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RESEARCH ARTICLE

Cloud Computing Challenges and Needs in Higher Education Institutions in Post-COVID-19 Times: A Case of a Japanese Survey

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ABSTRACT Cloud computing has become essential for Higher Education Institutions (HEIs) due to its high availability, scalability, and support for virtual learning environments. The COVID-19 pandemic further accelerated this trend, prompting HEIs to transition their learning environments to the cloud. Consequently, this rapid shift has introduced post-adoption challenges, including security and privacy concerns, compliance, cost management, technical expertise, and the necessity of reliable Internet connectivity. Previous research has primarily focused on frameworks for cloud adoption in HEIs. However, there is a gap in studies addressing post-adoption challenges. Particularly in Japanese higher education, despite high adoption rates, HEIs are still facing institutional and technical difficulties in effectively leveraging cloud benefits. To address this gap, this paper presents an exploratory study conducted in 97 Japanese HEIs through a questionnaire based on the Technology-Organization-Environment (TOE) framework to examine the cloud post-adoption benefits and challenges. The survey assessed nine factors and various institutional attributes. Findings confirmed a high adoption level in Japanese HEIs (99%), with Hybrid Cloud (56%) and Software as a Service (SaaS) (96%) being prevalent. COVID-19 significantly influenced cloud adoption, with 92% of HEIs acknowledging increased awareness and use of cloud technologies, and 70% recognizing that cloud-based apps facilitated more efficient learning. Nonetheless, data security remains a concern, with 55% of HEIs worried about data leakage, unauthorized access, and storing critical information in the cloud. Future initiatives should address reported barriers such as budget management within the Pay-as-you-go model, lack of expertise, and the development of frameworks for continuous cloud operations in HEIs.

INDEX TERMS Cloud computing, higher education institutions, challenges, technology organization environment framework, COVID-19, IT services.

I. INTRODUCTION

The adoption of cloud computing (CC) in higher education institutions (HEIs) has experienced steady growth over the last decade owing to many benefits supported by the multiple cloud services and deployment models. Some of these benefits include high availability, mobility, fast deployment of services and infrastructure, reduction of CAPEX and OPEX in IT hardware and software supported by the Pay-as-you-go model, collaboration, and quality of service [1], [2], [3].

Additionally, this growth was exponentially accelerated during the recent COVID-19 pandemic, when HEIs had to

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migrate most of their services and learning environments to the cloud to maintain the continuity of their educational programs [4], [5], [6]. In this manner, due to the forced transition to virtual and blended learning, many HEIs rapidly adopted cloud platforms and services as a means to deploy virtual classrooms, virtual training laboratories, and required software tools for their students and teachers [7].

This rapid adoption and migration of learning environments to the cloud has introduced new challenges both at the institutional level and individual level of the end-users of the technologies such as teachers and students. Some of these post-adoption challenges are in terms of security concerns and privacy of student data, integration between on-premises systems with cloud systems, data migration and interoperability, vendor lock-in through long-term contracts, cultural resistance to change and perceptions from stakeholders, and technical difficulties such as implementing cloud-based e-learning systems [8], [9], [10], [11], [12]. However, in this context, there is a lack of studies dedicated to exploring and understanding the current benefits and challenges in effectively operating and implementing cloud-based learning environments following the post-adoption stage. To address this gap, this study proposes to survey HEIs in Japan in the current post-COVID-19 era and provide insights confirming their cloud adoption status and the challenges that they are currently facing.

In the particular case of Japan, the focus country in this study, it has been ranked among the top markets for global cloud services since 2016, with vast investments from both public and private sectors for ICT infrastructure and commitment from the government to support the usage of cloud technologies [13]. Since the early 2010s, Japan has been conducting nationwide surveys on CC adoption in HEIs through the Ministry of Education, Culture, Sports, Science and Technology (MEXT) [14]. However, these surveys only focus on basic questions about cloud adoption status and do not consider how other internal or external factors could drive or hinder cloud productivity, thus requiring additional survey efforts to obtain these kinds of statistics. This study aims to address these issues by providing insights that are difficult to find from prior literature and MEXT surveys and by assessing how technological, organizational, environmental, and other institutional profile variables could affect the post-adoption cloud operations of HEIs. In this way, this study contributes to the extension of the current literature on cloud adoption in HEIs by compiling insights from relevant institutions in Japan, including perspectives from both public and private affiliations, and looking at the future direction for HEIs to effectively tackle post-adoption cloud challenges by understanding the critical barriers that should be addressed.

The remainder of this paper is organized as follows: Section II discusses the related work on cloud computing adoption in HEIs, the COVID-19 influence on cloud adoption, and the current cloud adoption situation in Japanese HEIs. Section IV presents the methodology used for the study including the survey implementation and data collection and analysis. All the results are presented in Section V, followed by the discussion highlighting important insights in Section VI. For last, overall conclusions of the study and future work are presented in Section VIII.

II. RELATED WORK

A. RESEARCH ON CLOUD COMPUTING IN HEIs

Early studies on cloud adoption mainly focused on proposals of adoption models, analyzing key factors for efficient adoption, envisioning the use of cloud technologies to improve the quality of education and students' learning outcomes, roadmaps and evaluation frameworks for effective and reliable cloud adoption, and providing guidelines for HEIs to overcome challenges for the implementation and integration of cloud technologies with the main objective of increasing ICT proficiency to facilitate teaching, VLE, and research development [15], [16], [17], [18], [19].

Subsequently, as the use of CC became more common in HE, research interests began to shift to cloud adoption hypotheses and model testing by conducting more relevant analysis methods such as Partial Least Squares (PLS) and Structural Equation Modeling (SEM) [20], [21], [22], [23], [24], [25], Logistic Regression and Principal Component Analysis (PCA) [26], Exploratory Factor Analysis (EFA), and Confirmatory Factor Analysis (CFA) [4], [27], [28].

Similarly, interest in methods to assess CC adoption and acceptance has grown. Diverse frameworks and theoretical models have been proposed to study the factors influencing the adoption of emerging technologies such as the cloud. Some widely used models to this date include the Technology Acceptance Model (TAM) [29], Diffusion of Innovation (DOI) [30], and Technology-Organization-Environment (TOE) [31]. These frameworks consider different variables from multiple domains and behavioral traits to determine how users and institutions accept and adopt new technologies. Each of these frameworks, TAM [20], [28], [32], [33], [34], TOE [25], [35], [36], DOI [37], and mixed approaches integrating various frameworks [38], [39], [40], [41], [42], have been used to study the adoption of CC in HEIs.

However, although the use of CC in higher education started early in the last decade, there have been a scarce number of studies related to cloud adoption factors. An early literature review conducted in 2015 by Ibrahim et al. [43] analyzed 27 papers on the topic of the level of adoption of CC in HEIs, education systems, and institutional motivations for using the cloud. The conclusions from this study indicated a clear gap in the research on CC, where there was an evident lack of empirical studies focusing on the use of CC within HEIs. A more recent systematic literature review by Ali [2] showed that, from 2012 to 2017, only 17 cloud adoption studies were published in the higher education context that considered multiple perspectives for cloud adoption frameworks and socio-technical concerns.

As summarized in various systematic review studies on CC adoption [1], [2], [3], [43], significant factors for cloud adoption are a combination of variables seen in TAM-TOE-DOI models, where Technological Factors (e.g. Security, Compatibility, Complexity, Relative Advantage, and Privacy), Organizational Factors (e.g. Top Management Support, Institutional Size, and the Cloud Expertise of IT Staff), Environmental Factors (e.g. Government Support, Peer Pressure, Regulatory Policies, and Service Provider Support), and additional Personal Factors (e.g. Perceive Ease of Use, Perceived Usefulness, Self-efficacy, and Subjective Norms or Social Pressure) are the common determinant factors in most adoption studies.

From another perspective, the adoption of CC in HEIs also varies by region depending on multiple factors such as the level of technological infrastructure of institutions, funds and budget for cloud fostering, and the awareness of the advantages and affordances of using the cloud for education.

The United States and Canada have been worldwide leaders with a widespread adoption of CC in HEIs. Many institutions have adopted CC since its early stages for multiple applications including IT operations, administrative functions, cloud hosted LMS and VLE, collaborative research, and teacher and student services. Many leading Cloud Service Providers (CSPs) such as Amazon Web Services (AWS), Google Cloud, and Microsoft Azure have their roots and made the first cloud investments in this region, thus providing opportunities for HEIs to be early cloud adopters. Many publications in both countries are related to the study of the factors affecting cloud adoption and user acceptance of cloud technologies [44], [45], [46].

European countries such as the United Kingdom, Germany, and some Nordic nations also have a high level of adoption of CC in HEIs. One of the main projects encouraging the adoption and usage of CC is the European Open Science Cloud (EOSC) [47], with the goal of integrating high-capacity cloud solutions, not only for collaborative research and education but also for public and private industries. Some of the related studies in this region are on the themes of cloud adoption challenges and considerations for business and education, exploration of cloud-oriented E-learning, and lessons learned inside classrooms from using cloud services and distributed storage [48], [49], [50], [51], [52], [53], [54], [55].

Countries in the Middle East, and South and Central Asia are still experiencing substantial growth in CC adoption, as the region's commitment to technological and infrastructure development has driven adoption, particularly for administrative and educational needs in HEIs. India and Saudi Arabia have the highest output in terms of studies related to CC, with a few studies related to determinant factors for adopting cloud E-Learning, Education and Learning as a Service (ELaaS), and case studies on effective usage and deployment models of CC technologies [25], [32], [56], [57], [58]. Other countries such as Iraq, the United Arab Emirates, and Pakistan have also made efforts to understand the factors and issues that hinder the adoption of CC in their HEIs [59], [60], [61].

East Asian countries such as China, South Korea, and Taiwan have recognized the potential of CC since its early stages and have been encouraging its adoption to scale up educational services, especially in remote under-served areas. Other relevant studies are related to the cost of deployment of CC services for HEIs, cloud-based smart education systems and factors for success, the analysis of perspectives and behaviors of students regarding the use of the cloud for learning, and the assessment of students' readiness level in terms of understanding and using 4IR technologies such as the cloud [19], [34], [62], [63], [64], [65].

In Oceania, some countries such as Malaysia, Thailand, Australia, and Indonesia have adopted CC to enhance collaboration and access to learning resources. Studies conducted in these countries are related to determinants and roadmaps for cloud adoption in HEIs, cloud E-Learning, and other relevant topics [17], [33], [35], [66], [67], [68], [69], [70], [71], [72].

Cloud adoption in other regions such as Latin America and Africa varies by country. Despite being considered developing countries, many of them have made significant progress in adopting cloud-based services for education, while others still face significant challenges related to technology and Internet infrastructure, funding, and government support. However, efforts have been made to study the factors impacting CC adoption and using CC to enhance E-Learning capabilities in these regions [42], [73], [74], [75], [76], [77], [78].

The latest research on CC in higher education has focused on its adoption in developing countries, its practical applications in teaching and learning, and the challenges faced by HEIs for continued efficient operations after adoption. Riza et al. [79] conducted a study in Kosovo, assessing CC adoption challenges in security, infrastructure, and performance. Their research evaluated user awareness, perceived benefits of CC, and stakeholder willingness to adopt these technologies. Similarly, Abdelkader et al. [80] applied the TOE framework in Libyan HEIs, identifying technological readiness and complexity as key factors influencing CC adoption, with Internet connectivity and infrastructure as significant barriers.

Kankia et al. [81] developed a Comprehensive Technology Readiness Adoption Model to evaluate Nigerian students' perceptions of CC. They identified factors such as perceived innovation, usefulness, and reliability as critical for adoption. A study by Tom et al. [82] emphasized low CC adoption for e-learning in Nigerian HEIs, pointing out relative advantage, cost reduction, and CSP support as significant factors for adoption. In Bangladesh, Rahman et al. [83] interviewed HEIs stakeholders, revealing that innovation technophobia, complexity, and lack of training hinder CC adoption. Their subsequent study using the UTAUT framework, showed that perceived benefits and social influence positively impact CC adoption, while innovation technophobia and inadequate infrastructure act as barriers [84]. Regarding practical applications, Madhioub et al. [85] proposed a cloud-based learning environment for Tunisian engineering students. Their results indicated that around 40% of students found the platform helpful in improving communication, skills acquisition, and the teaching process.

In terms of continuous CC operations, Xuan et al. [86] conducted a systematic review, emphasizing security, privacy, and compatibility issues as key post-adoption challenges. Qasem et al. [87] analyzed the antecedents of CC adoption in Malaysian HEIs, identifying perceived benefits, technical capabilities, and competitive pressure as influential factors. Muhic et al. [88] examined barriers to the continuance use of CC, highlighting management process issues such as lack of vision and vendor communication. In Asian countries, Chen [89] explored the influence of student beliefs and satisfaction on cloud-based learning platforms in Taiwan, identifying interactivity, course content quality and design as primary drivers for continued use. Sithipolvanichgul et al. [90] also found that performance and effort expectations positively influenced CC adoption in Thailand, while perceived risks such as authentication vulnerabilities negatively affected usage.

B. COVID-19 INFLUENCE ON CLOUD ADOPTION IN HEIs

The awareness and adoption of CC in HEIs have become increasingly important, especially in the context of the COVID-19 pandemic. The recent literature highlights the effects of COVID-19 on cloud adoption and the outcomes of implementing cloud strategies for education.

A bibliometric analysis conducted in 2021 by Samyan and St Flour [7] observed the usage of cloud-based technologies to support E-Learning during COVID-19. In their review, 10 of the analyzed studies focused on the role of COVID-19 in cloud adoption and also reported on the opportunities and challenges of E-learning supported by cloud systems.

Another early study on the impact of COVID-19 on cloud adoption in HEIs was conducted by Madhumitha et al. [5] in 2021, assessing 404 students from various universities across South India. Their paper reported on the awareness and usage of cloud services, cloud applications for collaboration, and factors for adoption. The main findings indicate that, even though most participants were aware of cloud-based apps before the pandemic (84%), around 50% "Strongly Agree" that COVID-19 has increased the use of CC in learning, and another 32% had an "Agree" position on the same statement.

A survey by Agrawal [91] examined the application of CC technologies within HEIs in Taiwan from a COVID-19 perspective, noting the use of cloud rendering, gamification, cloud-based collaborative E-learning, and mobile CC to increase students' learning experience and learning outcomes. However, the author also noted some challenges faced by HEIs, such as data protection, security, and integrity of the cloud; lack of awareness of the benefits and leverage of using CC; lack of confidence from students, teachers, and administrative staff; and lack of redundant and reliable Internet access. Similarly, another study conducted by Dutta et al. [92] with 256 students from HEIs in Taiwan examined the factors predicting the adoption of cloud-based E-learning during COVID-19. Their findings suggest that attitudinal readiness is a critical factor in the adopting of cloud-based E-learning systems, and that self-efficacy and other subjective well-being variables also moderate adoption intentions.

Another study by Bhardwaj et al. [4] surveyed 300 HEIs in India on cloud adoption and the usage of E-learning solutions during the COVID-19 outbreak. Using a TAM-TOE-DOI integrated framework, they determined that competitive advantage, technology compatibility, technology readiness, senior leadership support, government support, and vendor support were the major factors for cloud adoption. However, their results also revealed that security concerns still have a negative impact, restraining HEIs from adopting some cloud solutions. Nonetheless, the COVID-19 outbreak has been an influencing factor for Indian HEIs, encouraging cloud adoption to facilitate E-learning and remote working.

Additionally, looking at critical success factors for CC adoption during COVID-19, a survey was conducted by Too et al. [93] with 362 participants from Kenyan HEIs. The authors followed the International Business Machine (IBM) theoretical model for CC adoption to analyze various hypotheses. Their results suggest that management support, technical support, and user preparedness have significant positive effects on cloud adoption. It was also noted that the government encouraged the use of CC to support remote teaching and learning in public HEIs in the country.

In a similar context, a quantitative research conducted by Al-Sharafi et al. [94] surveyed 200 students from HEIs in Oman with the objective of identifying key factors that influence the acceptance and usage of cloud technologies, with a particular focus on the COVID-19 outbreak. Using the Partial Least Square (PLS) analysis method, their main findings indicate that the perceived ease of use, usefulness, perceived reliability and responsiveness of cloud-based systems are statistically significant for the intention to use cloud technologies. They also shared the situation of Omani HEIs, how they migrated to E-learning and online platforms during COVID-19, the challenges faced during this transition, the importance of support from the public government, and how the cloud has supported and served as an efficient tool for teaching and learning activities.

From the perspective of faculty staff and researchers, a study conducted by Shakor and Surameery [6] with 319 participants from Iraqi HEIs reviewed the impact of COVID-19 on cloud-based environments in HEIs. Their main goal was to analyze how Iraqui HEIs responded to the COVID-19 pandemic in terms of research activities and how cloud-based applications were adopted to support this transition. Their results showed that data security and performance are the main cloud adoption barriers for Iraqui HEIs.

From the perspective of learners, a study by PJ et al. [95] surveyed 360 students using smart devices for online learning through cloud-based platforms during COVID-19. Their findings indicate that smart devices play a critical role in E-learning and that students' perceptions of device usage, connectivity, and period of time using the devices have a statistically significant effect on cloud-based online learning.

Furthermore, a study by Chaveesuk et al. [96] using the TAM framework analyzed data from 373 IT students from five HEIs in Thailand on their intentions to adopt virtual learning systems and cloud-based classrooms. Their proposed model suggests that perceived ease of use, facilitating conditions, and computer self-efficacy factors have a positive impact on students' adoption of cloud-based classrooms.

Another mixed study focused on semi-structured interviews was conducted by Wolfschwenger et al. [97]. In their paper, the authors interviewed 10 participants who played key roles in the educational digitization process in Austrian HEIs, assessing how cloud technologies and ubiquitous technologies supported teaching, learning, pedagogical work, and digital transformation during COVID-19. Conclusions from the interviews emphasize the importance of using cross-device and device-independent resources alongside proper cloud solutions and ubiquitous networks for synergistic effects and improvements in teaching and learning processes.

Implementing a novel approach using an enhanced TAM framework with mediation effects, an empirical study conducted by Sharma et al. [12] investigated how external factors such as COVID-19 influence technology adoption and decision making. In their survey of 867 students from 25 different HEIs from India, they examined how the intent to adopt cloud-based services impacts the actual adoption of the technology in both pre-COVID-19 and post-COVID-19 eras. Their findings highlighted a significant difference in perceived usefulness and perceived ease of use on cloud adoption as a consequence of COVID-19. This novel study also demonstrated the positive influence of COVID-19 on cloud adoption and its relationship with academic performance.

C. CLOUD COMPUTING ADOPTION IN JAPANESE HEIs

As one of the top markets in CC investment [13], Japan has developed a proper regulatory environment for CC through the implementation of many projects for open data flow, privacy protection, and cloud research collaboration such as joining the Asia-Pacific Economic Cooperation (APEC) Cross-Border Privacy Rules (CBPR) framework, the Trans-Pacific Partnership (TPP), and the "Government Cloud" that encourages public institutions to use the latest cloud technologies for building scalable and flexible IT infrastructure [98]. The COVID-19 pandemic has also served as a Digital Transformation catalyst, promoting the use and investments in cloud technologies and artificial intelligence for the public government, private business, and the education sector [99].

There are also projects focused on higher education and academic cloud research, such as the Science Information Network (SINET) [100], a network managed by the National Institute of Informatics (NII) to connect private clouds of HEIs and research institutions, and the "Academic Inter-Cloud Project" [101] run by Hokkaido University alongside other institutions to promote collaborative research and the usage of inter-university private clouds. Similarly, the NII also manages a project known as JAIRO [102], which promotes the use of community cloud services for software repository development, where approximately 625 HEIs are in collaboration. Another relevant project is the NII Research Data Cloud (RDC) [103], where a common cloud infrastructure is proposed for managing and sharing large-scale academic knowledge and research data in open science and other multi-disciplinary domains.

Early efforts to report cloud adoption and usage in Japanese HEIs were conducted by institutions such as MEXT [14]. Yearly reports show that the adoption of CC in HEIs in Japan has grown from 55% in 2012 to a 95% adoption rate in 2022, where hybrid cloud has been the predominant deployment model with the main purpose of implementing IT management infrastructure and educational environments.

Research on CC in Japanese HEIs has mainly focused on adoption effectiveness and applications in educational environments. A study by Yan et al. [104] reviewed CC usage trends and its impact on education and academic research based on previous surveys conducted by MEXT. A pilot by Kajita [105] proposed a cloud teaching and learning environment for HEIs to create flexible collaboration and learning environments through research and practice. A study by Ishizaka et al. [106] analyzed the application of CC in an engineering college and reported the organizational and individual factors that influenced the rejection of CC adoption. An ongoing project known as Edubase Cloud [107] encourages the use of CC platforms for cloud education, where the authors proposed an open-source multi-cloud architecture platform for the education and training of future cloud engineers. A contemporary study by Watanabe et al. [108] proposed an evaluation model for an objective and quantitative assessment of the importance of organizational information security governance for HEIs migrating their IT systems to the cloud.

Some Japanese HEIs have also published their experiences of migrating to and adopting cloud services. Although most of these papers provide relevant literature on cloud adoption, they are usually published in domestic journals or conferences in Japan and are only available in Japanese. Early experiences in using the cloud for e-Learning were reported by the University of Tsukuba [109], where they implemented a cloud infrastructure software known as "Kumoi" to ensure the high availability of an e-Learning system by dynamically controlling virtual resources and applications in response to failures. Another paper by Kanazawa University [110] reported on their Research Data Management (RDM) infrastructure needed for the "Advanced Research Infrastructure Sharing Promotion Project", where they implemented a hybrid storage system integrating external cloud storage services and on-campus storage. In another case, Shizuoka University [111] renewed its entire ICT infrastructure to be fully cloud compatible while emphasizing technical, operational, and procurement changes for proper cloud implementation.

III. RESEARCH GAP AND PURPOSE

In accordance with previous systematic studies on CC adoption [2], [43], although there is a high level of adoption in Japanese institutions, in-depth empirical studies based on formal adoption frameworks are lacking. This study aims to expand the current literature by considering relevant factors that were not part of previous studies, such as COVID-19, and providing new insights by analyzing the relationship between HEI profiles and cloud usage. As a developed country, with an established high level of CC adoption in HEIs, this study is not focused on traditional factor analysis to propose models for cloud adoption, but rather on investigating the challenges and benefits of CC post-adoption. However, the survey was based on the well-known TOE framework as the proposed factors are also applicable to continuous cloud operations.

Additionally, recognizing the critical influence of COVID-19 on CC adoption in HEIs, this factor was also considered in this study as an "Environment" variable inside the TOE framework. In this way, a few questions were formulated to assess the impact of COVID-19 on the use, adoption, and awareness of CC in HEIs, how learning through cloud-based apps made learning easier and more efficient during COVID-19, and if CC technologies have provided proper learning environments for students and teachers during COVID-19.

IV. METHODOLOGY

A. SURVEY

An online cross-sectional survey based on the TOE framework was the methodology applied for this study. This is a theoretical framework that explains technology adoption in organizations and describes how the technological context, organizational context, and environmental context influence the process of adopting and implementing technological innovations [31].

The implemented survey consisted of three sections:

- (S1) Personal information and HEIs demographics.
- (S2) Current adoption status and usage of cloud services at the institutional level.
- (S3) Effects of TOE factors, benefits and barriers of cloud adoption.

In section one (S1), personal information from the respondents, such as age, computing level knowledge, job position, and years of experience were collected. Likewise, institutional profile information such as active IT staff, faculty staff, student population, and institutional age were compiled.

In section two (S2), the current adoption status of cloud technologies, types of cloud services and deployments currently in use, and which critical IT applications (e.g., E-mail, E-Learning Systems, LMS/VLE, file sharing, websites) HEIs are willing to host in the cloud were assessed.

In section three (S3), the survey instrument implemented by Tashkandi and Al-Jabri [25] using the TOE framework to determine CC adoption factors on Saudi Arabian HEIs was adapted and modified in the context of Japanese education. The TOE model was selected for this study because it provides an integrated approach that considers multiple domains to analyze the factors influencing cloud adoption. In their study [25], the suggested TOE model was used to identify the factors and prove the hypotheses for cloud adoption. However, as Japanese HEIs already have a high rate of adoption, the purpose of using the TOE framework is not to develop or confirm the model within Japan, but rather to provide a better understanding of both pre- and post-adoption challenges faced by HEIs and how to effectively continue adopting and managing CC at the institutional level.

TOE factors were evaluated using a five-point Likert scale ranging from "(1) Strongly Disagree" to "(5) Strongly Agree" following earlier references. Descriptions of each factor construct and questionnaire items are summarized in Table 1. Other questions regarding the benefits, barriers, and influence of COVID-19 on the adoption of CC in higher education were adapted from Madhumitha et al. [5] and Shakor and Surameery [6] as well.

Additionally, non-parametric statistical analysis was used to further examine how institutional profile variables such as public or private affiliation, IT staff, teaching staff, student population, and institutional age present any significant difference in terms of the cloud computing level of adoption and the use of IT services in the cloud reported by the HEIs.

B. SURVEY DISTRIBUTION AND DATA ANALYSIS

A total of 278 HEIs were invited to the survey. The selection method was based on: (1) HEIs formally recognized by MEXT [14]; (2) HEIs with undergraduate or graduate programs accredited by MEXT; and (3) HEIs that are members of the National University Corporation of Information Processing Center Council (NIPC) [112] or the Japan Universities Association for Computer Education (JUCE) [113].

The final survey instrument was implemented in Microsoft Forms and distributed online via e-mails. The instrument was validated and translated into Japanese by native speakers. Only one person designated by each institution with the capability to decide whether to adopt or not cloud computing at the institutional level (e.g. Directors or IT Managers) was required to answer the survey. An external call center company was hired to outsource survey distribution and contact tasks. The survey was available for nine months,

TABLE 1. Cloud computing TOE factors description.

TOE Domains	Factors	Item	Description
Technology	Relative Advantage (RA)	RA1	Cloud Computing can shorten Information Systems deployment time.
		RA2	Using Cloud Computing allows us to perform specific tasks more quickly.
	Compatibility (CO)	CO1	Cloud Computing is compatible with our institutional operations
		CO2	Cloud Computing is compatible with our current IT infrastructure
	Complexity (CX)	CX1	Skills needed to implement Cloud Computing are too complex for our institution.
		CX2	Skills needed to use Cloud Computing are too complex for our employees.
		CX3	The use of Cloud Computing is frustrating.
Organization	Management Support (MS)	MS1	Top Management provides resources for adopting Cloud Computing.
		MS2	Top Management supports the implementation and usage of Cloud Computing.
	Vendor Lock-in (VL)	VL1	Cloud Computing mandates the use of specific IT technologies and resources.
		VL2	Cloud Computing makes us dependent on a particular Cloud Service Provider.
	Data Concerns (DC)	DC1	We are concerned about the leakage of confidential data.
		DC2	We are concerned that unauthorized people may access our student and research data.
		DC3	We are concerned about storing our data in the cloud.
Environment	Government Regulation (GR)	GR1	Laws and regulations in my country are sufficient to protect the use of Cloud Computing.
		GR2	Laws and regulations in my country facilitate the use of Cloud Computing.
	Peer Pressure (PP)	PP1	Other HEIs in my country are currently adopting Cloud Computing.
		PP2	Other HEIs in my country will be adopting Cloud Computing in the near future.
	COVID-19 (CV)	CV1	COVID-19 has increased the use and adoption of Cloud Computing in HEIs.
		CV2	COVID-19 has increased the awareness about Cloud Computing in HEIs.
		CV3	Learning through cloud-based apps made learning easier and more efficient during COVID-19.
		CV4	Cloud Computing during COVID-19 provided proper learning environments for students and teachers.

from July 2022 to March 2023, and weekly reminders were sent to encourage participation. All responses were then validated and imported to IBM SPSS V26 software for further statistical analysis.

V. RESULTS

A. DEMOGRAPHICS

Of the 278 contacted HEIs, 98 responded to the survey. One of the responses was deemed invalid and discarded, resulting in a total of 97 valid responses and a 35% response rate. Details of the demographics are presented in Table 2. Responses were balanced between public (45%) and private (55%) HEIs, providing insights from both perspectives. As described later, the adoption rate of CC technologies followed the same trend as in the previous MEXT survey [14]. Therefore, the sample was deemed appropriate for investigating the situation in Japan.

Institutional profiles show that 48% of HEIs have between 10-30 IT staff, 52% have less than 500 teaching staff, 50% are in the range of 5,000-20,000 student population, and 82% were founded more than 50 years ago. Regarding personal profiles, 43% of the answers were from the Head of Departments and 27% of the respondents were also professors.

B. CLOUD COMPUTING ADOPTION STATUS

The findings in Table 3 show that HEIs in Japan have a high level of adoption of CC technologies (99%), where only one institution reported to be currently evaluating the adoption process. These results follow the same trend as the MEXT survey [14], which reported that 94.7% of HEIs are using CC, while the remaining 5.3% have not adopted CC.

The most used CC service was Software-as-a-Service (SaaS), reported by 96% of HEIs, followed by Infrastructure-as-a-Service (IaaS) (48%), and then Platform-as-a-Service (PaaS) (32%). For CC deployment models, approximately 56% of HEIs reported the use of hybrid cloud (combining public and private cloud), while 38% are exclusively using the public cloud, and only a few HEIs are using dedicated private clouds (5%). However, the use of community clouds was only reported by 2 HEIs, indicating that the use of CC for collaborative research is still not high.

Corroborating with the high level of cloud adoption previously reported, Table 4 presents a list of critical IT applications for HEIs, alongside their considerations on whether they have any intentions to host them in the cloud. HEIs reported that for most IT services, except for E-Learning Systems, Academic Record Systems, and Virtual Laboratories, they have already hosted them in the cloud. For clarification, E-Learning Systems do not refer to LMS or VLE; they refer to special online services such as Adobe Captivate and Elucidat.

Most teachers use LMS to create their courses and use E-Learning Systems as additional support services. Consequently, a noticeable 36% of HEIs reported they have not implemented or adopted them, neither on-premises or in the cloud. This suggests that most HEIs recognize that these services do not need to be adopted in urgent situations. Virtual Laboratories are considered the same, and the percentage of those already hosted in the cloud was the lowest (9%). This also accords with the general absence of Asian countries' contributions to research on virtual laboratories in HE, where the United States and some European countries have been the leading contributors for the last decades [114].

However, as the Japanese government encourages the use of digital technologies to adapt to post-COVID-19 educational trends (The Council for the Implementation of Education Rebuilding (2021) [115]), the use of virtual laboratories in the cloud is expected to continue growing, allowing HEIs to leverage cost-effectiveness, accessibility,

TABLE 2. Demographic information (N=97).

Personal Information	Count (%)	Institutional Information	Count (%)
Age		*Institutional Affiliation*	
20-30	1 (1)	National or Public	44 (45)
31-40	7 (7)	Private	53 (55)
41-50	27 (28)		
51-60	50 (52)	*IT Staff Population*	
>60	12 (12)	<10	39 (40)
		10-30	47 (48)
Job Position		30-50	6 (6)
Chancellor / Principal	0 (0)	50-70	2 (2)
Vice Chancellor	3 (3)	70-90	0 (0)
Dean	0 (0)	90-100	0 (0)
Head of Department (Dir. / Mgr.)	42 (43)	100-500	2 (2)
IT Staff	32 (33)	>500	1 (1)
Academic Staff	7 (7)		
Other[1]	13 (13)	*Teaching Staff Population*	
		<500	50 (52)
Also a Professor or Lecturer		500-1,000	25 (26)
Yes	26 (27)	1,000-3,000	18 (19)
No	71 (73)	>3,000	4 (4)
Computing Level Knowledge		*Student Population*	
Beginner	11 (11)	<5000	37 (39)
Intermediate	45 (46)	5000-10,000	30 (31)
Advanced	41 (42)	10,000-20,000	20 (21)
		>20,000	10 (10)
Years in Service			
<=5 years	16 (16)	*Institution Age*	
6-10 years	12 (12)	<=5 years	0 (0)
11-15 years	14 (14)	5-10 years	0 (0)
16-20 years	13 (13)	11-20 years	0 (0)
>20 years	42 (43)	21-50 years	17 (18)
		>50 years	80 (82)

Other[1]: Academic Affairs Manager, Office Worker (x2), Specially Appointed VP for Information, School Information Center Staff, Operations Manager, Professional Staff, Special Assistant to the President (x2), Director of Research Center (x2), Director of Academic Information and Media Center, and Director of IT Infrastructure.

TABLE 3. Cloud computing adoption status (N=97).

Cloud Computing Adoption Status	Total (%)	Breakdown (%)	
		Public	Private
Cloud Computing Level of Adoption[1]			
(A) Not considering	0 (0)	0 (0)	0 (0)
(B) Evaluated, but not planning to adopt	0 (0)	0 (0)	0 (0)
(C) Currently evaluating	1 (1)	0 (0)	1 (1)
(D) Have evaluated and planning to adopt	0 (0)	0 (0)	0 (0)
(E) Have already adopted	96 (99)	44 (45)	52 (54)
Cloud Service Models[2]			
Infrastructure as a Service (IaaS)	47 (48)	21 (22)	26 (27)
Platform as a Service (PaaS)	31 (32)	13 (13)	18 (19)
Software as a Service (SaaS)	93 (96)	43 (44)	50 (52)
Currently under consideration	1 (1)	0 (0)	1 (1)
Cloud Deployment Models[1]			
Public Cloud (Only)	37 (38)	18 (19)	19 (20)
Private Cloud (Only)	5 (5)	3 (3)	2 (2)
Hybrid Cloud (Both Public and Private)	54 (56)	23 (24)	31 (32)
Currently under consideration	1 (1)	0 (0)	1 (1)
Community Cloud (In addition)	2 (2)	1 (1)	1 (1)

[1]Single choice question.
[2]Multi-choice question.

repeatability, and the facilitation of integrating coursework with relevant simulated environments and laboratory experiences.

TABLE 4. IT services hosted in the cloud (N=96)*.

IT Services	A (%)	B (%)	C (%)	N/A (%)
E-Mail	5 (5)	5 (5)	85 (89)	1 (1)
E-Learning Systems	20 (21)	12 (13)	29 (31)	35 (36)
LMS or VLE	20 (21)	12 (13)	63 (66)	1 (1)
Library Systems	21 (22)	12 (13)	62 (65)	1 (1)
University Website or Portal	20 (21)	17 (18)	58 (60)	1 (1)
File Sharing, Backup and Storage	8 (8)	10 (10)	75 (78)	3 (3)
Office Suite	6 (6)	4 (4)	83 (86)	3 (3)
Collaboration	0 (0)	0 (0)	96 (100)	0 (0)
Academic Record Systems	35 (36)	20 (21)	32 (33)	9 (9)
Virtual Laboratories	28 (29)	18 (19)	9 (9)	41 (43)

*Only from HEIs that have already adopted the Cloud "(E)" in Table 3.
(A) = Not Planning to Host in the Cloud.
(B) = Planning for Hosting in the Cloud.
(C) = Already Hosted in the Cloud.

Although the adoption of Academic Record Systems is high (90%), the percentage hosting them in the cloud is lower than that of other services (33%). These systems deal with highly confidential data; thus, HEIs tend to prefer to use on-premises environments. Overall, Collaboration or Conference systems were the applications most hosted in the cloud, reported by 100% of HEIs, followed by E-Mail (89%), Office Suite (86%), and File Sharing and Storage (78%).

TABLE 5. Institutional profile influence on cloud computing adoption (N=96)*.

Cloud Adoption Attributes	Institutional Affiliation			IT Staff			Teaching Staff			Student Population			Institutional Age		
	H	df	p-value	H	df	p-value	H	df	p-value	H	df	p-value	H	df	p-value
Cloud Service Models															
IaaS	0.049	1	0.825	7.625	5	0.178	**11.434**	**3**	**0.010**	6.791	3	0.079	0.495	1	0.482
PaaS	0.277	1	0.598	7.385	5	0.194	**15.081**	**3**	**0.002**	**10.330**	**3**	**0.016**	**3.940**	**1**	**0.047**
SaaS	0.722	1	0.395	2.127	5	0.831	0.301	3	0.960	3.974	3	0.264	0.889	1	0.346
Cloud Deployment Models															
Public	3.193	1	0.074	6.884	5	0.229	5.588	3	0.133	4.454	3	0.216	0.214	1	0.644
Private	1.004	1	0.316	6.572	5	0.254	5.046	3	0.168	4.984	3	0.173	0.130	1	0.719
Hybrid	0.772	1	0.379	9.269	5	0.099	1.351	3	0.717	4.001	3	0.261	0.922	1	0.337
Community	0.014	1	0.905	**23.289**	**5**	**0.000**	0.889	3	0.828	0.907	3	0.824	0.435	1	0.510
IT Services in the Cloud															
E-Mail	3.369	1	0.066	5.587	5	0.348	3.012	3	0.390	1.612	3	0.657	0.027	1	0.869
E-Learning	**5.276**	**1**	**0.022**	5.898	5	0.316	2.404	3	0.493	2.796	3	0.424	3.700	1	0.054
LMS/VLE	**6.238**	**1**	**0.013**	4.084	5	0.537	2.860	3	0.414	7.315	3	0.063	0.214	1	0.644
Library Systems	**12.044**	**1**	**0.001**	9.362	5	0.095	**9.629**	**3**	**0.022**	1.933	3	0.586	0.005	1	0.941
Website / Portal	0.686	1	0.408	2.354	5	0.798	5.599	3	0.133	1.433	3	0.698	0.123	1	0.725
File Sharing / Storage	0.767	1	0.381	2.357	5	0.798	1.151	3	0.765	4.552	3	0.208	0.154	1	0.695
Office Suite	0.352	1	0.553	1.968	5	0.854	2.423	3	0.489	5.020	3	0.170	0.005	1	0.942
Collaboration[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Academic Record System	0.442	1	0.506	3.822	5	0.575	5.106	3	0.164	1.668	3	0.644	0.652	1	0.420
Virtual Laboratories	**4.250**	**1**	**0.039**	7.162	5	0.209	1.673	3	0.643	2.329	3	0.507	0.017	1	0.895

Institutional Profile attributes that presented a significant difference in Cloud Computing Adoption Attributes (Sig p-value <0.05) are highlighted in **bold**.
*Only from HEIs that have already adopted the Cloud "(E)" in Table 3.
[1] Number of observations for each of the empty categories were lower than 2, thus not meeting the required conditions for the analysis.

C. INSTITUTIONAL PROFILE EFFECT ON CLOUD ADOPTION

Statistical non-parametric tests were conducted to assess whether institutional profile variables such as affiliation, IT and teaching staff population, student population, and institutional age have a significant effect on the adoption of a particular cloud service or deployment model, or the IT services that HEIs are willing to host in the cloud. First, the Kruskal-Wallis H test [116] was used to determine if the sample groups originated from the same distribution and if there were significant differences between them. Additionally, the Dunn-Bonferroni post hoc test [117] was conducted to determine the categories within groups that presented significant differences. A summary of the Kruskal-Wallis H test results is presented in Table 5.

Institutional affiliation presented significant differences in IT services hosted in the cloud. The results suggest that E-Learning platforms, LMS and VLE, library systems, and virtual laboratories are influenced by the affiliation of HEIs. Fig. 1 shows that out of the 29 HEIs that use cloud-hosted E-Learning platforms, 72% are private. This number is higher than that of public HEIs, accounting for only 28% of the total. One possible reason could be the cost associated with E-learning platforms licensing models, as private HEIs usually have more flexibility to allocate funding to such projects.

As for LMS and VLE, Fig. 2 shows that private HEIs also had a higher percentage of institutions hosting such services in the cloud (63%) than public HEIs (37%). In addition, public HEIs had a higher percentage of cases not planning to host LMS/VLE services in the cloud in the future (70%) than private HEIs (30%). A similar distribution was observed for the hosting of library systems (Fig. 3). On the other

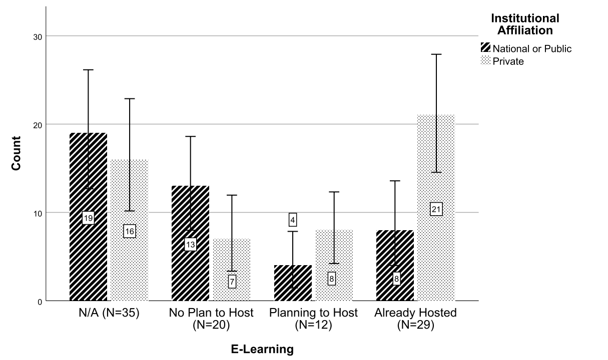

FIGURE 1. Institutional affiliation significance on E-Learning.

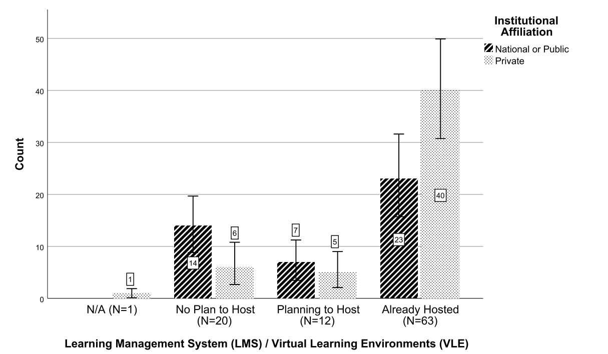

FIGURE 2. Institutional affiliation significance on LMS/VLE.

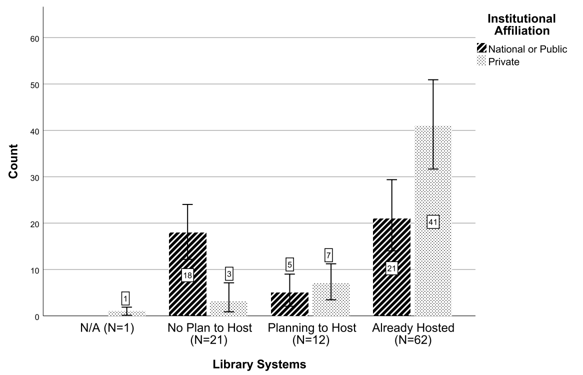

FIGURE 3. Institutional affiliation significance on Library Systems.

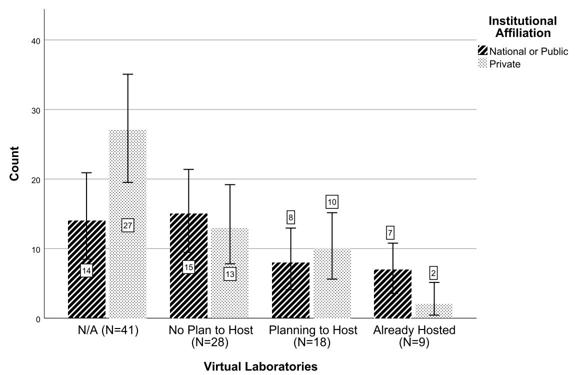

FIGURE 4. Institutional affiliation significance on virtual laboratories.

hand, institutional affiliation showed an opposite influence on virtual laboratories in the cloud. Fig. 4 shows that 78% of HEIs that already have virtual laboratories in the cloud are public, compared to a lower 22% of private institutions.

Institutional age revealed significant differences only in the adoption of PaaS. From the total of HEIs using PaaS services (N=31), %94 are above the 50 years of establishment, while the rest 6% were younger HEIs in the range of 21-50 years. IT staff population only showed a significant difference in community cloud adoption. However, only two HEIs reported the use of community clouds; thus, more data might be needed to determine whether the significance is biased or not. For the sake of reporting, the two corresponding HEIs are in the ranges of 10-30 and 50-70 IT staff population, respectively.

The results from teaching staff population suggest a significant difference in the adoption of IaaS, PaaS, and library systems. In the case of IaaS, HEIs with more than 3,000 teaching staff had a 100% adoption rate, while both middle-range HEIs between 500-1,000 and 1,000-3,000 staff had an average adoption rate of 60%. On the other hand, HEIs with less than 500 teaching staff presented the highest rate of no adoption, with an average of 66%.

In terms of PaaS adoption, HEIs with more than 3,000 teaching staff had a 100% rate of adoption as well. However, middle-range HEIs manifested the opposite behavior compared to IaaS, where the average between both groups showed a 41% rate of adoption, which represents a 20% reduction compared to IaaS. HEIs with less than 500 teaching staff also showed a higher percentage of no adoption with an average of 82%. With regard to library systems, all teaching staff population groups exhibited an average of 73% of hosting this service in the cloud, with the exception of HEIs with a teaching population in the range of 1,000-3,000, which presented a lower hosting rate of 35%.

Dunn-Bonferroni post hoc test was conducted on teaching staff groups to confirm the significant difference among each individual group combination. For the case of IaaS, all results were non significant at the given test size, with all p-values above the 0.05 threshold, considering family-wise error rate. This implies that there is no way to tell if the significance was a result of an actual difference or a random chance in the interaction between the multiple comparisons.

For PaaS, results show that groups of <500 & >3000 were significantly different with a p-value of 0.005 after the post hoc test. In the case of library systems, the significant difference in teaching staff was between groups (<500 & 1,000-3,000) and (500-1,000 & 1,000-3,000) with p-values of 0.047 and 0.020, respectively.

Student population also showed significant differences PaaS adoption. Findings showed that the higher the student population, the higher the adoption rate. This is denoted by HEIs with a student population <5,000 with a only a 19% of adoption when compared to a 70% of HEIs with more than 20,000 students. Subsequent post hoc test only confirmed the significant difference for PaaS adoption, where the groups <5,000 and >20,000 presented a p-value of 0.014.

D. CLOUD COMPUTING ADOPTION FACTORS

Allowing for multiple perspectives of Likert-scale data, a comprehensive descriptive analysis is displayed in Table 6. For every TOE factor for cloud adoption, the mode, mean, standard error, standard deviation, and variance are presented. However, the total score of the mean for each factor was used, in accordance with the previously referenced study [25].

Cronbach's alpha (α) coefficient [118], [119] was used to measure the internal consistency and reliability of the survey instrument. First, Cronbach's alpha was calculated for each factor and their constructs independently. Then, factors below the recommended value for acceptable reliability ($\alpha < 0.6$) were dropped from the survey. This resulted in Complexity (CX), Vendor Lock-in (VL), and Peer Pressure (PP) factors to be dropped and excluded from further analyses. The remaining factors had a Cronbach's alpha value between 0.665 and 0.890. The overall Cronbach's alpha for the survey was ($\alpha = 0.647$), above the minimum recommended ($\alpha = 0.6$) for acceptable internal reliability.

Relative Advantage (RA) was the second highest factor with a mean of 3.902, and a mode of 4 for both constructs, where 73% of responses were between "Agree" and "Strongly Agree". Results suggest that the advantages offered by CC are one of the main reasons for its adoption.

TABLE 6. Cloud computing adoption descriptive analysis (N=97).

Factors Constructs	Cr. α (0.647)	Mode	Mean	Mean Std. Error	Std. Dev	Var
Relative Advantage (RA)	0.745		3.902	0.077	0.759	0.576
RA1		4	3.866	0.093	0.920	0.846
RA2		4	3.938	0.079	0.775	0.600
Compatibility (CO)	0.689		3.675	0.077	0.760	0.578
CO1		4	3.835	0.081	0.799	0.639
CO2		4	3.515	0.095	0.937	0.877
Complexity (CX) (Dropped)	**0.598**		2.873	0.075	0.737	0.543
CX1		3	3.093	0.103	1.011	1.023
CX2		2	2.959	0.099	0.978	0.957
CX3		2	2.567	0.099	0.978	0.956
Mgmt. Support (MS)	0.864		3.217	0.108	1.065	1.135
MS1		3	3.021	0.120	1.181	1.395
MS2		4	3.412	0.110	1.087	1.182
Vendor Lock-in (VL) (Dropped)	**0.332**		3.577	0.074	0.727	0.528
VL1		4	3.619	0.091	0.895	0.801
VL2		4	3.536	0.099	0.980	0.960
Data Concerns (DC)	0.890		3.443	0.107	1.050	1.104
DC1		4	3.691	0.119	1.176	1.383
DC2		4	3.557	0.121	1.190	1.416
DC3		2	3.082	0.113	1.115	1.243
Govt. Regulation (GR)	0.697		2.825	0.069	0.681	0.464
GR1		3	2.814	0.079	0.782	0.611
GR2		3	2.835	0.078	0.773	0.598
Peer Pressure (PP) (Dropped)	**0.173**		4.206	0.055	0.539	0.290
PP1		4	3.959	0.072	0.706	0.498
PP2		5	4.454	0.076	0.750	0.563
COVID-19 (CV)	0.665		4.206	0.054	0.536	0.288
CV1		4	3.979	0.075	0.736	0.541
CV2		5	4.371	0.077	0.754	0.569
CV3		5	4.443	0.072	0.707	0.499
CV4		4	4.031	0.085	0.835	0.697

High availability was the major reported advantage (92%), followed by the outsourcing of development and maintenance (56%), saving costs on IT infrastructure (53%), and the fast provisioning of IT resources (52%).

The Compatibility (CO) factor had a mean of 3.675, and a mode of 4 for both constructs as well. However, responses were closer between "Neutral" (34%) and "Agree" (39%), suggesting that although compatibility is a positive factor in CC adoption, it is not as important as the other relative advantages offered by the cloud. In terms of compatibility, the reduction of migration costs and the avoidance of hardware upgrade hassles were reported by institutions as benefits of adopting the cloud.

Management Support (MS) was considered a neutral factor by most HEIs with a mean of 3.217. On average, answers followed a normal distribution with 30% of HEIs standing on the "Neutral" side. Findings suggest that top management support and resource provisioning play a neutral role in cloud adoption. Budget and resource provisioning issues were the major barriers reported by HEIs (85%). In that sense, a few respondents also indicated that lack of awareness at the institutional level and difficulties in provisioning due to accounting rules and budget execution are noticeable barriers to cloud adoption. This is in contrast with the On-Demand/Pay-as-you-Go model not being seen as a major benefit of adopting the cloud, only voted by 12% of HEIs.

Data Concerns (DC) factor showed a negative effect on CC. With a mean of 3.443, the answers were spread according to the standard deviation (1.050) and variance (1.104). Around 55% of HEIs answered between "Agree" and "Strongly Agree" on having concerns about leakage, unauthorized access, and storing data in the cloud. This was also supported by HEIs reporting governance (49%), confidentiality and trust issues (48%), and lack of access control (37%), as barriers to adoption. Business Continuity Plan (BCP) response in the event of a cloud service failure was also reported.

Government Regulation (GR) had a mean of 2.825. In this context, around 56% of HEIs had a "Neutral" position on whether laws and regulations from the government facilitate the use and adoption of CC, while another 29% of the answers were between "Strongly Disagree" and "Disagree". A possible reason for this neutral position could be that there are no official laws to regulate the procurement of cloud services in the country [120], aside from a few exceptions such as the medical industry.

Overall, the COVID-19 (CV) factor had the highest mean (4.206) and the least standard deviation (0.536) and variance (0.288), indicating a high level of agreement among respondents. Around 92% of HEIs had an "Agree" or "Strongly Agree" position that COVID-19 has increased the awareness and use of CC in the education sector. Similarly, the statement that the increased use of CC due to COVID-19 provides proper learning environments that fulfill the requirements for students and teachers was supported by 90% of HEIs, with responses ranging between "Agree" and "Strongly Agree". However, only 71% of HEIs had an "Agree" or "Strongly Agree" position on the statement that learning through cloud-based applications has made learning easier and more efficient during the COVID-19 pandemic, while another 27% had a "Neutral" position, and a few outliers on the "Disagree" side. Findings indicate that although COVID-19 has increased the use of CC, there is a scattered level of satisfaction with the ease of use for learning and education.

E. CLOUD ADOPTION BENEFITS VS BARRIERS

In this section, the results are contrasted to highlight both the benefits and the barriers of using cloud computing, as reported by HEIs in Table 7.

High Availability (92%) was the most reported benefit of adopting CC. The high percentage of HEIs citing the "Always-on" capabilities as one of the main benefits reflects on the accessibility of cloud services and the preference for redundant and uninterrupted access to computing resources for continuous operations. At the same time, the opportunity to outsource development and maintenance tasks to CSPs was also considered by more than half of the respondents (56%). This offloading of responsibilities can facilitate IT operations and allow HEIs to focus on core educational competencies.

Cost savings on IT infrastructure and the fast provisioning of IT resources were both on the same grounds, as around half of HEIs (52%) reported on these major benefits as well. In this sense, HEIs recognize the cost-saving potential of the cloud through the reduction of CAPEX on hardware and maintenance, and the agility afforded by cloud platforms to rapidly scale up or down in response to changing demands, which are appealing incentives for HEIs aiming to optimize resource allocation.

TABLE 7. Cloud computing adoption benefits vs barriers (N=97).

Description	Total (%)	Breakdown (%)	
		Public	Private
Cloud Computing Adoption Benefits			
High Availability (Always-on)	89 (92)	41 (42)	48 (49)
On-demand / Pay-as-you-go model	12 (12)	4 (4)	8 (8)
Save costs on IT infrastructure	51 (53)	21 (22)	30 (31)
Fast provisioning of IT resources	50 (52)	21 (22)	29 (30)
Outsource development and maintenance	54 (56)	25 (26)	29 (30)
Minimal training on the personnel	12 (12)	4 (4)	8 (8)
Easy access to high-performance computing	19 (20)	9 (9)	10 (10)
None of the above (N/A)	1 (1)	0 (0)	1 (1)
Other benefits[1]	4 (4)	4 (4)	0 (0)
Cloud Computing Adoption Barriers			
Compliance	24 (25)	12 (12)	12 (12)
Lack of expertise	62 (64)	25 (26)	37 (38)
Budget	82 (85)	38 (39)	44 (45)
Governance	48 (49)	15 (15)	33 (34)
Performance	18 (19)	5 (5)	13 (13)
Reliability	18 (19)	5 (5)	13 (13)
Lack of access control	36 (37)	14 (14)	23 (23)
Confidentiality and trust	47 (48)	21 (22)	26 (27)
None of the above (N/A)	2 (2)	1 (1)	1 (1)
Other barriers[2]	6 (6)	6 (6)	0 (0)

Other benefits[1]: (1) Lower labor; (2) No hardware updates hassles; (3) Redundancy; (4) Reduction of migration costs.
Other Barriers[2]: (1) Internal provisioning systems; (2) Lack of awareness; (3) Accounting and budget execution; (4) On-site computing doctrine; (5) Pay-as-you-go model; (6) Business Continuity Plan (BCP) in case of service failure.

On the other hand, financial considerations still play a major role in the decision-making process for cloud adoption, as 85% of HEIs reported budget as the main barrier to shifting to the cloud. In this scenario, HEIs must evaluate the long-term implications of adopting the cloud and prioritize investments and funding to overcome this obstacle.

Another barrier cited by 64% of HEIs was the lack of expertise and training of the staff managing the cloud technologies. This also highlights the importance of allocating appropriate funds for training and talent development to address skill gaps and maximize the benefits of cloud adoption. Additionally, nearly half of HEIs (49%) expressed governance-related issues to cloud adoption, indicating the level of importance of data management authority and the alignment of cloud solutions with organizational policies and standards. Furthermore, confidentiality and trust (48%) and lack of access control (37%) were also noticeable barriers in addressing the importance of robust security measures and the transparency of cloud services to mitigate risks and ensure the safeguarding of confidential data.

VI. DISCUSSION

This study reaffirms the high level of CC adoption in Japanese HEIs (99%), following a similar trendline as reported in previous national surveys [14], with the predominant use of SaaS solutions (96%) in Hybrid Cloud deployments (56%). Overall, compared to the previous study by Tashkandi and Al-Jabri [25], all TOE factors have decreased their effect and inclined more to a neutral position, thus suggesting that, as HEIs have adopted CC over time, the technological advantages of the cloud are becoming widespread, and barriers to adoption are becoming less vigorous.

Despite the high rate of CC adoption, Japanese HEIs still face some barriers to post-adoption, and continuous operations could be constrained by the security risks inherent in the cloud. Approximately 55% of HEIs agreed to having concerns about leakage, unauthorized access, and storing confidential data in the cloud. This was also supported by governance (49%), confidentiality and trust (48%), and lack of access control (37%), which were the most reported barriers after budget (85%) and lack of expertise (64%).

To face budget and expertise issues, HEIs must have a clear vision and strategy towards CC adoption aligned with their business and IT goals. In addition, by having a concrete roadmap divided into small incremental projects, HEIs can start seeing the compound benefits of CC adoption that accumulate over time for greater impact. This could mitigate the initial spending on tight budgets, while effectively tracking fund expenses for cloud operations and staff training. Furthermore, HEIs must leverage the use of automated monitoring and elasticity tools offered by CSPs, such as dynamic resizing and scheduling, to improve cloud cost predictions.

With regard to security and data concerns barriers, the cultural perception that a private or on-site IT infrastructure is more secure than that maintained by CSPs is still a prevailing challenge for Japanese HEIs. As pointed out by one respondent (Table 7), there is a persuasive "on-site computing doctrine" in some HEIs that could be hindering cloud productivity. This could be mitigated by slowly migrating non-critical systems to the public cloud to help build steady security confidence and properly assess the outcomes of these changes. Another possible way to address these issues is to use proposed frameworks for the validation and assurance of architectural requirements from CSPs [121], where constructs such as cloud service flexibility and availability, Service Level Agreement (SLA), data security and privacy, and interoperability standards are assessed. This could lead HEIs to be more aware of the operational and security risks that they face and to devise a robust risk management plan.

Additionally, Japanese institutions could follow recommendations and strategies from recently proposed models on addressing cloud adoption and trust issues and how to effectively migrate to the cloud [122], [123]. In essence, HEIs should be assessing their current IT infrastructure and resources to envision the suitability of cloud adoption in the long term. This needs to be accompanied by strategies and informed decisions from top management and key decision-makers in order to choose the suitable cloud services and deployment models that adjust to their needs and goals, while also minimizing risks and leveraging the benefits of the cloud. Furthermore, this needs to be supported by proper periodic training of all related staff and users, encouraging the awareness and usage of new cloud solutions, and how to effectively integrate them with their current IT infrastructure while easing the implementation processes.

Nonetheless, the COVID-19 pandemic has forced HEIs to migrate to the cloud to maintain their blended learning environments [4], [5], [6], and Japan was no exception. In response to COVID-19 measures, around 90% of Japanese HEIs formally implemented distance education to continue with scheduled classes, as reported by MEXT on their survey on "Response status of universities regarding measures against COVID-19" [124]. As a result, the use of cloud and distance learning tools such as Massive Open Online Courses (MOOC), Interactive Online Courses, LMS/VLE, and Artificial Intelligence (AI) based tools, has experienced substantial growth [125]. This statement was also supported in this study, where COVID-19 (CV) had the highest overall mean (4.206) among all factors, and around 94% of HEIs agreed that COVID-19 has increased the awareness of CC in education. Primarily, there was a high score (4.443) on the statement that learning through cloud-based applications has made learning easier and more efficient during COVID-19; the results show that most universities recognized the effectiveness of CC in providing proper learning environments for students and teachers during COVID-19.

After 2022, universities in Japan have gradually returned to face-to-face classes. At the same time, the Council for the Implementation of Education Rebuilding in Japan has put together its 12th proposal, which pertains to what new ways of learning in the post-COVID-19 era should be like [115]. In this proposal, they recommended the importance of realizing education by utilizing the advantages of both online and face-to-face lectures. Cloud technologies should be the primary key to developing new educational models blending online and in-person formats. HEIs should also recognize and address possible limitations and barriers in properly using the cloud for successful implementations of E-Learning environments [126]. In this sense, various barriers such as belief and attitudes of students and teachers, management and operations of E-learning environments, pedagogical strategies for teaching and learning, and ethical concerns should be taken into consideration.

VII. STUDY LIMITATIONS

The results reported in this study should be considered in the light of some limitations. First, as a voluntary survey, many invited HEIs refrained from participating, resulting in a sample size of only 97 institutions. However, the sample size had an acceptable representation of 35% of all HEIs in the country, covering answers from major national and private universities, and showing adoption level insights are homogeneous with the surveys reported by the Ministry of Education in Japan [14].

This survey only focused on institutional-level insights. Other surveys including perceptions and practical experiences from both teachers and students could provide relevant insights in terms of the benefits and barriers related to cloud-based learning environments. Other considerations are regarding the use of the TOE framework for this study. While this framework is useful for understanding the adoption of new technologies in organizations, it has limitations in incorporating individual elements such as attitudes, perceptions, and personal motivations to use the technologies, which are crucial in technology adoption and continuous usage. Additionally, it does not account for cultural differences that might influence technology adoption in different countries or regions. In this sense, outcomes and insight from this study particular to Japanese HEIs might not be directly translated or applicable to other countries. To address these limitations, it is necessary to use the TOE framework alongside other models that consider individual behaviors, cultural differences, and the changes in technology adoption processes.

VIII. CONCLUSION AND FUTURE WORK

A TOE-based online survey was conducted in 97 Japanese HEIs on the topic of cloud computing post-adoption benefits and challenges. Although previous literature has reported on the adoption status of CC in HEIs [14], [104], to our knowledge, this is the first in-depth exploratory study integrating a questionnaire based on the TOE framework in the country, aiming to explain the continuous effects of technological, organizational, and environmental factors on the post-adoption stage and usage of cloud services in higher education.

Overall, COVID-19 was the most influential factor affecting CC awareness and usage. However, HEIs still face some challenges in terms of data concerns factors and budget execution within the Pay-as-you-Go model of the cloud. Hopefully, the findings from this study will serve as future guidance for both CSP and IT decision-makers for continuous cloud adoption in HEIs in Japan and other countries. Future studies could focus on periodic surveys to analyze factor changes and identify effective strategies to tackle the cloud barriers and post-adoption challenges reported in this study.

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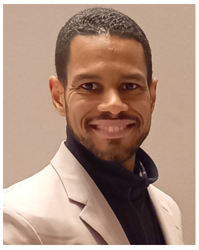

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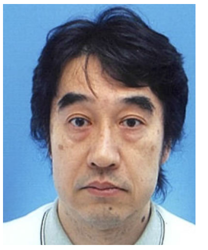

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