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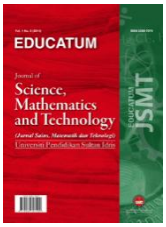
A Systematic Review of Virtual Desktop Infrastructure (VDI) Implementation for Smart Campus in Higher Education Institutions



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Abstract
The use of digital technologies has led to the advancement of higher education institutions to establish smart campuses in a bid to improve the efficiency of the institutions and the quality of education. VDI has become a popular choice as it provides central processing, flexibility, and enhanced access. However, the implementation of this technology in higher education has several challenges that need to be understood with the help of enablers, barriers, and impacts. This paper will give a comprehensive understanding it as a solution for smart campuses in higher education with the focus on the factors that affect success, the problems encountered and the consequences on teaching and learning. The study has the following objectives: The first is to determine the major factors that enhance the chances of successful its adoption in smart campuses. The second objective is to explore the problems that institutions go through during its implementation. The third objective is to assess its effect on the quality of teaching and learning experiences in higher education. The research design that is used in this paper is a systematic review and the articles used in this study are peer-reviewed articles, conference and papers. The criteria for inclusion of the studies were based on the requirement that the studies related to technology in the higher education system and how it integrates with the smart campus. Key factors influencing that influencing its adoption and challenges Some of the challenges associated with including high capital expenditure, security risk and user resistance to change. This study confirms that VDI is one of the key technologies that can be used to achieve the smart campus and sustainability in learning and teaching. Although it has the potential to revolutionize higher education and improve learning and teaching experiences, its implementation also poses several challenges that needs to be addressed such as planning, stakeholder involvement, infrastructure and cybersecurity. Based on the findings of this study, it is recommended that higher education institutions should adopt a staged approach in the implementation of this technology and this should be done in conjunction with other smart campus solutions.

Keywords Digital Transformation in Education; Education Digitalization; Higher Education; Smart Campus; Virtual Desktop Infrastructure (VDI)

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INTRODUCTION

The process of digital evolution has revolutionized the education system, putting pressure on higher learning institutions to change. In the smart campuses which have been adopted by many institutions to enhance the delivery of teaching, learning, and administration using technology, VDI has been identified as a viable solution. Through the centralization of desktop management and providing easy access to educational resources, this technology has the capability of addressing the digital divides, improving on collaboration and supporting the blended learning models [1]. Nevertheless, the integration of this technology in higher education is a challenging process that is associated with several technical, financial, and organizational issues.

Today's students require a digital learning environment that is more flexible, easier to access and more environmentally friendly. Higher education institutions are challenged to ensure the effective provision of remote learning environment. The COVID-19 pandemic has accelerated this challenge and highlighted the importance of remote learning the scattered character of these investigations raises numerous questions: What are the factors which facilitate the successful implementation of VDI in higher education? What limitations need to be addressed to enhance the utilization of VDI? And how does VDI enhance the teaching and learning process in the smart campus concept?

This knowledge gap shows that there is a need to perform a systematic review to compile the findings and assist management of higher learning institutions who are planning to adopt this technology. As smart campuses develop rapidly, the application of Virtual Reality (VR) technology is becoming more common in the educational field. As for virtualization technology, it is widely used in higher education institutions to deal with the challenges of resources scalability and sustainability [4]. There is no research found in the literature that examines in detail the challenges and impacts that occur after adopting the VR technology. Current studies focus on network issues, such as required bandwidth, server capacity and ability to handle many users, as well as user experience and cost-effectiveness [5]. Nevertheless, the scattered character of these investigations raises numerous questions: What are the factors which facilitate the successful implementation of VDI in higher education? What limitations need to be Today's students require a digital learning environment that is more flexible, easier to access and more environmentally friendly. Higher education institutions are challenged to ensure the effective provision of remote learning environment. The COVID-19 pandemic has accelerated this challenge and highlighted the importance of remote learning environment [2].

This paper aims to investigate the adoption of VDI technology in higher education institutions and to identify the barriers it encounters. This technology can provide a remote centralized server to reduce the need for local hardware and allow students to access virtual desktops from various devices. The technology has advantages in terms of increasing working efficiency, optimizing resources, protecting data, and protecting the environment [3]. However, higher education institutions are still facing many challenges, such as high infrastructure costs, data breaches and student resistance to change. Therefore, it is necessary to investigate the barriers to VDI adoption and the impact on students' learning outcomes.

METHODOLOGY

This study adopted a systematic literature review approach to investigate the impact of campus technology and data-driven decision-making on management sustainability in higher education institutions. The main objective of this study is to synopsize the current state of research on smart campus practices and its impact on enhancing the administrative efficiency and management sustainability of higher education institutions. Based on the PRISMA methodology [6], this study designed and executed the research approach and procedures for the systematic literature review. IEEE Xplore, SpringerLink and ScienceDirect databases were searched for publications. These sources were chosen because they are repositories of scholarly articles from many different engineering, computer science, and digital technology fields.

From the searched databases, the relevant studies were selected based on the inclusion criteria that were derived from the keywords of smart campus, campus technologies, higher education, sustainability and data-driven decision-making. There were many repeated citations because of the search results. Hence, the figure shows the process of filtering out the repeated citations. Once the repeated studies were filtered out, the process proceeded with the title and abstract screening to ensure that the studies selected were relevant to the scope of the systematic review. The studies that did not seem to be related to higher education, campus technologies and sustainability in management were excluded. The relevant studies for this research were chosen from the literature review based on whether they were related to higher education, smart campus applications and sufficient information about the technology used, administrative efficiency and sustainability of higher education institutions. Those that were eligible based on the first level screening were assessed in the eligibility stage through a full text assessment. The Joanna Briggs Institute (JBI) Critical Appraisal Tools [7] were used to assess the methodological quality and reliability of the included studies to ensure validity of the final review.

Based on the literature analysis above, the studies included in this systematic review referred to the appropriate research design, and thus, the inclusion and exclusion criteria were based on the PRISMA checklist to screen, evaluate and include the relevant studies. In addition, the JBI Critical Appraisal Tools were used to evaluate the quality and reliability of the included studies. Please refer to Figure 1 for the flow diagram of the study selection process shown in this systematic review.

RESULTS

Guided by the three research questions established in the Introduction, this section presents the main findings derived from the reviewed studies. For clarity, the results are discussed under three interrelated areas, namely the factors facilitating the successful implementation of VDI in higher education, the limitations requiring further attention to improve its utilization, and the role of this technology in enhancing the teaching and learning process within the smart campus concept.

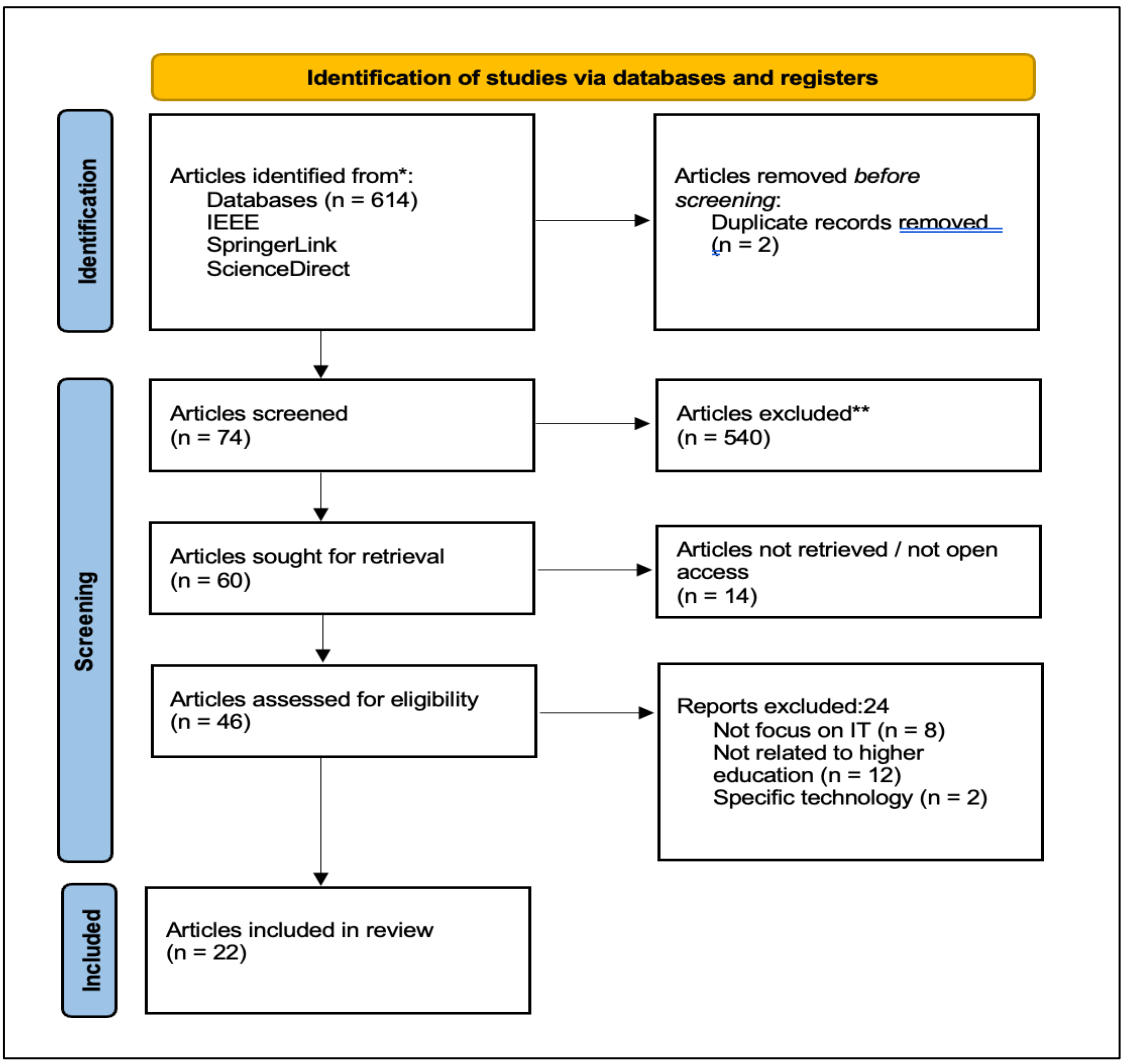

Figure 1 Analysis Selection Chart

Key Factors Influencing the Successful Implementation of VDI in Higher Education. From a technology perspective, network infrastructure and system capacity are key. A school with a robust network infrastructure and sufficient server capacity will gain the most from VDI implementations. In general, schools with good network infrastructures and high-performance servers will provide latency-free access to the environments and are able to manage the dynamic workload fluctuations that come with the new hybrid and remote learning models [8]. Multi-factor authentication and encryption are other critical components that need to be implemented to ensure the security of the data and thus also the safety of users.

User readiness is one of the variables that will influence the success of a VDI deployment. It is important to train and educate the faculty, staff and students to manage possible opposition to this technology and to address their low level of digital literacy. In fact, it is necessary to train users on the benefits of it, such as accessibility and resource management, to ensure a good level of acceptance for the technology [9]. It is also very important to involve end users in the planning activities and to consider their feedback when designing it, to increase user satisfaction and productivity.

Challenges in Implementing VDI in Higher Education

As we have already discussed the initial high costs of e-Learning, it is important to remember that the infrastructure required for e-Learning is also expensive, with the costs associated with servers, storage and networking equipment not making life any easier for the cash-strapped institutions that have to continue to spend money on maintenance and upgrade infrastructure[10]. For community colleges and for emerging markets this too will be a major source of worry as they will have to try and secure some form of funding for the technology required for e-Learning.

Another challenge that is encountered is cultural resistance within the institutions. This is because faculty and staff who are used to traditional IT setup may tend to oppose the use it due to perceived difficulties that it may cause or fears that it may disrupt their work [11]. These issues must be handled by the institutions by providing the right training and information to ease the transition.

Impact of VDI on Teaching and Learning

The most significant benefit that it offers the possibility to connect to educational material at any time and from any location. It also allows the students to connect to virtual desktops with all the necessary software and tools installed, independent of the device they are using. This flexibility is especially useful for the nontraditional students and those who are enrolled in both traditional and online courses. For example, virtual labs make it possible for students to utilize software such as those used in engineering or data management classes without having to invest in costly personal equipment.

This is where it comes in as it creates shared virtual desktops thus promoting collaborative learning environments. Group projects and student interactions are improved where students can all be in the same page literally. The features are in line with the constructivist theory of social learning and interaction and hence support enhanced engagement with the learning content [12]. Nevertheless, VDI's effects are influenced by the availability of devices and a stable internet connection. This means that students in areas of poverty or with no access to devices are left out, therefore underlining the need for policies that seek to address the inequalities in access.

DISCUSSION

Based on the research questions set for this study, this chapter delves deeper into the findings of the literature review. This chapter explores three main issues, namely, the factors that support VDI success in higher education institutions, the challenges that may hinder the achievement of its success, and its effect on teaching and learning in the smart campus context.

RQ1: What are the key factors influencing the successful implementation of VDI in smart campuses within higher education?

The study established that VDI implementation in higher education institutions is determined by the level of technological, institutional and users' readiness. The study revealed that

having reliable network connectivity, sufficient server capacity, strong virtual desktop controls among other issues affected its performance in higher education institutions [14]. The studies supported the assertion that VDI cannot be implemented in higher education institutions without sufficient infrastructure to support it and without ongoing maintenance [15]. Therefore, higher education institutions that heavily depend on applications, data and learning resources that are always "on", it cannot be efficiently implemented without sufficient infrastructure and ongoing maintenance.

VDI technology is characterized by several advanced features that enable users to work more productively, and it can significantly increase the productivity of users in the digital age [16]. However, its successful implementation is not solely based on technology. Other institutional factors such as leadership, budget, policies, processes and change management should be considered. In line with the literature, the implementation of VDI will be more successful when there are strong institutional leadership and sufficient investment in infrastructure and staff training [17]. In other words, it should not be seen as a technological tool, but as a new working model that transforms institutions into digital organizations and smart campuses.

User readiness, training, interface design, level of technical support given to users are some of the other factors mentioned in the literature as affecting the level of acceptance of technology by students, staff and management. Where users feel competent to use the technology and are adequately supported during the changeover period the level of resistance to change will be low and the users will be more confident [18]. Where there are little training and little communication with users, even with a technically competent system, the rate of take up will be low. It is the people aspect of the implementation of technology that must not be ignored.

The results collectively indicate that VDI implementation in higher education is a complex function of technology, information and people factors. Hence, to implement successfully in higher education, a university should blend technology planning with effective stakeholder management and staff development activities.

RQ2: What are the challenges in implementing VDI in higher education?

Most literature highlights many challenges that must be overcome to ensure it become a viable desktop technology for universities and colleges. One of the most cited is cost [19]. While the initial capital outlay for this technology can be enormous (including servers, storage, networking and application and desktop software licenses, as well as integration costs) it is then not always clear what actual benefits are gained from this investment. Such institutions are already under pressure to reduce costs in their organizations, and such a large capital investment may be difficult to justify in such environments even though academic literature suggests it should be a viable option for universities, which are typically better resourced.

It's also worth highlighting that several of the papers we reviewed this month touch about cybersecurity [20]. Centralizing users and workstations with VDI can leave the door wide open for an attacker to push through in the event of a vulnerability being discovered. Some studies indicate however, that with the use of encryption, multi-factor authentication and continuous monitoring, that the centralized structure will aid in the management, consistency and control of the environment. Again however, centralizing users and workstations to a VDI environment can

also leave an organization's environment in a worst-case scenario if the infrastructure is not properly maintained [21]. VDI security is dependent on more than just initial infrastructure and architectural design. Furthermore, ongoing maintenance, patching, governance and disaster preparedness and response also play a role.

This review also points to cultural and organizational resistance as a factor [22]. There will be many faculty and staff members who will be opposed to VDI based on perceived difficulties with respect to complexity, rigidity and general inconvenience. Users may object it on the grounds of poor usability, poor application performance and limited flexibility and it is likely that it will fail to meet faculty and staff needs if they are not given the opportunity to try out the technology in a fully supported environment prior to its official launch [23]. The resistance to VDI is unlikely to be a simple attitude to change, but a more practical response to the change brought to their work environment.

Moving VDI from the proof-of-concept phase to the problem-solving phase will require a multi-phase rollout strategy. Many recent reviews of this technology implementations indicate that a staged approach that includes a pilot with user training and vendor engagement to test the concept, to identify its strengths and weaknesses and to achieve institutional readiness before moving to a full-scale rollout is a recommended strategy [24]. In addition to helping to ease budget pressures a staged rollout may also alleviate some of the costs associated with vendor engagement or aid programs. Good governance and change management practices should also be maintained to ensure that the initial successes of VDI can be built upon. The challenges to the adoption of this technology as a suitable alternative to desktops and laptops are not a series of discrete problems, but are a complex set of interrelated technical, financial and social challenges.

RQ3: How does the adoption of VDI impact teaching and learning in higher education?

VDI can help improve the learning and teaching experience in higher education through more flexible, accessible and collaborative digital learning environments. Some of the benefits of this technology that are widely recognized include accessibilities on any device; students and staff can work from any location, on any device, at any time. Many institutions are now delivering a mix of on and off campus learning, which has created a new priority around continuity of access to critical systems and applications [16]. With VDI, students can access the same virtual learning environment from any location either on or off campus which giving them a more consistent and better-quality learning experience.

Another advantage mentioned in the literature is the students' easier access to applications and academic software [16]. In the conventional environment, students generally must depend on computer laboratories or school hardware to use high-performance applications. On the other hand, it enables students to use applications from a central virtual environment. Therefore, students will have easier access to specialized applications in curriculum subjects that require the use of technical software, simulations, design tools, programming environments etc. It also increases students' access to academic resources and therefore students can benefit from academic resources from any location at any time, whether they are physically available or not [25].

This review also suggests that VDI could be used for collaborative learning and for teaching more efficiently. Students could share workspaces to work together on projects, access common

documents and resources and to enable real time access to activities across all devices [26]. It can improve the efficiency of the teaching and learning process through the quicker deployment of applications for teachers and faster setup of a student's workspace and through better management of access to learning resources and behaviors. Students cannot really benefit from VDI when they have bad internet, bad equipment or not enough digital learning materials. If there is a big digital gap in terms of internet access, hardware and digital learning resources, VDI is not going to reduce the inequalities, but even sustain them [27]. So, this technology can be an instrument to ensure access to and continuity of learning, while at the same time sustaining inequalities in the digital sphere.

In general, the VDI implementation is believed to have positive effects on learning and teaching in higher education. It provides better access to learning materials, more flexible learning, and more efficient distribution of digital learning materials. However, educational effect of VDI is only a part of learning environment and the socio-technical conditions of educational institutions, hence, it is one of the measures for making educational institutions more inclusive and sustainable for smart learning environments.

CONCLUSION

VDI can be adopted in a smart campus after having the necessary infrastructure in place and after approval from the institutions. While it has enabled remote access, flexibility in learning and collaborative features, the cost of this technology is very high and is also a security risk which is a major challenge that institutions are facing. With proper planning, incremental rollout and staff and students' education, it is possible to mitigate these challenges. It can be adopted by institutions to achieve smart learning that ultimately results in better learning and teaching experiences that also achieves the objectives of smart campus in creating inclusive and flexible learning spaces.

The study has several limitations. First, the results of the study cannot be generalized to other higher education institutions due to the heterogeneity of higher education institutions with respect to size and technology readiness and institutional priorities. The factors and challenges that emerge in this study may not be the same for other institutions. Future studies should use primary data to examine in more detail the factors influencing student use and sociocultural factors as well as using a longitudinal design to investigate the longer-term impacts of introducing an e-portfolio technology into a higher education environment.

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AUTHOR CONTRIBUTIONS

Mohd Rashid: Writing—draft the original, conceptualized the study, developed the research framework, designed the methodology, data collection, data cleaning, conducted data analysis, prepared figures and tables, and drafted the manuscript. **Jasni Zain**: Writing—performed statistical analysis, contributed to the manuscript literature review, validation and provided

expertise support; while **Ariff Ameedeen**: Writing—interpreted results, discussion the manuscript, and validation. All authors reviewed, and edited this final approved manuscript.

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DATA AVAILABILITY

The dataset used for this research paper could be provided upon reasonable request from the corresponding author.

DECLARATIONS

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

None

CONSENT TO PUBLICATION

In this paper, the results/data/figures/tables have not previously been published, or are not under consideration for publication elsewhere.

COMPETING INTERESTS

The authors declare no competing interest

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