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The Practicality of Virtual Reality Applications in Education: Limitations and Recommendations

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Abstract: The use of virtual reality applications has grown tremendously in recent years. Virtual reality applications in the education domain have many benefits: they engage students, arouse students' curiosity, ease the communication of information, and motivate the students to improve their learning and performance. Despite literature showing that there has been a clear development in the education domain that shows improvement in students' learning skills, its application in Higher Education Institutions (HEIs) is limited to certain courses and fields. Furthermore, there has also been under-utilization and misutilization of virtual reality applications. Thus, the primary research question in this paper would be what the issues of the practicality of virtual reality applications for HEIs are. This paper aims to look at practicality issues to understand why VR is underutilized, particularly in HEIs. A review of the literature based on seventeen papers published between 2010 and 2020 taken from databases such as Science Direct, Ebscohost, and Scopus has found that despite the positive continuous intention to use VR applications, there are many issues regarding their practicality, such as the affordability of VR application tools, the technology-savviness of instructors, as well as the sustainability of VR use. This paper is significant as it explored and identified the practical issues of why VR applications are underused and provides practical suggestions to overcome these issues of practicality. It is hoped that HEIs would not allow these limitations to hinder the use of VR applications so that the students of this era, who are digital natives, would learn and perform better with VR applications; thus, making the use of VR applications in HEIs more widespread.

Keywords: virtual reality, higher education, learning environment, student performance.

虚拟现实应用在教育中的实用性：局限性和建议

摘要：近年来，虚拟现实应用程序的使用增长迅猛。虚拟现实在教育领域的应用有很多好处：它们吸引学生，激发学生的好奇心，简化信息交流，激励学生提高学习和表现。尽管有文献表明教育领域出现了明显的发展，表明学生的学习技能有所提高，但其在高等教育机构 (高等教育机构) 中的应用仅限于某些课程和领域。此外，还存在虚拟现实应用程序未充分利用和误用的情况。因此，本文的主要研究问题是高校虚拟现实应用的实用性问题。本文旨在研究实用性问题，以了解虚拟现实未被充分利用的原因，尤其是在高等教育机构中。基于 2010 年至 2020 年间发表的 17 篇论文的文献综述，这些论文取自科学直通车、埃布斯科主持人和斯科普斯等数据库，发现尽管使用虚拟现实应用程序的积极持续意图，但在实用性方面存在许多问题，例如虚拟现实应用工具的可负担性、讲师的技术水平以及虚拟现实使用的可持续性。这篇论文具有重要意

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义，因为它探索和确定了虚拟现实应用程序未被充分利用的实际问题，并提供了克服这些实用性问题的实用建议。希望高校不要让这些限制阻碍虚拟现实应用的使用，让这个时代的数字原住民学生更好地学习虚拟现实应用；因此，使得虚拟现实应用在高校中的使用更加广泛。

关键词：虚拟现实、高等教育、学习环境、学生表现。

1. Introduction

Virtual Reality (VR) stands for the practice of computer machinery to create real-world properties and scenarios artificially [23], [24]. Virtual reality applications are computer applications that allow users to experience 3D sound and visual stimulation. According to Checa and Bustillo [25], virtual reality applications allow users to be engrossed in the 3D world, in which they interact with virtual objects and take part in exploring the virtual environment. Virtual reality applications have grown tremendously in almost all domains and thus have shown a remarkable impact on various sectors like Learning, Teaching, Attitude, Marketing, Engineering and Robotics, Entertainment, Clinical Treatments and Health, Heritage and Archeology, Industrial Protection, Community Skills [25].

This paper seeks to focus on why the application of VR is underutilized in the educational field. VR has many applications within the field of education that create new opportunities, increase participation, and enhance student learning, particularly in higher education institutions [24]. Likewise, according to Fernandez, Rio, Cecchini, Méndez, Mendez, and Prieto [26], in higher education institutions, VR is primarily to increase the level of student motivation, participation, understanding, and confidence in learning [27]. The recent trends of VR applications in education have also shown that they have become a means to enable students to acquire information. Through the applications, students can build their knowledge [26].

Cherif [28] reported that in the United States, 370,000 learners had been said to fail out of institutions each academic year due to several factors such as lack of motivation that influences study habits, instruction, academic preparation, external factors, and attitudes. These students were not fond of the traditional mode of teaching and learning methods alone [28]. Thus, the learning environment has to be enriched with the efficient utilization of technology [29], [44]. Therefore, to upgrade the quality of education, there is a need to activate VR usage [30]. For developing this technology and utilizing it successfully, there needs to be proper training provided for both teachers and students [13], [29], [31].

VR applications not only enhance the professional development of the teacher's experience, but they would also stimulate students' curiosity and attract their participation through effective simulations and innovations and the new environments [5], [31], [32]. Winn [31] reported that the reasons for the continuous intention of using VR applications as advanced technology are the same as the reasons why learners liked using the two-dimensional (2D) program used when technology-enhanced learning was initially introduced. These reasons can be considered as important factors that lead to the acceptance and use of VR applications.

Constructivism plays a crucial role in the development of educational applications. The employment of VR applications stretches the students' opportunities exclusively to build and enhance knowledge [1], [5]. VR environments enable students to create a model that simulates reality, and they also provide students the familiarity in creating such environments [27], [32]. In addition, VR applications provide three-dimensional (3D) perceptions into the organizations and behaviors of any chosen system. Students can thereby learn the principles and theories of the systems in a quicker, effective, and enjoyable way by interacting with and traversing through the environments created for such systems [27]. Yet, the use of VR applications is still limited.

This paper is organized into several sections. It first begins with the background of the study, followed by a literature review collected from several open-access databases. A summary of selected papers is represented in a table that illustrates issues, VR applications used, contributions, and the limitations of the VR applications. Looking at the practicality issues of VR applications, recommendations on how VR applications can be applied are proposed in hopes that the use of VR applications will become more widespread in HEIs.

2. Literature Review

In this section, different studies conducted in different fields in education such as engineering, physics, neuropsychology were reviewed and analyzed based on VR applications for teaching and learning purposes. These were then summarised in Table 1.

According to Hu-Au and Lee [4] in their paper titled "Virtual Reality in education: a tool for learning in the Experience age", the use of VR for education purposes and the effect of this technology on the educational process shows the shift from the information age to the Experience age [4]. This is due to the prevalent online presence where 92% of teens are reported to be online every day to play games, live-stream their memorable experiences, share ephemeral moments on Snapchat, or post pictures on Instagram [4].

Thus, in the education domain, many HEIs are using new forms of advanced technology, mostly integrated into collaborative networks and other more complex forms to provide students experiential learning [30], [33]. Experiential learning has more advantages in terms of merging many approaches in which VR applications can be exploited to magnify students' learning evolution. One study that illustrates how VR was exploited to maximize learning is the study by Albert et al. [18], [19], conducted in the neuropsychology field titled "Analysis of assets for virtual reality applications in neuropsychology". The said study focused on specifying the assets that are available with VR for neuropsychological applications. The study used the VR system as a model to analyze the impact of the clinical test and the self-image to optimize the patient's feedback with selected cases. The results prove VR to be a successful option for clinical assessment and retraining [18], [19], [33].

There are many features related to virtual reality that provide the experiential element in the learning process, such as interactive learning environments, visual learning, learning by doing, Head Mounted Display (HMD) devices, the ease and flexibility of VR use; all of which make learning memorable with the VR applications. Furthermore, various learning activities are offered to students who take courses with VR applications. The interaction with these activities in the learning environment is a vital element directly tangible to student performance [1], [5].

Moreover, VR applications have also given a significant opportunity for people with disabilities who do not have the linguistic or physical ability to experience real-world events. Sometimes a VR application becomes a requisite to make the system tangible and prevent mistakes that may occur in the practice of the existing system, causing impairment, thereby leading to unintended financial losses. Thus, VR applications become mandatory for teaching and providing training by introducing a real system prototype [3], [23], [34].

Al Musawi et al. [1] reported the effectiveness of 3-D Lab on Omani students' achievement in terms of knowledge, application, and metacognitive abilities in science. For making the learning process easier, the degree students were required to build a model using VR technology. Using 3-D Lab also made learning safer for these students because it prevents accidents from happening. Otherwise, the students would be handling dangerous laboratory materials. Through experimental methods, the findings revealed that the use of 3-D Lab improved students' interest significantly, which led to the improvement in their achievement [1]. These findings are in line with the study of Capatina et al. [5], whose results show that VR tools increased learner engagement (72% of respondents), allowed a wider market segment, and enhanced students' interest through e-learning models [5].

Apart from Science students, VR applications have also improved students' achievements in engineering education due to the enhanced learning environment [3]. Alhalabi [3], who examined the effects of different teaching approaches to assess the students' learning outcomes and their feedback, found that the VR system improved students' achievements.

Thus, the important goal of using virtual reality as an educational tool is that it appeals to the needs of students, particularly youth [4], being digital natives. VR applications are especially valuable because they support students' imagination and even 'disturbing paradigms' [4] and provide them opportunities to use their capabilities through constructivist learning and authentic situations in the interactive learning environment. VR applications also very much build the personality of the students as they react viscerally to the experiences, which are vital in forming memories, thus making them better learners [10].

In their research, Dima et al. [10] focused on the behavior intention of animation usage among universities to increase student engagement. The whole animation model was done using graphical visual animation learning in their program application to make a simple vision for students. The results obtained from sampling and questionnaire administration revealed the influence of effort expectancy and students' performance [10]. Furthermore, the graphical visual animation learning application was found to increase imagination and communication abilities amongst learners.

Levac [2] introduced an improved intervention system. This study in the medical field highlighted some factors that could impact rehabilitation, such as perceived behavioral, self-efficacy, and facilitating conditions. A multi-faceted intervention using the Interactive Exercise Rehabilitation System was designed and implemented to support physical and occupational therapists in two-stroke rehabilitation units to acquire competency [2]. Findings showed significant improvement where VR application was used in therapist perceived behavioral control ($p = 0.003$), self-efficacy ($p = 0.005$) and facilitating conditions ($p = 0.019$) [2]. Findings also showed that while the VR application appealed to the stroke patients, continuous intention to use the VR was low for the therapists as the application did not support fine motor skills.

Therefore, on the negative side, especially in the education process, some practical issues exist when using VR applications [34], hence, affecting the continuous intention to use VR applications. One of the challenges that the teacher has to face when using VR applications is teacher motivation to communicate with the students [35], [36] and to access the virtual experience [31], [35], [36], [37]. Other reasons why VR applications have not been perceived as attractive would be due to the applications themselves. All applications and VR devices have varying qualities and performances depending on the manufacturers of the technology. Furthermore, how effective these applications are to improve the students' competency level in the educational process is also a factor [31], [36], [37].

For exploring these issues further, seventeen related studies were reviewed and summarised in Table 1. The literature reviewed was retrieved from several open-access database systems, such as Science Direct, Ebscohost, and Scopus, particularly on articles relating to the applications of virtual reality, its effectiveness, and impact on learning and academic performance. Table 1 has summarized the seventeen related studies in terms of learning issues, VR applications used, the contribution to knowledge, and the limitations.

Table 1 Summarized studies

No	Author	Learning Issues	VR Application and contribution	Limitations of VR Application
1	Al Musawi et al. [1]	Poor achievement of the students learning	3D Lab VR application - basically an online environment that mimics actual environments through virtual games and simulation software which enable learners to interact with elements, machines, and interfaces safely, testing ideas and observing the results before or instead of conducting them in real life. Using 3D Lab VR application, the students were found to have significantly improved their metacognitive abilities in science, with their achievement score at 80% (15% higher than before using 3D Lab) [1].	Virtual labs are generally limited to working with computers and devices with effective technical specifications for clear, multi-faceted visualization of phenomena. Other practical issues include insufficient computers and programs inside the computer and the quality of the computers and the programs [1], [2].
2	Alhalabi [3]	Poor achievement of the students	Head Mounted Display (HMD) is a device that is used for gaming, aviation, engineering, and medicine. There are three types: HMD with tracing system, Head Mounted Display Standalone (HMD-SA) with no tracing system, and the Corner Cave System (CCS). The three different VR devices were used by three different groups of students in this study. When their scores were compared, students using HMD had higher performance (86%) than when they were not using HMD (70%). HMD is a useful option for clinical assessment and retraining. The immersion level in HMD is better than the immersion level in HMD-SA and the CCS corner cave system.	Three types of VR were used, but each immersion experience was different due to the number of cameras and degree of freedom. HMD has eight cameras and 6 deg of freedom, making it better than the other 2 HMD types. In other words, different HMD leads to different results. This means For better results, better devices should be used.
3	Levac [2]	Low use of VR Applications for patient therapy	A multi-faceted Knowledge Translation (KT) intervention was designed and implemented to support physical and occupational therapists in two-stroke rehabilitation units in acquiring proficiency using the Interactive Exercise Rehabilitation System IREX®. A VR therapy system places patients into virtual sport or gaming environments using immersive video gesture control technology.	Despite the significant increase in self-reports of knowledge and skill, sustained use over time, and VR appeal to stroke patients who felt like the therapy using IREX was engaging and fun, the application would be more beneficial if it was suited more to the patients' needs, particularly for fine motor skills, which IREX does not support. When they were using VR, sometimes the VR application did not work. Time was unnecessarily spent to get it to work.
4	Hu-Au, E. & Lee, J.J. [4]	Students lack engagement, and they struggled to see the relevance of what they were learning to their lives.	CoSpaces and Tiltbrush, among other interactive simulation tools, are tools that allow learners to create and explore their own VR content. These VR applications lead to new opportunities that support learners, new	The wrong application of virtual reality in education would be simply repeating the educational experiences for the learners.

5	Capatina, Schin & Rusu [5]	Feasibility of using VR applications to make learning more appealing, meet current needs, and increase learner engagement	perspectives, empathy, creativity, and the ability to visualize complex models and systems. Virtual reality tours managed by Brand Verisign Media were designed to be viewed on all platforms, PC, phone, tablet, and compatible with VR headset devices, such as OCULUS, RIFT, HTC Vive, Oculus Gear, and Google Cardboard. VR headset devices	Despite the positive interests (72%) towards the VR application and its advantages and its abilities to build scholarly brand awareness, there arose questions of how easily professors and students could adopt VR technologies in their work as well as the affordability of VR technologies to be integrated at a greater extent in academia.
6	Erdem, Hakan, Turhan, & llhan [6]	Gifted students were observed to have difficulty learning about chemical bonds.	A force feedback haptic augmented simulation (using Phantom Omni, OpenHaptics, OpenHaptics libraries, Visual C++, OpenGL VR, 3D spectacle (Head-Mounted Display – Wrap 1200)) in VR environments was introduced to 30 of 52 gifted students (survey group) on chemical bonds, who found this approach more engaging than traditional education methods. Force Feedback Haptic Applications in Virtual Reality Environments (FFHAVRE) are VR applications that allow users to interact with the virtual world and create an experience of touch by applying force, vibrations, or motions.	The limitation would be that the control group was not qualified to give their attitudes toward VR as an educational approach as they were not exposed to the method. Therefore, more studies need to be done using different qualified sampling groups to make comparisons.
7	Nishaben Desai et al. [7]	Effectiveness of passive learning used in traditional and constructivist approaches for safety training	Engineering students designed their Virtual Reality Interactive Learning Environment (VRILE) to produce an interactive environment for chemical laboratory safety. Using Kolb's Experiential Learning Theory (ELT), students were effectively engaged in learning instead of being a latent beneficiary or a passive recipient.	As the VLE and games were developed by the students themselves, they probably lacked sophistication. Thus, non-technical students found the materials more interesting (perhaps because of their novelty), but technical students were not so impressed. Perhaps if professional designers and professional game developers developed the VLE, it would be more interesting to technical students as users/rather than as developers. As developers, students would learn a lot by developing the VLE, but if they were just users learning through the VLE, the VLE was not as interesting as it was to non-technical students.
8	Chien Wen Shen et al. [8]	Low achievement of the students	Kolb’s experiential learning theory (ELT) was applied to examine research hypotheses regarding the effects of four modes of learning styles on students’ behavioral intentions to use VR HMDs. Virtual reality headsets (VRH) and head-mounted devices (HMDs) were introduced in learning VR to engineering students.	Participants did not have a chance for virtual reality immersion. Reflective observation and active experimentation alone cannot provide a complete learning experience in terms of transformation. Because of this limitation, a real VR HMD learning experience for the students could not be implemented.
9	Yang et al. [9]	Low achievement of students	HMD VR application was introduced as a new medium for the students to explore and learn and to assist in their creativity.	The time given to use the HMD VR application was fixed and deemed insufficient due to a large number of students and insufficient VR devices. The immersive VR, however, brought a sense of tension compared to traditional learning. This is due to the lack of dimensions of activity spaces. Students' creativity and goals related to creativity, such as meditation, flow, and attention, can only be achieved when students realize them.
10	Dima Dajani [10]	Limited use of animation in the learning process, particularly in Jordanian universities. Lack of imagination and communication abilities amongst learners	Findings from 320 completed returned surveys that were randomly distributed among 370 marketing students in classroom settings ranging from freshman to senior years who have used animation at least once in their marketing classes showed that they enjoyed using animation. The research	While there is an increase in imagination and communication abilities amongst learners, the sample size is small and ungeneralizable.

			provides practitioners and teachers in the marketing field with advantageous methods in their learning process.	
11	Xiaozhe Yang et al. [11]	Lack of imagination in individual creative performance methods.	HTC Vive is a VR application. The virtual reality headset produced by HTC and Valve company allows its users to move in 3D space (immersive virtual reality environment) and use movements that increase creative performance, flow, attention, and meditation.	One limitation was that the students were only given 5 minutes each. There were also technical issues related to the quality of the devices used and the technology of the devices.
12	Halaweh [12]	Lack of application of ET or Emerging Technology. Traditional technology has been used for a long time with little development and modification.	In this case study, the HMD VR application was used to enhance the learning performance by developing a model for technology adoption (META). It provided validation through the VR example.	Accessibility, development, and cost may explain why the use of this innovation has not pervaded, particularly in the instruction part.
13	Santamaría et al. [13]	Minimizing the risk when teaching live-line maintenance, which is a high-risk activity.	ALEn (Energized Lines Maintenance Training) VR Training System (VRTS) was introduced, and trainees' performance was assessed when performing several maintenance maneuvers (MMs) in a VRTS. The VRTS provided educational stakeholders with information that might help them improve line workers' training and activities for supporting learning and their ability to detect untrained students.	The focus of this study was in a specific knowledge domain and geographical region, which means that the results might be particular to that context only. Thus, future research should use different VRTS so that lecturers and students are more comfortable with the technology and the validity of the results can be extended. This study also proposes that future studies should have a balanced data sample to better identify untrained students in other high-risk domains, utilize a formal knowledge model, and use a human instructor so that trainees can get feedback.
14	Baceviciute et al. [14]	Difficulty in engaging learners to learn scientific courses	An immersive virtual reality (VR) application was introduced to 78 participants who received identical instructional information, rendered in three different formats: text in an overlay interface, text embedded semantically in a virtual book, or audio. To immerse themselves in VR, the participants used HMD. The benefits of using VR include self-efficacy and prompt attention. These findings provide important considerations for the design of educational VR environments.	For comparing which of the three different formats rendered was most effective, learning outcome measures, self-reports, and an electroencephalogram (EEG) were used. Of the three conditions, reading from a virtual book was less cognitively demanding than reading from an overlay interface. It was also more superior to listening for the learning outcomes of retention, self-efficacy, and extraneous attention. EEG analyses demonstrated that audio conditions showed significantly lower theta and higher alpha activation. It was also found that HMD restricted bodily movements.
15	Huang et al. [15]	There is a need to reduce the gap between the learner's knowledge and real-life experience.	The study used a simulation of a virtual 3D shopping mall applying hedonic theory and self-determination theory. The findings showed that the 3D VR application increased intrinsic motivation and engagement in the virtual domain due to the experience of autonomy and feeling of connection with others in virtual worlds.	The majority of the sample being from the United States and the age being mainly from 18 to 24 is not generalizable. The impact of learners' virtual experience on their learning performance should also be examined by employing different pedagogical platforms. Furthermore, this study explored three psychological factors and did not consider other potential motivational factors and recommends future studies to focus on other psychological factors related to implementable design factors of virtual environments to generate more comprehensive pedagogical insights.
16	Valenti et al. [16]	Feasibility of using VR applications to make learning more appealing, meet the current needs, and increase learner engagement	Through Cardboard VR, physical presence is much more closely emulated than non-interactive or non-immersive videos and texts.	The delay in some VR headsets' arrival led to delays in distributing them to students who consequently had less opportunity to review the content than they otherwise may have had. For distance students, there were issues accessing VR, that several students opted to discontinue participation due to the problems they had with the technology.

17	Eva Benedikt [17]	Low acceptance and desire of students to use virtual reality applications	VR glasses ability to induce presence, a sense of being in another environment, Using VR glasses allows for more efficient targeting strategies, such as games and video.	Future research is encouraged to examine the post-adoption behavior of VR glasses users on a more heterogeneous sample in terms of age. The study only captured a one-time glimpse of the acceptance of VR glasses, but the importance of determinants for user acceptance might vary by situation and over time. Specifically, the novelty fascination of VR glasses can be expected to diminish over time, and future research might find different importance of determinants for the adoption of VR glasses.

From Table 1, even though the review's focus was limited to educational performance, several patterns can be deduced. Firstly, virtual reality applications can indeed be used to increase learning motivation and enhance academic performance in many areas of education, such as metacognitive abilities in science [1], clinical assessment and retraining [3], engineers and instructive foundations [8], and engineering area [7]. For example, the increase ranged from 70% to 86% [3], evidently showing that VR is positively perceived by the majority of the learners. Studies also showed students' positive attitudes toward using 3DL Virtual Reality application in their learning which led to improvements in logical and visual thinking [1].

Literature also shows that the use of animation in VR has increased students' innovativeness [3], [5], [8] and that the VR system for therapists successfully incorporated e-learning, experiential learning, and a reminder feature in the application that has significantly increased self-reported confidence, knowledge, and skills in VR use [2].

Thirdly, virtual reality applications that were used in the fields of education and learning as well as to enhance academic performance were used in instances or areas where learning in the actual environment is a hazard and place them in all these hazardous domains without harming them [7], [17], [18]. Simulations from VR were able to train learners to perform in unlimited ways and allowed them to learn and increase the experiential learning in special topics, such as laboratory, chemistry, medical, and any area where safety is a priority.

However, despite the usefulness of VR and students' acceptance of VR, which showed a positive effect of VR in terms of suitability, learners' engagement, and their performance [6], [7], [10], [15], [17], the literature reviewed in Table 1 also demonstrated that VR applications are not without limitations.

VR issues can be summarised into three main limitations, which will be discussed in the next section, and each limitation is followed by recommendations that address that limitation. Each recommendation is based on the limitations deduced from the literature that had been reviewed.

The literature review illustrated clearly that the application of VR is very important in any higher education institution and learning sectors and that we need to overcome these main limitations, namely (1) the perception that using VR is costly and not necessarily effective, (2) the quality of computers and the related applications and technology and (3) the lack of confidence of instructors to use VR, in other words, their hesitance to step out of their comfort zone.

3. Limitations of and Recommendations for VR Applications Use in HEIs

This section recommends how HEIs can begin using VR applications or increase VR use to improve students' performance based on the three main issues mentioned earlier.

3.1. VR is Costly and Not Necessarily Effective

Based on the review in Table 1, one critical point is that VR applications are perceived to be related costly [1], [2], [5], [9], [12], [16] and may not solve a specific problem [2]. Levac [2] mentioned that the VR the therapists used did not support fine motor skills for rehabilitation patients. Similarly, Baceviciute et al. [14] reported that the devices used restricted bodily movements, indicating that if VR is to be implemented in HEIs, VR applications must be matched to the learning outcomes that must be achieved. Thus, the respective management of the universities may feel that their decision should be based on which courses would benefit the most that require the investment of VR applications. The management should also select VR applications for courses in which learners particularly would be put at risk.

This paper recommends ways to utilize and maximize the use of VR applications in HEIs in light of the limitation in terms of cost. The use of VR technology and the adoption of VR applications could greatly assist students' learning.

Firstly, cost-wise, it is recommended that HEIs purchase VR tools that are now sold at a lower price, such as Google Cardboard, compared to when such devices were first introduced into the market. According to Robertson [38], when the Oculus Rift first debuted, the price was $599, and its setup must include a gaming PC that would cost $1000.00 or more. Table 2 below illustrates the lower costs of VR viewers in 2021 compared to 2019.

Table 2 The cost of the main VR viewers in the market in 2019 and 2021

	Oculus (Rift)	HTC Vive	Google Cardboard	Samsung Gear VR
Platform	PC	PC	Most mobile phones	Most mobile phones
Price in USD as of Dec 2019	399	899	25	129
Price in USD as of March 2021	300	799	20-30	89

Note: Prices in USD as of December 2019 are taken from [20]. Prices as of March 2021 are taken from [21], [22].

Table 3 The cost of the Oculus viewers in the market 2021

Model	Oculus CV 1	Oculus Rift	Oculus Go (Stand Alone)	Oculus Quest
Specifications	1080×1200 90 refresh rate, and a 110° field of view.	2560x1440 Refresh: 80Hz.	2560 x 1440 Refresh Rate: 72Hz	3220×2880 Refresh Rate: 72Hz
Price (USD)	599	499	450	299

This table shows how the price of Oculus cv1, then Oculus Rift, then Oculus Go, and the latest Oculus Quest have dropped significantly. The prices given above are the prices of the different Oculus models when they were launched and the current price as of March 2021. Thus, this shows that VR devices are indeed more and more affordable. In addition to the price, the displayed resolution is also increased for a better graphics display.

To reiterate, and as supported by Table 2, HEIs should consider investing in AR/ MR/ VR tools and applications as they will play an even more significant role in the coming years in determining the way we live, work and play in the future. HEIs should proactively consider studying the evolving market requirements in key sectors (such as retail, logistics, construction environment, and media entertainment) and assess the resources available to reassess optimal technologies to invest in. Google, for example, is always striving to improve their VR devices, such as a cardboard smartphone. When the device was first introduced, the price was very high and more expensive than it is at present. Now, consumers could get it at a fraction of the price as low as only USD 10 (during a sale) for even better, newer, improved technology. This has truly made VR more accessible to the public allowing users to experience virtual reality at an affordable price. In the education field, the benefits of VR application use would be priceless when learners are engaged, and learning performance is improved, particularly since the price of VR has drastically reduced [39].

Secondly, the HEIs may save on expenses if they could invest in VR tools commonly used by different applications for different courses. For example, Google Cardboard could be used in medical science and engineering (Oculus Rift). HTC Vive, Google Cardboard, and Samsung Gear VR are used in different educational fields.

Thirdly, HEIs could invest in applications that more than one student could use simultaneously by sharing the network and using a wireless connection. VR devices have transformed from having a very bulky and complicated setup that used to be wired and limited users' involvement to wireless devices running independently. PCs are no longer required, thus allowing users to have better freedom of movement [8]. Furthermore, without PC requirement, the cost of a VR product is also now much reduced. Anyhow, an example of how VR was utilized for group work would be by Albert et al. [18] using neuropsychological applications. Other examples are Desai et al. [7] for engineering applications, Baceviciute et al. [14] for scientific applications, and Erdem et al. [6] for chemical applications.

Fourthly, the HEIs could establish a VR center that could include many VR applications to accommodate many students. This has been done by Iowa State University's Virtual Reality Applications Center (VRAC) [40]. This will overcome the limitation mentioned by Yang [9] that students had insufficient time to immerse in VR. The benefit of having a center would be for easy management and monitoring of the VR applications and tools that the HEIs have invested in.

Lastly, the HEIs could also perhaps consider not investing in VR tools and spend more on quality VR applications and technology as there is a possibility that there are already many students who must possess their own VR tool that they are already using to play games with on their PCs and mobile phones. As some tools are getting more affordable, the HEIs could suggest that students buy their own VR tools based on university or instructors' recommendations. This will save some cost on the part of HEIs.

3.2. The Quality of Computers and the Related Applications and Technology

Apart from VR being costly and not necessarily effective, the literature review has shown that using VR applications too could be a hindrance rather than a boon, particularly when the immersion experience was of poor quality due to reasons such as outdated hardware or computers [1] as well as the VR applications and VR technology as certain brand names are less sophisticated [11]. Other reasons in this limitation category would be the complex way of using VR technology [30] and external factors beyond the control of the users, such as poor internet quality that causes lagging and restarting [8]. Such reasons may be demotivating for some VR application practitioners.

To overcome this, HEIs are encouraged to invest in VR wisely by recommending VR applications like 3D Lab to be used in HEIs. This is recommended because it is an online environment that mimics actual environments through virtual games and simulation software which enable learners to interact with elements, machines, and interfaces safely, testing ideas and observing the results before or instead of conducting risky activities in actual real-life situations that could endanger the students themselves or the people in the simulated contexts and environments [43]. The selected VR applications should benefit every faculty in the HEIS, subsequently benefitting every industry in the market with the advances in VR technology [41]. Lately, many VR/games engines are available in the market, such as CryEngine, Unity 3D, UnReal, and many others. These engines enable VR developers to create a more realistic virtual environment faster than before at a lower cost which allows users and developers to reach both natural and artificial creatures easily and quickly [42].

Furthermore, in selecting 3D Lab VR applications, HEIs should choose 3D Lab applications manufactured with devices with effective technical specifications for clear, multi-faceted visualization of the phenomena. These VR technologies are consistently being upgraded and improved.

Some companies and manufacturers are better than other companies, such as Qualcomm. Thus, before investing in a particular brand of VR application, HEIs should, therefore, take advantage of any trial versions and test their features before selecting one to commit to by having some good practitioners to create accounts to enable them to use and test the technology and decide if they suit the learning outcomes and achieve required learner performance. Al Musawi et al. [1] emphasized the need to conduct more research on different virtual labs in science education at higher education institutions. Granted, trial versions have limitations, but they provide ideas on the user interface, ease of use, and sophistication of the virtual environment. HEIs should also get novice users to test the VR applications to see if the VR technology is intuitive for them to use and if they have a continuous behavioral intention to use. If they do, it would mean that they see the potential of the VR applications and would use VR in their lessons and live the immersion.

Doing this would lead to meaningful investment that would sustain learning for a longer period as the selected VR technology would be constantly being upgraded and thus preventing issues related to the wrong way of using VR technology, high cost of VR technology, the difficulties of using VR technology and adopting it in education, poor quality of VR technology and the VR constructions. Proper research is required before selecting the most suitable VR to obtain the desired results.

3.3. The Lack of Confidence of Instructors to Use VR

In the literature, instructors were found to lack the confidence to use VR as they were not accustomed to the technology [4], [13]. Some students were also unwilling to try as they were not comfortable with the technology [13]. Thus, nobody in HEIs will use VR unless it is compulsory or a top-down directive.

For overcoming this limitation, this paper proposes that the HEIs must provide VR training for instructors as was recommended by Al Musawi et al. [1], Santamaría et al. [13], and Priatna et al. [30]. Sometimes, the reason behind low intention to use VR is ignorance. The instructors, especially the more senior ones, are unaccustomed to using technology in general, preferring the more conventional teaching methods [10].

The benefits of having such training would be that once the teachers or instructors have learned the tools, they would introduce to the students how to use VR and ask them to apply. The instructors would also be able to decide the materials and contents in their syllabus that would be suitable to use VR applications and how students could achieve the learning outcomes of that topic.

Secondly, in terms of the adoption of VR applications to customize to the needs of learners, the approach of Desai et al. [7] could be emulated. In [7], the instructors made the students develop their own VR, which was more interesting and engaging for the students. They had to work in groups and research to create the VR environment, and from the previous semester to the next, the VR that had been developed would be improved by the students of the following semesters. Thus, this practice allows students to learn through teamwork and lifelong learning. This illustrates how constructivism plays a crucial role in the development of educational applications. The employment of VR applications stretches the students' opportunities exclusively to build and enhance knowledge [1], [5]. VR environments enable students to create a model that simulates reality, and they also provide students the familiarity with creating such environments. However, this cannot be achieved if instructors are not even aware of the VR applications available to them and applicable for the learning process. As Al Musawi et al. [1] stated, more training, practice, and curriculum development should be done to attract the students' attention [1]. Such is the reason why instructors must be provided with the training.

Lastly, emulating Desai et al.'s [7] practice of getting students to create their own VR environment will keep the costs lower than purchasing existing applications and technologies. The students' schedules could also be arranged in such a way so that they could use the labs sequentially at different times, and they can use the shared devices in the labs on the same network.

4. Significance of the Study

This study is significant because it compared and reviewed past literature focusing on the methods used in various VR technologies with parameters, such as 1) affordability of VR application tools, 2) sustainability of VR use, and 3) the technology-savviness of instructors. However, the limitation is that the findings and analysis were based on 17 papers. Should more articles be reviewed, perhaps more issues would surface. This paper has found that most of the issues can be grouped into three main categories.

This paper is also significant as it recommends ways in which HEIs can overcome these issues to use VR applications in their institutions to engage learners, enhancing learner performance so that learners achieve their learning outcomes.

5. Conclusion

The literature review has highlighted that, undoubtedly, virtual reality applications positively affect learners during the learning process, allowing them to improve their learning outcomes, safely live experiences that are usually dangerous, develop intrinsic motivation, and increase interest in learning. In other words, the positive outcomes of VR applications shine through. Yet, literature has also shown that virtual reality has not reached its full potential despite students showing more interest and engagement in virtual reality in comparison to the traditional model of education. This paper has identified three main reasons why VR has been underutilized. Generally, VR has been perceived as being costly and that it may not be effective. The second reason is related to the quality of computers and the related applications and technology. Lastly, it is also perceived as a challenge by the less technology-savvy. These, however, could be overcome with careful planning and wise decision-making. The training for educators would be the most important to see the potential of VR applications in achieving learning outcomes in a way that learners look forward to and are excited about. Thus, Virtual Reality applications are investment-worthy as the use of virtual reality applications influences the engagement and performance of the learners, particularly where real-life situations are too dangerous as in certain engineering fields and the field of medicine.

In the future, it will be interesting to see artificial reality enhancing learning systems in which we can connect virtual reality technology and create more realistic images and graphics that simulate reality with more authenticity. In the present, virtual reality applications are not only used in the educational area but could also be used in day-to-day activities and work environments. However, if educators dare not tread into the 'uncertain', their students would miss out on learning that may be more meaningful than the conventional methods. The future of learning is virtual reality applications, but the future of VR applications would be bleak, particularly in the education field, if they are not maximized to the fullest of their potential. Having proposed feasible ways to increase VR applications in HEIs, it is hoped that future research would show the increase in VR applications and investigate how they have been applied and if educators are more open to using them in the classroom.

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