Technology Adoption of Augmented and Virtual Reality in a Progressive Philippines: A Socio-techno-economical Analysis

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Abstract— **Living in the information technology era amidst the rapid digital transformation that we are experiencing, Virtual Reality (VR) and Augmented Reality (AR) are regarded to have great potential in changing the landscape of many fields such as gaming and entertainment, education and training, tourism and cultural heritage, architecture, and engineering, automotive, defense and security, and healthcare. While it is true that AR and VR technologies brings tremendous growth and potential, these technologies face a wide range of challenges. The most common challenges and issues among the AR/VR applications as observed in this study are the privacy and security concerns of users where personal and sensitive information can be gathered and collected and are vulnerable to unauthorized intrusion. Affordability, latency, health concerns, perceived usability challenges, and ethical issues are among the other issues that are being addressed in recent research to improve adoption of these technologies. Most of the identified concerns lies upon the responsibility of manufacturers and industry actors, but policymakers should maintain balance and promulgate regulations to allow for the growth and adoption of these technologies. This study highlights several policy recommendations for the technology adoption of augmented and virtual reality.**

Keywords—augmented reality, virtual reality, technology adoption, disruptive technology

I. INTRODUCTION

We are living in a technological age of rapid changes with increasing generation of digitized devices and services. Together with Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR) are technologies considered to have a disruptive effect on the way we live and work. Clayton Christensen coined the term disruptive technology from his book "The Innovator's Dilemma" in 1997 [1]. Virtual reality gives the user an immersive experience in an artificial world [2], while augmented reality superimposes digital information to the user's view of the real world [3].

GlobalData estimates that global VR market will generate total revenue of 51 billion US dollars, while AR market with 152 billion US dollars by year 2030, with the enterprise to be the key market [2]. The COVID-19 pandemic caused a shift to remote working which boosted the adoption of VR for training, collaboration, data visualization, and training experience [2]. At the same time, the pandemic fueled enterprise adoption of AR across sectors such as healthcare, law enforcement, and manufacturing [3].

This study presents the most common applications of AR/VR technologies in different sectors. Facilitating factors and constraints of technology adoption in the Philippines were also discussed. Policy recommendations for the adoption of these technologies were highlighted for a possibly more effective customer experience.

II. APPLICATIONS OF AUGMENTED AND VIRTUAL REALITY

AR and VR technology have been used in various fields such as gaming and entertainment, education and training, tourism and cultural heritage, architecture, and engineering, automotive, defense and security, healthcare and many more. Most common applications of augmented and virtual reality are discussed in this section.

A. Games and Entertainment

VR and AR offers impressive and enjoyable gaming experience than traditional smartphone games. Aside from the traditional controllers, players can now use head rotation, eye movements, or a special controller that corresponds to body movements to interact with virtual content [4]. Launched in 2016 by Niantic in collaboration with Nintendo [5], Pokémon Go allow players to catch and train Pokémon characters in real locations using mapping technology and location tracking to create an augmented reality. To make the tour interactive, AR and VR technologies are also being integrated in museums and art galleries. The tour provides a richer user experience with contextual background [6]. Though it is quite difficult to simulate, virtual rides were also developed for theme parks [7]. In our everyday lives, the integration of AR technology is evident using smartphone camera on various social media platforms. The camera filter uses computer vision technology that categorizes and recognizes human face which relies on an active shape model [8].

B. Education and Training

Education and training are likewise considered as one of the main areas of concern for VR/AR solutions. A lot of educational applications were reported for VR and AR which includes simulation, training, and distance learning, with associated pedagogical (constructivism, collaboration, and gamification) and intrinsic (deeper learning and increased immersion, motivation, and enjoyment) factors as motivations. Using VR is one of the most feasible ways to undertake activities that are too dangerous but can be done safely using simulations or virtual explorations. Training using VR is also common in-flight simulations and construction [9]. VR is an impressive tool to learn anatomy through virtual 3D models. In surgical training, one study identified the common uses of VR which includes laparoscopic procedures, carotid artery stenting and ophthalmology [10].

Education has been regarded as one of most highly benefited sector. AR/VR technologies are used to help students develop their skills as the transfer of knowledge becomes more attractive. Thus, enhanced students learning gains, motivation, memory retention, collaboration, and interest [11]. Recent progress in AR/VR hardware allow students to overcome learning barriers and improve their knowledge, skills, thinking, and understanding through interaction and integration of several environment and multi-sensory devices [10].

C. Tourism and Cultural Heritage

There are several identified VR and AR applications in the field of tourism and cultural heritage. The applications of VR in tourism includes virtual visit and interactive exploration of cultural sites, and digitization of sites especially those in danger of destruction. It also allows visitors or users to view destination sites when fully restored and its projected appearance in the future, under different conditions like global warming scenarios [10]. AR on the tourism industry will reduce the need for human tour guides and information kiosks [12]. In addition, virtual visit and field trips are not affected by weather conditions. VR technology makes the destination site accessible to people with illness or disability and rejects the risks of contracting tropical diseases, accidents, and untoward incidents. Concomitantly, virtual visit does not cause harm or damage to cultural sites [10].

D. Architecrure and Engineering

Several applications of VR and AR in the fields of architecture and engineering includes stakeholder engagement, design and construction support, operations and management, and training [13]. One study incorporates special communication protocols and gesture recognition techniques for city planning and object modelling [14]. In progress monitoring, VR can be a great tool to carry surveillance especially for dangerous sites [15]. Visualizing renovations and retrofit works by combining real environment with virtual objects can be easily implemented using AR [16]. By providing safer working environments, assists in hazard identification, safety inspection and education, AR and VR technologies can be used to promote construction safety [17].

E. Automotive

A study identified the automotive-specific trends of AR and VR which includes augmented GPS navigation, vehicle design, integration with advanced driver assistance systems (ADAS), servicing and maintenance, and manufacturing that enables safer operation of vehicles, faster training of automotive staff, and more in-depth entertainment experiences [18].

With the use of VR technology, people not geographically close can work together, gearing towards the increase of quality and reduction of time and cost. When designers want to rapidly simulate the interior or exterior of a vehicle, they can generate a digital representation on a computer and then view it in VR without ever needing to create a physical model. AR in automotive industry on the other hand, include the use of overlaid navigation instructions on real-world images, enabling clearer guidance based on the actual road layout facing the driver. AR could also play a role in enhancing the efficiency of processes in maintenance and servicing. Technicians can have repair and maintenance instructions overlaid on their physical view of the car being repaired, directing them to the next task without them needing to research it separately [18].

F. Defense and Security

By creating innovative methods, immersive technology also has impact for combating crime and terrorism. Without putting the soldiers in danger makes VR application more impressive by providing the military men the ability to prepare the soldiers cost effectively especially in extreme situations. Through the integration of virtual reality simulation, combat situation re-enactment allows soldiers to learn how to react appropriately in befitting the circumstance [19]. Real-time intelligence improved data collection and visualization, and other biometric recognition data of known criminals; capture of dangerous criminals and terrorists; and realistic training scenarios to simulate dangerous police operations are some of the AR applications for policing.

G. Healthcare

AR and VR are increasingly used as tools to aid medication education across the globe. These technologies allow the user to explore elements of the human body virtually using a headset and controller, improving medical training in procedures and techniques, and simulating patient interactions and experiences in a more immersive and realistic way. Projection of a fully sized human body in real-time realizes a new chapter for medical education, where medical students or surgeons looking to specialize can fully immerse in the learning experience, thus moving away traditional medical education [20]. With VR and AR in surgical procedure training, trainees may have patient information superimposed with reality or perform steps on a virtual patient [21]. VR technologies are being integrated and is considered a great tool in surgical skills improvement and surgical procedure errors reduction, as it allows trainees to practice sessions, thus, giving opportunities to correct error and polish performance. Immersive technologies can also improve the cognitive abilities of stroke patients [22]. Patients with eating disorders, substance abuse, anxiety, or depressions can also benefit from VR [23].

III. Technology Adoption of AR/VR in the Philippines

A. Facilitating Factors

In the Philippines, innovation is regarded as one of the primordial means for sustainable economic growth, improving the quality of life of its people. Thus, efforts in building the inclusive innovation in the country has been initiated through policies and development plans such as Republic Act 10055 or the Philippine Technology Transfer Act of 2009, the Philippine Development Plan (PDP) for 2017 – 2022 of the National Economic Development Authority (NEDA), and the Harmonized National Research and Development Agenda (HNRDA) of the Department of Science and Technology (DOST). The country's initiative to pursue innovative efforts can be gleaned from the 2017 Global Innovation Index Report showing the Philippines' gradual improvement in the past 4 years [24].

Section 2 of RA 10055 mandates priority to R&D, invention, innovation, and their utilization by encouraging stakeholders to participate in policymaking related to S&T. This Act also promotes greater public access to government-funded R&D

results to become sustainable and competitive, through cooperation with small and medium enterprises, with proper management and protection of intellectual property [25]. Based on the PDP 2017-2022, disruptive technologies may create new industries and new jobs, change the way things are done, and at the same time may cause job losses. As evident, the rate of development and adoption of these technologies in many countries is very fast. However, the Philippines has yet to develop its own abilities to fully produce or adopt these technologies, causing delays or constraints the ability to utilize disruptive technologies envisioned to raise potential economic growth. There is a need for the government to minimize the potential adverse effect while maximizing the utilization and promising positive results of disruptive technologies by investing in capacity building and R&D program [26].

The HNRDA is aligned with AmBisyon Nation 2040 and its three pillars – Malasakit, Pagbabago, and Kaunlaran, aiming to form a more inclusive society and globally competitive economy. HNRDA has five sectors which includes the National Integrated Basic Research Agenda (NIBRA) of the National Research Council of the Philippines (NRCP). In support for the PDP 2017 – 2022, NIBRA will prioritize fundamental research though their issue-based programs addressing "water security, food ang nutrition security, health sufficiency, clean energy, sustainable community, and inclusive nation-building". Ang Tinig Natin or ATIN Program which aims inclusive nation building, will focus on "data collection and analysis on social phenomena, documentation of indigenous knowledge, education, national security and sovereignty, and arts, history and culture". AR and VR technologies offers solutions for the attainment of the ATIN Program goals through digitization of Philippine indigenous and popular culture, and documentation and preservation of Philippine arts [27]. In 2019, Philippine Competition Commission held a forum to discuss the market competition and challenges brought about by disruptive technologies, where key stakeholders from different sectors and international community gathered to deliberate on the appropriate repones of competition authorities to the technological disruptions that are transforming the business landscape. As identified, closer collaboration among the government, industry, and the academe are needed to promote mutual capacity, facilitate adaptive regulation design, and alignment of objective with existing and available talents and resources. Inclusion and access to disruptive technologies will open potential markets and will have positive impact to the economy [28]. Department of Trade and Industry (DTI) is working on the establishment of an Industry 4.0 pilot factory to house manufacturing technologies including virtual and augmented reality, aiming to accelerate digital transformation of the country [24], [26].

B. Barriers and Constraint of Adoption

In marginalized communities, risks and challenges are prevalent that discourage users from using immersive technologies. Insufficient broadband connections and infrastructure, affordability, or digital literacy gaps are some of the potential barriers to accessing or adopting AR/VR technologies [29]. Further, issues such as nausea, high prices, latency, and underdeveloped ecosystems have been identified as constraints to widespread adoption. The bandwidth limitations of current telecommunication networks are a significant factor restricting adoption. To develop stronger ecosystems, companies are encouraged to increasingly use AI and cloud technologies.

For educational purposes, challenges identified in recent literature are the cost of implementation, lack of realism in VR or AR simulations, complexity, technical difficulties, effects on students, and health issues. It is noteworthy to emphasize the following common problems like lack of precision, latency between sensors' data and the effects to visual system, and GPS errors and navigation problems which cause students' frustration and learning interruption [11].

In tourism, barriers of adoption include cost, space needed for installation of VR equipment, and some visitors hesitant to wear VR equipment as they consider it as a single person experience. Large amount of data is needed to process digital acquisition and rendering cultural heritage sites. Meanwhile, virtual visits were considered threat to travel and tourism as it might result in the eventual displacement of actual visits to tourist sites. It will also affect social interaction with the locals. Notably, revenues of countries who depend greatly on tourism will be a problem [10].

Establishing VR systems in clinical setting is challenging and costly. Moreover, these technologies often have lower levels of acceptance in the elderly population. There is a need for a comprehensive guideline to warrant further consideration and sanitization of the use of these technologies in medicine [30]. Cybersickness, motion sickness, and perceptuomotor after-effects have been reported as potential side effects of VR [31]. Thus, patients are recommended to prevent some activities, such as driving after using VR [32].

Another critical issues that need to be addressed are the vast amount of virtual data and information overload that are being collected by these technologies, require higher data transfer rate, and invades sensitive personal information in countless ways. As an example, the user's motions such as movement of the eyes and head and even voice commands are being tracked by VR Headsets using multiple cameras to scan everyone and everything to collect information [33]. Sensitive personal information gathered or inferred about a user of AR/VR can put the user at risk of discrimination as it can be used by invaders to spread misleading information or impression [29]. Virtual stalkers, impersonation and possible crimes might be prevalent in virtual worlds [33].

Concomitantly, to address these challenges in the adoption of immersive technologies, AR/VR stakeholders need to take closer look and analyze the underlying issues and concerns in various fields, like the privacy and safety of users which might be jeopardized and potentially leads to discrimination, harassment, bias, and abuse [29]. Relatively, a global standard, regulation, or cohesive regional policy on the adoption of immersive technologies should be put in place, like in Asia, where a standard or policy has yet to formulate to regulate data collection, privacy, and network access to resolve the underlying issues of AR/VR technologies [33].

IV. IMPACTS OF AUGMENTED AND VIRTUAL REALITY

A. Economy

According to the research conducted by PricewaterhouseCoopers (PwC), VR and AR will boost gross domestic product (GDP) up to $1.5 trillion by 2030 [34]. Several benefits of VR and AR to the organizations are the trainings, testing procedures, and virtual collaborations which will accelerate product development. Without having to invest in physical prototypes immersive technologies open the opportunity to the design teams in exploring, testing, and evaluating different concepts easily. This potentially allow organizations to bring higher quality products to market more efficiently. From a recent study, it was concluded that advances in VR and AR are transforming processes in the healthcare sector and will ultimately provide positive economic impact. These technologies together with AI and robotics will improve quality of life for patients all over the world through increased training and collaboration, toward hospital digitalization [35]. It was reported that by 2030, 93% of the jobs will be enhanced through adoption of VR and AR technologies [34].

B. Industry, Manufacturing, and Labor

AR and VR also have great impact on manufacturing. Companies can eliminate or compress physical prototype cycles with the use of virtual prototyping, thus, reducing time and cost to production and commercialization. AR approach for visualizing information to improve construction panel manufacturing leads to improved quality of the final product and reduced offset distances by ensuring that tolerance levels are met [13]. A key benefit of AR in this setting is the potential for reducing mistakes on the line that would require costly repairs. This could also reduce the time needed to perform quality control processes, again increasing manufacturing efficiency. In addition, the training of manufacturing personnel could be made faster by delivering instructions through augmented reality, with guidance directly overlaid in the field of view [18]. It was found out that the error rate, completion time, and essential workload were all improved with the introduction of AR [36]. VR interfaces for controlling equipment and robotic arms in manufacturing facilities have been investigated as well. Recent studies emphasized that the future of construction industry will focus on human-robot collaborations using immersive technologies [13].

C. Society

In a recent study, it was found out that immersive virtual reality experiences have engender racial sensitivity, increase respect for the environment, promote greater empathy for those with disabilities, and an increased willingness to help others. Immersive solutions can enhance opportunities and create new avenues for inclusion as virtual reality could provide new experiences to disadvantaged persons. Using AR/VR tools, people with disabilities may succeed by learning new skills, experiencing environments, and actively participating and embracing new avenues and opportunities in the workplace [37]. They can have access to destinations using virtual reality, which will contribute to the social equity goal of the government [38]. AR and VR applications can be used as assistive technologies for people with disabilities by adding virtual elements to physical environments, making it more accessible [39].

Culture preservation and inheritance is treated as one of the practical applications of VR and AR technologies. The social importance of preserving cultures have been carried out by UNESCO and each country even before the introduction of immersive technologies and is being continuously reinforced around the world. Application of these technologies in museum, library, and archives will help the whole society in contrasting a better culture preservation system using digital data [40].

Virtual trainings supplementing real-life training will offer better health and safety outcomes, reducing negative impact on the environment and will result in a better and safer community. Users of AR and VR technologies may also form virtual communities and support systems beyond the bounds of physical distance. Indeed, collaborative virtual spaces will expand social networks and build a geographically diverse global workforce. However, emergence of these groups and communities can cause fragmentation of traditional society and can cause isolation of individuals [39]. With the potential benefits of adopting AR/VR technologies, researchers are now taking comprehensive studies on how to enhance these technologies, therefore build a more inclusive and equitable opportunities to transform the way people work, learn, and communicate. The World Economic Forum and the United Nations are working together with leading companies to promote the development of applications for immersive technology that will drive positive social impact.

V. POLICY RECOMMENDATIONS

As we thrive toward a more immersive future, unique considerations should be raised by our policymakers as AR/VR technologies spread across workplaces, classrooms, and even at home [37]. These technologies clearly present enormous potential which requires intervention to address the challenges brought by the adoption thereof. Identified as barrier for the adoption of these immersive technologies, global standard, or cohesive policy to regulate immersive technology is necessary to be established to address the underlying issues and concerns of AR/VR technologies, especially in the areas of privacy and security, data collection and network access, must be given of great importance. China, together with several countries in the West, have adopted and/or modified the regulations from the US and EU. Understanding immersive technologies and examining the degree of acceptance Asia countries of these trends are vital in the formulation of cohesive regional policy or standard [33].

To drive equitable adoption and to achieve the optimal benefits of AR and VR devices, policies and initiatives should be prioritized. Inevitably, a collaborative effort is necessary among AR/VR stakeholders, such as industry leaders, civil society, current and potential users across diverse communities, and most importantly the policymakers, to develop a robust, actionable guidelines, and clear standards in maximizing its potential and mitigating unintended consequences.

A. Labor and Employment

Rejection for people with disability (PWD) is a regular occurrence especially when it comes to work and career. Most often, companies are reluctant to hire people with disability due to the fear that they cannot accommodate their special needs no matter how qualified they are in terms of skills and experience. But, with AR and VR technologies developed with inclusivity

and accessibility, barriers to employment will be resolved, giving opportunities for them to join the workforce. Policymakers should promote the adoption and use of these technologies, and mandate companies to employ a certain percentage of its workforce coming from the PWD sector.

Another problem identified is the migration of professionals in search for better standard of living and higher salaries or "Brain Drain" that occurs due to a lower local demand as compared to the increasing supply of STEM graduates, causing them to seek employment opportunities abroad. It raises the need to formulate a roadmap or strategic plan to increase the number of researchers, scientists, and engineers absorb by the industries in the country. The government, in collaboration with various stakeholders, including those coming from the academe, shall create a unit to spearhead the study and analysis on the underlying issues regarding the continual existence of brain drain problem in the country. Emergence of disruptive technologies is associated with fear of displacement of employees, especially those performing routine work. The government shall manage the flow of employment distribution, including flow of skills and talent, as labor market demand shifts. Likewise, to compliment the requirement of digital skills, flexibility, and innovative behavior, a reform in formal education should be initiated to equip incoming labor forces with required skills. Moreover, policymakers shall pass a law requiring companies adopting these disruptive technologies to retrain and upskill the affected employees to minimize the number of displaced workers. With these technologies, workforce should reinvent and reskill themselves to cope with the change and job requirement.

B. Human Resource Development and Education

As discussed in this paper, numerous positive impacts of VR and AR technologies are evident especially for the education sector. However, to achieve the optimal potential of these technologies, intervention of the government in collaboration with various stakeholders must be initiated to increase the capability of adopting these technologies. Partnerships of the public and private sectors should be strengthened to facilitate building social institutions and programs to address gaps in skills and literacy. Hence, reform in the educational curriculum should be prioritized to cope with the required digital skills, flexibility, and innovative behavior, as well as to mitigate potential adverse effects of AR/VR technology adoption. With the evolving demand of industry and labor market, academic curriculum should be revised regularly in accordance with the emerging needs. Associated with the need for curriculum development, faculty trainings and industry exposure are likewise essential. Harmonizing the skill set of faculties with the curriculum reform, will address the demand driven by industry needs. Once employees are on board, training can be costly, time-consuming, and ineffective. VR and AR technologies can help provide an immersive environment for new employee induction and training, without wasting resources. These technologies can help speed up the process, and workforce development. Thus, the government may encourage companies to adopt these disruptive technologies to retrain and upskill the employees. A forum or conferences may be conducted to showcase these technologies and its applications to strengthen human capital development and management. With these technologies, workforce will be able to reinvent and reskill

themselves to cope with the change and job requirement. However, policymakers shall promulgate guidelines and mechanisms on the responsible use of these technologies especially the information collected from the employees, for security and protection.

C. Government Policy and Laws

AR and VR devices require a large amount of user's information, thus requiring strong data protection and privacy measures. Rules and standards should be clearly set to prohibit malicious misrepresentations. Users should clearly understand how biometric data is used, and companies should ensure that they have regulations to prevent unauthorized third parties. Leaders should make an assessment on how mobile devices are being used nowadays, to determine desirable elements and those that should be regulated out of the system. Stricter guidelines on data management should be implemented. Ensure the protection of civil rights by implementing standards for the use of law enforcement. In addition to mitigating potential privacy harms, there should be a policy on AR and VR applications giving control to the users on when to infer and share sensitive data or potentially identifying information. In addition, the ability of users to record of gather data in sensitive space should likewise be limited. Government support for cybersecurity, particularly for the vulnerable and underprivileged sectors should have a clear digital regulation, including data privacy and competition.

D. Research and Development, and Innovation

Knowledge gaps have been identified to significantly prevent widespread exploration and adoption of AR/VR devices and applications. Government agencies should allocate funds to support projects and initiatives in which AR/VR can promote equity and inclusion, and to identify potential risks that might occur. Understanding the potential benefits and challenges of immersive technologies may lead to a more effective and inclusive AR/VR solutions. Research on accessible and inclusive design should prioritized before policymakers and stakeholders can put standard practices and implementing guidelines. Inclusion of disruptive technologies like VR and AR in the research areas and roadmaps, while ensuring its effective implementation thereof will help boost interest of Filipino researchers in this field. Government agencies should invest in research and development for AR and VR innovations and solutions. For example, the Department of Science and Technology may allocate funds for research projects and programs that will explore creative solutions for the benefit of users with disabilities. Likewise, intensive research on the use AR/VR applications, exploring on its efficacy, potential drawbacks, and best practices should be made to mitigate bias concerns and discrimination.

VI. CONCLUSION

AR/VR technologies create an immersive and engaging world as it shapes different levels physical and virtual environment integration. The customer experience landscape is enhanced and evolved into a hybrid experience using highly interactive devices. However, several challenges and issues for AR/VR applications as observed in this study includes the privacy and security concerns of users. Hence, developers should transparently regulate data collection, use, and sharing, while considering sensitive information safety and ensuring that

data are encrypted. Policymakers should identify solution to address the specific risks associated with certain applications while ensuring ethical integrity and respect user's control. Likewise, policymakers should develop or improve existing data protection policies that provides significant rights for the users and clear commitment for companies regarding AR/VR technologies. Further, policymakers should keep AR and VR technologies revolutionize learning and enable the opportunity to reach everyone.

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