**Research Title: "Exploring the Impact of Augmented Reality Technology on Student's Learning Outcomes in Education"**

1. **Introduction**

The use of Augmented Reality (AR) has surfaced as a promising technological advancement in the present times. Over the recent years, Augmented Reality (AR) has instigated a significant transformation in various fields, including the field of education. The ability of AR to combine virtual elements and reality provides users with an enhanced perception of their physical surroundings. Its potential to revolutionize education and transform traditional teaching methods has sparked significant interest among educators and researchers. Augmented Reality technology presents a distinct and immersive educational experience by combining virtual data onto the physical environment. The utilization of digital content facilitates real-time interaction for students and further strengthens their capacity to visualize complex concepts and abstract ideas. Through the fusion of physical reality and virtual simulation, augmented reality (AR) technology offers an immersive and interactive medium for students to navigate educational material, thereby cultivating participatory learning and bolstering information retention.

It has been twenty eight years since the development of the first augmented reality (AR) application constructed solely for employment in an academic and educational environment. Since then, augmented reality (AR) applications have been successfully integrated across diverse educational domains, levels, and settings, providing positive benefits to students and learners.

1. **Objectives**

Research Objectives:

1. To explore personalized learning experiences enabled by AR systems and examine their impact on students' learning outcomes.
2. To assess the influence of AR technology on knowledge acquisition and retention among students.
3. To evaluate the effectiveness of augmented reality (AR) technology in improving student engagement and motivation in the field of education.
4. To investigate the effectiveness of AR technology in promoting collaborative learning among students.
5. To provide a view of the current status of augmented reality in Philippine education, including the level of adoption, implementation challenges, and impact on teaching and learning outcomes.

The researchers hold the perspective that augmented reality (AR) technology is promising and has the potential to positively impact the education industry. However, it is important to note that this stance is based on their prior knowledge about Augmented Reality in the context of education. The examination of existing literature and observations of related studies is needed to verify whether the stance is true or not. Therefore, the primary objective of this research is to objectively explore and evaluate the impact of AR technology on student learning outcomes in order to determine whether its integration in education is beneficial or presents challenges. By adhering to the research objectives, the researchers aim to uncover empirical evidence that will shed light on the effects and implications of AR technology on students' engagement, motivation, knowledge acquisition, personalized learning experiences, collaborative learning, and the current status of AR in Philippine education. Through this research, the intention is to provide a comprehensive understanding of the potential benefits and limitations of AR technology in education, enabling educators, policymakers, and instructional designers to make informed decisions about its integration and utilization for enhancing student learning outcomes.

1. **Scope and Limitation**

This study is confined to the examination of the influences and effects of augmented reality (AR) technology within the domain of education. This investigation extensively examines the impact of Augmented Reality (AR) applications on the academic learning of students, highlighting specific aspects including student engagement and motivation, knowledge acquisition and retention, personalized learning experiences, and collaborative learning. Moreover, it presents an overview of the current status of augmented reality technology in the educational system of the Philippines.

The current investigation is not devoid of limitations. The study is delimited to the examination of augmented reality (AR) applications that are exclusively utilized within the context of education. This analysis disregards other conceivable applications of AR technology, which may have practical implications in diverse fields such as healthcare, tourism, or industry. The present study centers on students’ education, however, it does not extensively explore the various demographic and learning-style variables that may have effects on the potential influence of augmented reality technology on students' academic achievements. Furthermore, the present study fails to evaluate the precise hardware and software prerequisites for the implementation of augmented reality (AR) technology and its feasibility in different economic situations prevailing in the Philippines. Lastly, there is a constraint pertaining to the possible partiality or preconceived notions of the researchers towards the advantages of augmented reality (AR) technology within educational contexts, given that the researchers were mandated to disclose their preliminary stance with regard to the said technology. The present study endeavors to address potential biases by systematically and objectively evaluating the impact of Augmented Reality (AR) technology on students' academic performance. To achieve this goal, the study will employ a rigorous methodology, utilizing both secondary sources and empirical research to generate unbiased and reliable findings.

Despite its limitations, the present research can offer significant contributions and serve as a foundation for future investigations in diverse settings.

1. **Presentation of the Chosen Technology**

**What is Augmented Reality?**

Augmented Reality (AR) is an important technology that provides significant tools to improve the experience of interacting with reality (Garzón, 2019). Numerous literatures, including the writings of Buchner et al. in 2022, described that Augmented Reality must possess three key features. Similarly, Microsoft has expounded on the same three important characteristics of Augmented Reality (AR), namely the merging of digital and physical world, instant interactions in real time, and precise 3D recognition of virtual and physical entities. As a result of these features, Augmented Reality has the potential to provide a more immersive, interactive, and collaborative learning environment, offering a dynamic, experiential, and participatory approach to education that transcends the passive knowledge transfer often associated with traditional learning modalities.

**First Augmented Reality System in Education**

Based on scientific and academic literature databases, it has been reported that the initial development of an augmented reality (AR) system solely intended for educational purposes was aimed at facilitating the teaching of anatomical structures in three dimensions. The system was developed in University of Carolina and was first presented by its innovators to the scientific community during the International Conference on Computer Vision, Virtual Reality, and Robotics in Medicine convened in Nice, France in 1995. Their system employed a process of superimposition and registration to accurately align and depict bone structures in relation to real anatomical counterparts within a human subject. This innovative approach was introduced to facilitate the teaching and learning of anatomy through utilization of a head-mounted display.

**Three Generations of Augmented Reality in Education**

In Garzón’s study on the overview of twenty-five years of Augmented Reality in 2021, he proposed three generations of Augmented Reality technology in education.

**First Generation (1GARE)**

The first generation of Augmented Reality in Education was named 1GARE by Garzón. This period spans from 1995 to 2010, and during these years, AR systems were heavily hardware-based. AR systems during this generation were distinguished by the utilization of high-priced and intricate AR technologies, including head-mounted displays, heads-up displays, and handheld displays. The aforementioned systems were originally developed with an aim to impart knowledge in health, natural sciences, and engineering academic spheres, and catering primarily to undergraduate students. Nevertheless, the utilization of 1GARE applications was hampered by two major constraints, specifically, elevated expenses and difficulties associated with usability. As a consequence of these factors, the application of 1GARE in educational settings did not garner widespread acceptance, resulting in limited dissemination.

Early researchers such as Billinghurst in 2002 and Dunleavy in 2009 have underscored the prospective significance of augmented reality (AR) in the realm of education, with particular emphasis on its capacity to generate seamless interactions between authentic and digital environments. During the early phases of integrating augmented reality (AR) in the realm of education, there were only less instances of the technology being implemented, leading to a lack of comprehensive user assessments. Due to this constraint, their capacity to comprehend the full extent of Augmented Reality's influence on education was restricted during the early period of educational AR technologies.

**Second Generation (2GARE)**

The second generation has witnessed a significant surge in the popularity of augmented reality (AR) systems, with Google Glass and Pokemon GO emerging as two of the most notable commercial products in this era. In the year 2014, Google Glass, representing one of the primary advancements towards augmented reality technology in mainstream markets, presented a version of wearable technology that overlayed digital data onto the physical surroundings of users (Bower, 2016). Although Google Glass fell short of meeting its expected commercial success, it incited vital discussions and explorations concerning the potential of augmented reality (AR) in diverse industries, such as education (Bower, 2016). The experimental utilization of Google Glass within educational settings has illustrated the potential of augmented reality (AR) in promoting personalized learning, augmenting student collaboration, and cultivating an immersive and embodied learning modality, as illuminated by the research endeavors of Al-Emran, Elsherif, and Shaalan in 2016. In contrast, Pokémon Go provided a different effect in the implementation of AR in education. Through its utilization of Augmented Reality (AR) technology, the mobile game emerged as a cultural sensation, thereby showcasing the potential of AR technology to enter the mainstream market. The success of Pokémon Go revealed that augmented reality possesses the potential to be accessible, user-friendly, engaging, and effective in facilitating real-world exploration (Serino, Cordrey, McLaughlin, & Milanaik, 2016). In recent times, the educational community has capitalized on the widespread acceptance of Pokémon Go to incorporate Augmented Reality (AR) technology in teaching and learning techniques. This approach has succeeded in paving the way for developing stimulating and dynamic learning programs that enable learners to immerse themselves in interactive and enjoyable learning experiences (Klopfer & Sheldon, 2010).

The emergence of Google Glass in 2014 and the subsequent success of Pokémon Go in 2016 were crucial factors in acquiring attention from both developers and users of augmented reality (AR) technology, thereby highlighting its status as a significant tool in the field of educational technology.

**Third Generation (3GARE)**

Lastly, the third generation of Augmented Reality in education (3GARE) pertains to the AR systems from 2020 up to the future as stated by Garzón. 3GARE denotes a notable advancement beyond conventional modalities such as head-mounted displays and smartphones. The evolution in the field of augmented reality (AR) can be identified and classified according to three specific trajectories or scenarios, namely smart glasses, WebAR, and the integration of AR technology with Artificial Intelligence (AI) systems.

The initial scenario pertains to smart glasses, including HoloLens, Oculus Rift, as well as the upcoming iGlass. It is predicted that standalone headsets will become progressively prevalent. The International Data Corporation (2017) has projected a remarkable surge in the worldwide shipment statistics of these devices - from 225,000 units in 2017 to an expected total of around 32.7 million units in 2022. This observed growth suggests a prospective adaptation of augmented reality in diverse sectors, indicating a revolutional stance within the realm of education.

The WebAR scenario has been developed as a response to the reluctance of some users to install specialized mobile applications solely for the purpose of accessing augmented reality (AR) content. The utilization of WebAR technology facilitates access to augmented reality (AR) via the internet, which efficiently enhances user involvement with AR by eliminating the need for installation of an application. Despite the current efficiency deficit of WebAR compared to app-based AR, the potential for transformative web interactions and advancement of AR technology is significant (Rauschnabel, Rossmann, & tom Dieck, 2017).

Ultimately, the development of augmented reality (AR) and artificial intelligence (AI) represents the third and final scenario. The integration of Artificial Intelligence (AI) into Augmented Reality (AR) technology facilitates the convergence of physical and digital realms, providing new solutions to a variety of everyday problems. The integration of artificial intelligence (AI) enhances the quality of augmented reality (AR) experiences by facilitating a more realistic and immersive encounter, consequently providing advanced levels of application customization (Billinghurst, Clark, & Lee, 2015). The incorporation of AI integration has the potential to not only broaden the intellectual scope for developers and academics, but it also has the ability to introduce a powerful and revolutionary model for augmented reality in various industries, including education.

**Assess the influence of AR technology on knowledge acquisition and retention**

In the field of education, research studies have shown the positive impact of augmented reality (AR) on knowledge acquisition and retention across various disciplines. AR technologies have been found to enhance academic achievement, facilitate a deeper understanding of abstract concepts, and improve students' higher-order thinking skills.

A study conducted in 7th-grade education revealed that the integration of AR technologies resulted in significant improvements in academic achievement and a deeper understanding of abstract concepts (Kul and Berbe, 2022). By providing visual and experiential learning opportunities, AR bridges the gap between abstract ideas and tangible experiences, allowing students to comprehend complex concepts more effectively.

Similarly, in engineering courses, the application of AR has demonstrated significant differences in students' learning outcomes compared to traditional teaching methodologies (Vicente dos Anjos et al., 2022). Students who utilized AR in the teaching-learning processes consistently achieved higher levels of learning compared to those who did not use AR.

Moreover, in formal education settings, studies have shown that AR applications contribute to increased student motivation, satisfaction, and engagement (Saltan and Arslan, 2017). AR has been found to improve students' academic achievement, as measured by pre-test to post-test scores, and supports the development of higher order thinking skills, including problem-solving and critical and creative thinking.

**Explore personalized learning experiences enabled by AR systems**

The integration of augmented reality (AR) systems in personalized learning experiences offers numerous benefits for students. Participation in AR experiences has been found to increase student motivation, as measured by the Instructional Materials Motivation Survey (IMMS) (Loorbach et al., 2014). This survey evaluates dimensions such as confidence, attention, satisfaction, and relevance, which align with the personalized learning approach enabled by AR systems. Improved motivation has shown a significant relationship with enhanced performance and retention of learned information. Similar findings have been observed in studies focusing on the use of AR for personalized learning in university settings (Almenara et al., 2019).

AR systems also provide an opportunity for students to engage in immersive and personalized 3D learning experiences. By utilizing a combination of augmented reality toolkits, any lesson can be presented in a 3D format with zooming and viewing capabilities (El Sayed et al., 2011). This personalized approach allows learners to interact with content and manipulate virtual objects, enhancing their understanding and engagement.

Furthermore, AR technologies have proven effective in improving comprehension of complex or abstract subjects in personalized learning contexts. For example, studies have shown that utilizing AR technologies can facilitate a deeper understanding of intricate science concepts (Kul & Berbe, 2022). Additionally, in fields such as electrical engineering, the use of AR has been found to enhance concept comprehension and promote better understanding of the topics at hand (Kaur et al., 2022).

**Effectiveness of AR technology in improving student engagement and motivation**

AR technology can enhance scientific learning by visualizing complex concepts. A study conducted by Ziden, A & et al. (2022). NutricARd prototype delivers pedagogical content on the human digestive system. A comparative analysis compared NutricARd treatment to a control 9 group. Students are worried about having to download/print or scan the Zip code marker for the study, which interrupts their concentration. Although the issue arose upon starting with NutricARd, they were still motivated by its innovation. NutricARd boosted student motivation by 9% and improved academic performance. NutricARd improved student test scores, proving its effectiveness. The correlation coefficient of 0.895 indicates a strong link between motivation and academic performance. Augmented Reality tech boosts student involvement, motivation, and achievement.

Similarly a study by Shiue et al. (2019), AR technology was used to teach middle-school students about the human body structure. Research showed that pupils exposed to AR apps had higher academic achievement compared to non-exposed students. Augmented reality tech in education had a positive impact on motivation and engagement, resulting in superior academic outcomes.

Furthermore, Sirakaya, M., & Cakmak, E. (2018). studied the effects of AR technology on student engagement and motivation in computer hardware courses using the HardwareAR app, which focuses on motherboard assembly. AR technology improved student academic performance in motherboard assembly. The experimental group had faster assembly and higher proficiency than the control group. The investigation found that AR technology improves academic performance, fosters student engagement, and accelerates learning computer hardware-related curricula via immersive experiences.

In conclusion AR technology has positive effects on education and achievement. The NutricARd, HardwareAR, and augmented reality apps improve student motivation and engagement. AR technology is effective for complex ideas, improving understanding, and accelerating knowledge acquisition. Its importance in promoting successful educational experiences is highlighted by the link between motivation and academic achievement. AR technology can boost student engagement, motivation, and academic achievement in various scientific fields.

**Effectiveness of AR technology in collaborative learning**

According to a study conducted by El-Nahas, M. (2021). The results of the study indicate that the integration of augmented reality (AR) technology in the field of education has the potential to equip educators with engrossing digital media, enabling them to effectively engage and captivate learners in a more prompt manner. Furthermore, it enhances the level of collaboration between teachers and students within classroom settings.

A research study by Asquith, S. & Frazier, E. (2022) Choose Your Own Adventure (CYOA) AR digital storytelling studied how collaborative learning and AR can improve language learning. This approach has a powerful impact for students to effectively impact them in a positive manner. Based on the research findings students found using AR valuable. If AR applications become more widespread, adding AR projects in different teaching contexts would be a valuable improvement.

Furthermore, Their findings imply that the integration of augmented reality technology within a collaborative problem-solving context has a beneficial effect on the group's learning outcomes and ability to cooperate effectively Radu, I & et al. (2020). Moreover, augmented reality technology facilitated equitable participation of both individuals involved in the problemsolving tasks, ensuring a balance in their contributions. The results indicate that utilizing Augmented Reality (AR) in contexts that require problem-solving could potentially enhance equitable collaboration in settings where access to resources is imbalanced. Additionally, AR could serve as an aid for group learning more broadly.

In summary, the incorporation of augmented reality (AR) technology within the realm of education has demonstrated optimistic results. The utilization of this technology enhances the potential for educators to effectively engage and captivate learners, facilitates the cultivation of collaborative relationships between teachers and students, and ultimately contributes to an improved learning experience in regards to language acquisition. Applications based on Augmented Reality (AR) have been found to hold significant value among students, presenting diverse opportunities for enhancing the teaching and learning environment in multiple contexts. On top of that, the implementation of augmented reality technology in collaborative problemsolving exercises yields improved educational outcomes, facilitates effective teamwork dynamics, and fosters an environment of equitable participation amongst all members of the group. Overall, augmented reality (AR) possesses the potential to yield a positive impact on education as it offers captivating digital experiences, promotes collaborative practices, and fosters group learning.

1. **Summary**

Studies have found that using augmented reality (AR) technology in education boosts student motivation, engagement, and achievement. The NutricARd is a developed prototype by Ziden et al (2022) it is used to distribute educational content about the human digestive system. Students had to download/print or scan the Zip code marker for the study, which interrupts their concentration. However, it only arose at the beginning and NutricARd positively impacted student motivation by 9% and academic performance Ziden et al (2022). A Research by Shiue et al (2019). supports these findings. Their study found that middle-school students who used Augmented Reality (AR) apps had better academic performance than those who didn't. Furthermore Sirakaya, M., & Cakmak, E. (2018), studied the effects of AR technology on student engagement and motivation in computer hardware courses. Using the HardwareAR application improved students' ability to assemble motherboards, leading to higher academic performance. The intervention group performed assembly tasks more efficiently than the control group. Additionally, studies have explored AR technology in collaborative learning. AR fosters interactivity and cooperation between instructors and pupils, using captivating digital media that stimulates learners. Asquith, S. & Frazier, E. (2022) found that AR in language instruction with CYOA digital storytelling benefits students. Radu et al. (2020) highlighted AR's use in collaborative problem-solving, promoting fair participation and efficient teamwork. Overall, AR could have some lacking and issues that may arise, currently accessibility to technology, interruptions are one of its problems. However Augmented Reality technology improves education and academic achievement by enhancing learners' motivation, involvement, and scholarly attainment in diverse scientific disciplines. Augmented reality in education promotes immersive digital engagements, collaboration, and learning. The effectiveness of AR learning hinges on usability, intuitiveness, and satisfaction. Feedback, further research and data gathering about AR technology can improve in education.

It is noted by Gohoy (2022) that the implementation of AR technology in our education is now used especially on K-12 sectors. While it is stated that it is now being integrated in our education, there are several developments of prototypes that have gone testing and the results are promising. However, it is not fully implemented nor mandated for use. Such prototypes include HARA developed by Manuel Garcia and eS2MART Teaching and Learning Material developed by Sherryl Montalbo with the purpose of making the students become more engaged on a particular subject and also enhancing their spatial skills as stated by Sherryl Montalbo. While the intent and the potential is good, it comes not without problems as well. Garcia (2020) said that “the development and implementation of a mobile AR is daunting, complex, and expensive to develop”, meaning that its creation, development and integration will be challenging and we can see it as a challenge to implement AR that goes along the traditional way of teaching. The resources are also scarce for teachers that will use AR apps for educational purposes as stated by Virata & Castro (2019). Updates issues are also found as some bugs are never addressed nor fix, leaving the app on its mediocre state. All in all, the challenges include the complexity and expenses for its development, the lack of free resources and the time it takes to fully integrate a lesson to the technology. However, these AR technologies proved to be useful in education as well. Students have shown more interest and motivation towards the subject, increased their spatial skills and further developed student to student interactions and teacher to student interactions as well.

1. **Conclusion and Recommendations**

The researcher's preliminary stance resides with the promising and beneficial impacts in the education industry. The study of AR in education provided the researchers the knowledge, evaluation and investigation regarding augmented reality (AR). The investigation of augmented reality (AR) implementation in academic settings has brought to light its capacity to augment 15 learning through the integration of digital information with physical reality. Augmented Reality (AR) technology offers an all-encompassing and user-engaging experience that allows for the seamless integration of both virtual and physical objects. It provides a unique opportunity for hands-on exploration of intricate concepts, consequently enhancing the level of interactivity and immersive learning. Over time, this technology has undergone three generational advancements, culminating in increased accessibility and incorporation of artificial intelligence capabilities with smart glasses and WebAR. Augmented Reality (AR) has been found to enhance student engagement, motivation and academic attainment, particularly in scientific and linguistic domains. Augmented Reality (AR) has been increasingly garnering attention in the field of K-12 education in the Philippines. There have been proposals for the development of mobile AR applications that aim to enhance the learning experience. The implementation of Augmented Reality (AR) presents a number of impediments arising from technical requisites, inadequate availability of unrestricted resources and inconsistency in the quality of applications. Undoubtedly, augmented reality technology embodies significant potential for enhancing educational practices by means of immersive and interactive modalities. The impact of such technology on education is expected to be amplified, as the technology evolves and becomes more sophisticated. Therefore, the Researchers final stance remains the same as their preliminary stance, for the reason that numerous studies concluded a promising impact or effect of augmented reality (AR) technology in the domains of education, with expectations of facing challenges particularly the implementation having limited resources, technical issues, inconsistencies of applications, etc.

1. **References**

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. Foundations and Trends® in Human–Computer Interaction, 8(2-3), 73-272.

Billinghurst, M. (2002). Augmented reality in education. New horizons for learning, 12(5), 1-5.

Buchner, J., Buntins, K., & Kerres, M. (2022). The impact of augmented reality on cognitive load and performance: A systematic review. Journal of Computer Assisted Learning, 38, 285-303.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. Journal of science Education and Technology, 18, 7-22.

Garzón, J. A., & Acevedo, J. P. (2019). Meta-analysis of the impact of Augmented Reality on students’ learning gains. Educational Research Review, 27, 244–260. https://doi.org/10.1016/j.edurev.2019.04.001

Garzón, J. A. (2021). An Overview of Twenty-Five Years of Augmented Reality in Education. Multimodal Technologies and Interaction, 5(7), 37. https://doi.org/10.3390/mti5070037

Microsoft. (n.d.). What is augmented reality (AR) | Microsoft Dynamics 365. https://dynamics.microsoft.com/en-us/mixed-reality/guides/what-is-augmented-reality-ar/

Asquith, S. & Frazier, E. (2022). Using augmented reality for collaborative multimodal storytelling. https://files.eric.ed.gov/fulltext/ED625197.pdf

El-Nahas, M. (2021). The Impact of Augmented Reality on Fashion and Textile Design Education. https://digitalcommons.aaru.edu.jo/cgi/viewcontent.cgi?article=1543&context=faa-design

Radu, I., HV, V. & Schneider, B. (2020). Unequal Impacts of Augmented Reality on Learning and Collaboration During Robot Programming with Peers. https://dl.acm.org/doi/pdf/10.1145/3432944

Shiue, Y., Hsu, Y., Sheng , M & Lan, C. (2019). Impact of an Augmented Reality System on Students' Learning Performance for a Health Education Course. https://eric.ed.gov/?q=Impacts+of+Augmented+Reality+on+Students&id=ED605971

Sirakaya, M., & Cakmak, E. (2018). Effects on Augmented Reality on Student Achievement and Self Efficacy in Vocational Education and Training. https://eric.ed.gov/?q=Impacts+of+Augmented+Reality+on+Students&id=EJ1178349

Ziden, A., Ifedayo, A & Ziden, A. (2022). Effectiveness of Augmented Reality (AR) on Students’ Achievement and Motivation in Learning Science. https://eric.ed.gov/?q=Impacts+of+Augmented+Reality+on+Students&id=EJ1342916