**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**

**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.

**Status of Augmented Reality in Philippine Education**

In current times, Augmented Reality Applications have received increased attention. Augmented Reality is now widely used in the education sector at level K-12. AR is expected to be generally adopted in two-to-three years in higher education and four-to-five years in K‐12(Gohoy, 2022). There are also new emergence of significant proposals and prototypes that have been developed aimed to enhance the educational experience in our country. Example would be the HARA developed by Manuel Garcia and eS2MART Teaching and Learning Material developed by Sherryl Montalbo. Some of the purposes of applying AR technology in our current education system include ‘bringing history to life’ through a mobile application powered by augmented reality that can provide an immersive storytelling experience (Garcia, 2020) and also enhance the student’s spatial skills, an important student attribute in the STEM discipline, because of its capability to rescale virtual images and provide real time visualizations through tactile manipulations of virtual 3D images (Montalbo, 2021). AR technology in education also seeks to motivate students to engage in certain subjects such as history as most students find it boring, by leveraging connectivity, engagement, and accessibility of social media platforms, students exhibited enthusiasm in developing a deeper understanding of labor history where it was transformed from a collection of dates, facts, and figures into a study of people and their labor movement. Evidently, visualizing the past is critical in history education to allow deviation from the traditional memorization of historical dates, who killed who, and which countries colonized other countries. And what better way to widen the imagination for visualization than reliving the past by superimposing historical events onto the real world (Garcia, 2020).

While Augmented reality aims to help students be engaged in academic subjects, it is unavoidable that they may come with some challenges as well. Garcia (2020) stated that “As such, educational leaders are advised to define their goal first before diving into the development and implementation of a mobile AR app because it is daunting, complex, and expensive to develop. Furthermore, teachers have to learn how to design 3D models and animate them in order to add or extend the narrative scenes, not to mention the collective skills needed such as creativity, design conceptualization, scriptwriting, storytelling, pedagogy design, and technology expertise. This kind of instructional tool requires a team of developers for both content and technical aspects.” This means that producing content for an AR app will require a certain amount of technical and technological skill to maximize the use and capabilities of the said app. We can also state that the development of AR applications aimed for the enhancement of educational experiences can be complex due to reasons of having a limited amount of free resources for such tasks. Virata & Castro (2019) stated that “findings also show that teachers may have a hard time looking for free resources of apps that will meet their needs, and that there is a challenge in ensuring that misconceptions are avoided from AR apps’ oversimplification of visualization. Augmented reality is not without its difficulties to effectively utilize in the classroom setting. The teacher identified that although the app was designed for educational purposes, it does take time to design a lesson that fits perfectly to the purpose that AR can serve.” To reiterate the fact that there are limited resources for the use of AR, majority of the AR market leans more towards entertainment rather than educational purposes. This is one of the reasons why the pool of resources for the teachers are relatively low. There are also some cases where the developers have stopped updating their applications, resulting in unfixed bugs and errors. Virata & Castro (2019) perceived that “apps that are available are in relatively mediocre quality still. Some also no longer offer updates regularly. Theoretically, one can solve this problem by directly contacting the developers and informing them of the needed updates to their application. The inactivity of their download pages would however suggest that this would yield no fruit.”

The impact of AR technology in the education area in our country proved to be advantageous for the students as it enhanced student engagement on a particular subject. In the essence of HARA AR app, Garcia (2019) stated that “By infusing HARA in class discussion, co-designers were motivated and had a positive attitude towards the history subject that is perceived as boring by others; hence, the acceptance of HARA for educational environments by co-designers. However, there was no perceived change in personal knowledge of American colonization.” In that case, the motivation and the attitude towards the subject significantly improved. However, in the case of personal knowledge about a subject, there was no perceived change. We can conclude however that on the initial test of an AR app, there might be minimal to no change on the subject knowledge but if students will become more engaged on the subject, there is a significant chance that they gain knowledge easier than by using traditional methods of learning. Motivation towards a particular subject have also improved. Observations also show excitement among the students, a great intention to learn to become part of the class discussion. Students participated during the discussion, having a much better set of explanations to teacher-made questions. Student motivation is also apparent as they have been observed to raise more questions than usual. (Virata & Castro, 2019). There is also evidence that proves that the spatial skills of students were enhanced by means of AR technology. Montalbo (2021) finds that “the normalized high learning gains in content specific test items that require visualization, spatial orientation and spatial relations signify that by using augmented reality as a component in teaching and learning can enhance spatial skills of students, a trait that is very important for academic success in chemistry and in STEM discipline in general.” There are also findings that by infusing AR technology in our education system or in classroom setups, there is an obvious increase in student to student interaction and teacher-student interaction in Philippine classrooms. Virata & Castro (2019) have observed that “Students exhibited more interaction among themselves for various reasons. Some students sought guidance from each other on how to utilize the tablets and the cards, the use of the cards and their proper facing, along with the orientation of the camera. The use of augmented reality app fostered a chance for peer teaching and guidance. Observation reports also show that students have interacted more with the teacher. As mentioned previously, students had a tendency to raise more questions than usual, hence, requiring more opportunity for the teacher to interact with them. Students show strong interest to seek answers to questions relating to the usability, interface and meaning of the augmented reality visualization. It can be surmised that more teacher supervision is necessary during the lesson, for students may take time to develop familiarity with such new technology. However, students’ questions eventually changed from interface-related to more meaning-making attempts.” In general, the infusion of AR technology in our education system increased the student’s engagement in their particular subject even in the subject perceived as “boring” such as history. As stated by Godoy (2022) “As shown in the results of the review, AR has been proven to help organizations and teachers in teaching different STEM disciplines and can be applied here in the Philippines as well as in other areas of the region. Studies have shown that the use of AR can be more efficient in teaching support than other technology-enhanced settings”. Within those trends, we can conclude that AR technology can improve the student’s motivation and appreciation towards the subject, the increase of interaction between students and students and also students and teachers and also enhancing the student’s spatial skills through the means of AR on other subjects as well.

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- 14 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 Recommendation**

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.

**Recommendations:**

The study is recommended for the following individuals as this study can greatly help them: students, teachers, AR developers and other researchers. Students are recommended to study this research because students can acquire ideas about the background of AR technologies particularly to its influence on education and how they can use it to its full potential. Teachers are recommended to study this research so that the said educators can have additional options to educate learners in a more technological way and how these technologies improve their lesson delivery and the overall performance of the students in the class. The research is also recommended for AR developers as they can use this study for their reference on how to improve the current advancements of AR technology here in the country as they can use this document for addressing the challenges currently being faced by AR technology in this current time. And lastly, other researchers are also recommended to use this research for their reference if the latter would like to use our study as a tool for making a research about AR with significant improvements and a wider scope.

      The researchers would like to recommend that in studying or researching about AR capabilities, the individuals who would wish to use AR technology as a study  should focus more on the challenges being faced by the current AR technologies and how to address it because if problems are addressed, positive influence are maxed out because the AR will prove more efficient and can have better ways and outcomes for completing its objectives.

       The researchers would also like to recommend a few points for the overall essence of Augmented Reality in education. One recommendation would be to make this technology accessible to any students. One challenge of this technology is that it is expensive, so making it a tool that is easily accessible means that no one will be left behind in educational advancements by integrating this tool in traditional classroom activities. Another recommendation would be for the developers to commit to the development of any AR app as it was mentioned in the challenges part of the research that some developers “abandon” their work and that some errors or bugs remain unresolved. Lastly, the researchers would also like to recommend the tutorial of the usage of AR technology especially to teachers that does not have a deep technological literacy. Tutorial must be facilitated before fully integrating an AR technology as a mandatory part of traditional education. The tutorial will include proper usage, safety, and troubleshooting in case some problems arise.

1. **References**

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>

Garcia, M. B. (2020). Augmented reality in history education: An immersive storytelling of American colonisation period in the Philippines. Augmented Reality in History Education: An Immersive Storytelling of American Colonisation Period in the Philippines. <https://manuelgarcia.info/publication/augmented-reality-history-education#MBG-LITERATURE-REVIEW>

Godoy, C. H. (2020). arXiv.org e-Print archive. https://arxiv.org/ftp/arxiv/papers/2203/2203.07024.pdf

Montalbo, S. M. (2021). ES2MART teaching and learning material in chemistry: Enhancing spatial skills thru augmented reality technology. Philippine EJournals| Home. <https://ejournals.ph/article.php?id=17595>

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

Virata, R. O. & Castro, J. D. L. (2019, January 10). Augmented reality in science classroom | Proceedings of the 10th International Conference on E-education, E-business, E-management and E-learning. ACM Other conferences. https://dl.acm.org/doi/abs/10.1145/3306500.3306556

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>

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/