilitates effective integration of ICT in teaching and learning (IITL) that positively influences the online learning experiences of the students [24].

3.2. Functionality of information and communication technology infrastructure

Table 3 summarizes the faculty responses on the functionality of various ICT infrastructures used for online learning. Like Table 2, data is summarized using mean scores, SD, and verbal interpretations. The overall functionality, with a grand mean score of 3.63 (SD=0.58) and a verbal interpretation of "functional," indicates a generally positive view of the ICT infrastructure's functionality for online learning at CSUCC. These infrastructures offer students a virtual environment and the ability to access digital content based on their learning patterns [25]. However, investments in ICT infrastructure and professional development to improve classroom instruction have yet to produce positive results [26].

Table 3. Summary of faculty's assessment on the functionality of ICT infrastructure for online learning

Parameters	Mean	SD	Verbal interpretation
Computer laboratories for online learning	3.49	0.84	Somewhat functional
Internet connectivity	2.45	0.76	Less functional
The ICT infrastructures that support online learning	3.99	0.75	Functional
Equipment such as computers and projectors	4.06	0.66	Functional
Computer software application for online learning	3.46	0.76	Somewhat functional
Online learning materials to facilitate learning	3.48	0.74	Somewhat functional
Alternative supply of power in case of interruptions like generators	3.90	1.03	Functional
Video conferencing tools to facilitate online teaching and learning	4.22	0.68	Functional
Grand mean	3.63	0.58	Functional

Faculty responses on the University's ICT infrastructure's functionality for online learning also reveal mixed observations and experiences. Computer laboratories (mean=3.49) are perceived as somewhat functional, fulfilling basic needs but facing limitations for more demanding online learning activities. The overall ICT infrastructure supporting online learning (mean=3.99) is considered functional, though further details are needed to fully understand its strengths and weaknesses. Equipment such as computers and projectors are viewed as generally operational, meeting basic requirements. Computer software applications (mean=3.46) are also seen as somewhat functional, suggesting issues with compatibility, outdated features, or a lack of faculty training. Online learning materials (mean=3.48) are similarly rated, reflecting their quality and availability concerns. Internet connectivity (mean=2.45) is rated as less functional, highlighting significant issues with reliability in the Philippines, where slow or unstable connections hinder effective online learning. This mirrors findings in previous studies, such as Mensah *et al.* [27], which underscore students' challenges due to limited internet access. The alternative power supply or backup sources (mean=3.90) are perceived as functional, indicating some measures are in place to address power outages, although availability is inconsistent across the institution. Video conferencing tools (mean=4.22) are seen as functional, suggesting they are reliable and effectively support online interaction. While the ICT infrastructure shows some strengths, critical areas, particularly internet connectivity and content quality, need substantial improvement to enhance online learning effectiveness.

The findings again highlight the critical need for improved internet connectivity. Upgrading infrastructure and addressing affordability issues are crucial. A study by Cullinan *et al.* [28] highlights the disparities in access to quality broadband faced by higher-education students. It emphasizes the negative impact of poor internet connectivity on online learning experiences. While hardware and software are generally functional, investigate if

specific limitations exist regarding software compatibility or the need for faculty training. The somewhat functional rating for online learning materials suggests improving their quality, quantity, and alignment with online learning pedagogy. Developing high-quality instructional materials and activities aligned with students' learning styles will help them participate and be more motivated [29]. Skills and resources were found to affect student satisfaction directly [30]. The inconsistencies in backup power availability (high SD) must be addressed to ensure a reliable learning environment during power outages. By focusing on these areas, the university can enhance the functionality of its ICT infrastructure and create a more supportive environment for faculty to deliver compelling online learning experiences. It is essential to consider faculty suggestions for improvement to address specific challenges they encounter.

4. CONCLUSION

This study's findings revealed that the ICT infrastructure's overall adequacy for online learning at CSUCC is slightly adequate. While the infrastructure is generally functional, with a grand mean of 3.63, some areas require significant improvement. The key areas identified for enhancement include internet connectivity, where upgrading infrastructure and addressing accessibility is crucial for the effective implementation of online learning. Developing high-quality, engaging online learning materials that align with online pedagogy is essential for smooth implementation. Although the software applications are somewhat functional, issues such as compatibility, features, or faculty training on their effective use need to be addressed. Ensuring compatibility, providing training for faculty, and upgrading any outdated applications will contribute to a better online learning experience. The HEIs can create more powerful and supportive ICT infrastructures by improving these critical areas. Investing in online learning infrastructure can create engaging online learning experiences for both teachers and students. This aligns with the TPACK model, which helps educators learn how to use technology effectively in their teaching. The state of an institution's ICT infrastructure directly influences an educator's ability to develop and utilize its TPACK framework. For example, limited or malfunctioning ICT infrastructures can limit teachers' capability to experiment with and adopt modern technologies. This, in turn, hinders the development of their technological knowledge and their ability to integrate technology with their teaching methods seamlessly.

In contrast, an adequate and well-functioning ICT infrastructure empowers educators to explore and incorporate innovative technological tools into their instruction, thereby strengthening their TPACK and enriching the overall learning environment. In essence, the adequacy and functionality of ICT infrastructures play a crucial role in fostering the development and practical application of TPACK. A well-maintained ICT infrastructure provides the essential foundation for educators to build their technological knowledge and integrate it with their pedagogical and content knowledge, ultimately leading to more impactful teaching strategies.

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