Evaluating the Feasibility and Resource Implications of an Augmented Reality-Based E-Learning Application: A Comprehensive Research Analysis

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Abstract- In this study a detailed cost estimation shows the financial commitment required to implement hybrid pedagogies in educational institutions. The enormous financial burden of these innovative teaching methods is shown by the large difference in average student costs between conditional and experimental groups—PKR 229.24, 228.08, 255.6, and 303.02. PKR 229.24 per student is consistent in the conditional group, excluding electronic hardware expenditures, while the experimental groups climb 19,729.9%, 17,605.6%, and 14,883.5% to PKR 45,228.1, 45,255.6, and 45,403, respectively. With electronic hardware gadgets and gamification benefits, these educational advances may be less universally applicable due to rising costs. These technologies could improve learning, but cost restrictions may prevent certain institutions from adopting them. The investigation contrasts hybrid and traditional classroom resource costs. The hybrid design gives students program-management tools despite higher costs. Affordable hardware like the Xiaomi Mi Poco X4 at 45,000 Pakistani Rupees is recommended. When using hybrid pedagogies, benefits and budgetary implications must be balanced. Institutions should perform rigorous financial evaluations before transforming education. Detailed cost breakdowns let organizations evaluate the feasibility and financial viability of novel teaching methods.

Index Terms- Augmented Reality, E-Learning, Hybrid Pedagogy, STEM

I. INTRODUCTION

Education has experienced a significant transition, embracing technological breakthroughs that go well beyond the approaches that have traditionally been used. Computers, cellphones, smart boards, and a myriad of augmented reality applications are now commonplace in today's classrooms. Each of these programs endeavors to improve the learning experience in its own special way. The technology known as augmented reality (AR) stands out as a particularly promising tool among these developments because it has the ability to seamlessly integrate virtual elements into the very fabric of the real environment [1]. Even though there is a tremendous increase in the amount of research being conducted on the possibilities of augmented reality (AR) in education, there is still a lack of thorough research on the viability of AR and the implications it has for resources, particularly in the context of e-learning applications [2]. This analysis intends to fill this knowledge gap by conducting an in-depth investigation of the current state of augmented reality (AR) in education, investigating the possible benefits and problems associated with it, and methodically deconstructing the resource demands that are associated with it. This study draws inspiration from a wide range of fields, building upon previous research attempts that have been undertaken. The investigation that Abdul Hayee Baig conducted into the many methods of freelancing for beginners offers light on the ever-changing landscape of educational prospects [3]. While this is going on, investigations into interactive STEM education in online environments that have been carried out by other people offer vital insights into the potential of technology to alter learning paradigms [4]. Studies that have been undertaken on the learning impacts of tailored video game simulators, which demonstrate the efficacy of gamified experiences, have further enriched this exploration [5]. These findings are further supported by the unique deployment of a Smart Aquarium System implemented by students at HITEC University through the Internet of Things. This deployment exemplifies the limitless possibilities that can be achieved through the integration of technology in educational settings [6]. Data points that are crucial for determining the usefulness of augmented reality (AR) are provided by comparative evaluations conducted by computer scientists. These assessments rigorously evaluate the influence of AR on classroom performance in comparison to traditional approaches [7]. Using this varied basis as a foundation, the current study goes deeper into the fascinating world of augmented reality-based e-learning, with a particular emphasis on the practicality of this approach for the teaching of ninth-grade physics. A characteristic that can be easily witnessed in popular mobile augmented reality applications such as Pokémon GO and AR GPS navigation [8] is that augmented reality's intrinsic hybrid nature, which expertly blends virtual things with the user's real environment, stimulates an unprecedented level of interactive engagement with virtual information. Because augmented reality (AR) maintains the familiar context of the actual world, it may be less unsettling and more quickly accepted by pupils [9]. Virtual reality, on the other

hand, entirely immerses users in a digital universe. As Akçayır and Yalçın aptly captured in their meta-analysis of empirical research on augmented reality in education [10], the effective integration of augmented reality (AR) into the classroom requires careful consideration. This is because students' ability to navigate through vast amounts of data and a variety of technological tools can be overwhelming. It is dependent on the delicate interaction of numerous important elements whether or not augmented reality-based online learning is feasible: The pedagogical design of augmented reality applications requires that they be properly developed in order to connect with certain learning objectives and to apply instructional methodologies that are effective. As Abdel-Hamid's experiment on the impact of an augmented reality application on learning motivation excellently indicates [11], frameworks such as the ARCS model, which encompasses Attention, Relevance, Confidence, and Satisfaction, provide a great path for analyzing student motivation inside augmented reality environments. Considerations of a Technical Basis: It is necessary to pay careful attention to technical factors in order to ensure a seamless user experience in augmented reality-based online learning. Hardware compatibility is of the utmost importance, guaranteeing that all students have access to devices that can engage with the augmented reality application in a seamless manner. The development of software, which calls for specific skills and platforms that are strong, is an essential component in the production of high-quality augmented reality content. Another key component is dependable internet access, which enables the seamless transfer of data between various applications and devices. Studies such as the one conducted by Quwaider et al., which investigated the behavioral effects of video games, provide useful insights into potential engagement tactics that can be utilized in the process of building effective augmented reality-based e-learning apps [12].Support and Training for Teachers: Educators who have been charged with the responsibility of incorporating augmented reality (AR) into their curriculum require sufficient training and ongoing support. The research conducted by Cui and colleagues on the topic of perceived teacher excitement shows the significance of cultivating a positive and engaging learning environment. This involves ensuring that teachers are comfortable and confident in their ability to use augmented reality technology [13].It goes without saying that putting augmented reality-based e-learning into action requires careful consideration of the resource requirements that are associated with it: The creation of augmented reality (AR) content and applications of a high quality can be a resource-intensive operation that calls for specific expertise, powerful software platforms, and possibly the hire of specialist developers. An Investment in the Infrastructure: In order to guarantee that students and teachers have access to the appropriate technology, it is necessary to make investments in devices such as smartphones or tablets. Additionally, it may be necessary to upgrade the infrastructure that is already in place in order to accommodate the growing demands for internet bandwidth or processing capacity. Support and Maintenance on an Ongoing Basis: It is necessary to have dedicated resources in order to maintain augmented reality applications and provide technical assistance during the installation process. These resources should include professionals who are skilled in diagnosing and maintaining both hardware and software elements. Through the lens of pedagogical design, technical considerations, teacher training, and resource demands, educators and policymakers are able to make informed decisions regarding the incorporation of this promising technology into their respective educational environments. This is accomplished by conducting a critical evaluation of the feasibility and resource implications of augmented reality-based an online learning environment. This thoughtful evaluation has the potential to pave the path for a future [14].

II. Literature Review

When it comes to the educational scene, augmented reality (AR) has emerged as a game-changing technology that offers unique ways to improve learning experiences. A substantial body of literature has evolved as a result of educators and academics investigating the possibility of incorporating augmented reality (AR) into e-learning systems. This literature sheds insight on the possible benefits, obstacles, and resource implications of using AR. In order to provide a thorough overview of the present status of augmented reality (AR) in education, this literature review provides a synthesis of major studies. The review focuses on the viability of AR in education as well as resource considerations. Researchers Danish et al. [15] looked at the possibility of enhancing home automation through the implementation of Brain-Computer Interface (BCI) technology. This study demonstrates the wide range of uses for augmented reality technology, which is not directly related to education. It also paves the way for further investigation into the possibilities of this technology in online education. The researchers stressed the significance of adopting cutting-edge technology, which is in line with the overarching subject of investigating the practicability of educational settings. In Pakistan, Danish et al. [16] did a study to evaluate the effectiveness of an augmented reality (AR)-based e-learning application on learning outcomes. This study was built on the basis that was established earlier. VARK analysis and hybrid pedagogy were utilized by the researchers in order to investigate the impact that augmented reality has on a variety of learning styles. The findings of this study provide important insights into the possible usefulness of augmented reality (AR) in accommodating a variety of learning preferences. These insights are essential for determining whether or not widespread adoption is feasible. The System Usability Scale was utilized by Danish et al. [17] in order to evaluate an augmented reality e-learning application within the context of another study that focused on user experience. In addition to incorporating a user-centric perspective into the feasibility study, this research highlights the significance of user happiness and usability in determining the level of success that augmented reality applications achieve in educational environments. A contextual background for the application of augmented reality was provided by Yar Khan et al. [18], who investigated the network architecture in order to gain a better understanding of the wider technological landscape in Pakistan. This study highlights the significance of technological

infrastructure, which is a critical aspect in the assessment of the feasibility of augmented reality-based e-learning applications. Although it does not directly address education, this study does highlight its importance. The importance of time restrictions in secondary schools was brought to light by Danish et al. [19], who investigated the temporal complexity that are present in hybrid pedagogies that are based on augmented reality. The purpose of this study is to shed light on a nuanced aspect of feasibility, specifically how augmented reality apps operate under the temporal limitations of educational contexts. The findings of this study provide educators and developers with significant insights. The body of research goes beyond studies that are unique to augmented reality and encompasses more general talks on STEM education. Tsupros, Kohler, and Hallinen [20] placed a strong emphasis on the identification of missing components in STEM education. This is a reflection of the continuous discourse on the role that technology plays in bridging educational gaps. The purpose of this study is to establish a theoretical basis for evaluating the wide-ranging effects that augmented reality (AR) has on education. A number of researchers, including Resnick [21], Khanlari [22], Ludi [23], and others [24-27], have brought attention to the numerous ways in which technology can be utilized in STEM education. These applications include robotics and fun learning. Although these studies are not directly related to augmented reality (AR), they highlight the need to adopt technology changes in order to encourage student involvement. This is an essential factor to take into consideration when determining whether or not AR applications are feasible. To summarize, the literature that was examined provides a multidimensional perspective on the function that augmented reality (AR) plays in the field of education. This perspective emphasizes the user experience, technological infrastructure, learning outcomes, and time restrictions. The combined findings of these research make a contribution to the continuing discussion over the practicability and resource implications of incorporating augmented reality-based e-learning systems into educational environments. A basis for an all-encompassing study analysis in this ever-evolving topic is established through the synthesis of these various points of view's perspectives.

III. METHODOLOGY

The goal of this research project was to find out how augmented reality (AR) technology could change the way physics is taught by making and using an e-learning platform built on AR. The main goal was to find out how augmented reality (AR) affects how interested and knowledgeable students are about physics concepts.

Figure 1 Kinetic energy menu in app view from an angle

What the study was trying to find out at the same time was why educational institutions don't want to use this new technology, with a focus on how limited budgets stop broad adoption. In the beginning, it was said that augmented reality is becoming a bigger part of education, with a focus on how it might help teach science.

The study's results show that augmented reality could make learning more immersive and collaborative. This is a one-of-a-kind chance for students to connect with abstract ideas in virtual worlds that are three-dimensional. During the project's development part, a very detailed augmented reality (AR)-based e-learning platform for studying physics was made. Students could interact with virtual items and learn difficult subjects in a way that was easier to understand thanks to the platform, which tried to show physics ideas visually in a way that was useful and fun. By using this method, the goal was to help people understand and remember physics concepts more deeply. After careful examination, it was decided that the augmented reality-based e-learning tool was indeed useful for learning. It was found that augmented reality-based learning helps students understand difficult physics concepts better. This was shown by looking at things like student engagement, comprehension, and success. The first results showed that students were more interested and better at what they were doing when they were in the augmented reality learning setting. At the same time that the study looked at how effective education is, it also looked into the problems that schools have when they try to use virtual reality-based technology for learning. We were surprised to hear that institutions were worried about the beginning costs of installing augmented reality infrastructure, which was seen as a major obstacle. For this reason, a study into the viability of augmented reality technology was carried out. This revealed that, despite the high initial costs, AR gadgets were a cost-effective investment in the long run. The study gave a thorough look into the possibilities of augmented reality (AR) in teaching physics, as well as the money issues that keep it from being used more widely. Augmented reality (AR) was seen as a good way to improve the quality of physics teaching by the study. The reason for this was to show that virtual reality-based e-learning will last for a long time. The results add to the ongoing talk about how to use new technologies in schools and offer ideas for how to get

around budget problems so that augmented reality is used by more people.

This research project was to build and implement an augmented reality (AR)-based e-learning platform in order to evaluate the degree to which augmented reality (AR) technology has the potential to revolutionize the teaching of physics. The primary purpose was to assess the effect that augmented reality (AR) has on the level of engagement and comprehension of physics ideas among students. Concurrently, the study studied the concerns that educational institutions have regarding the use of such cutting-edge technology, with a particular emphasis on the financial constraints that prevent widespread integration. The introduction emphasized the growing significance of augmented reality in the field of education, with a particular focus on the potential advantages that it could bring to the teaching of physics. According to the findings of the study, augmented reality has the potential to deliver an immersive and interactive learning experience. This presents students with a one-of-a-kind opportunity to interact with abstract concepts within three-dimensional virtual settings. During the time of development, the project painstakingly developed an augmented reality (AR)-based e-learning platform that was intended for the instruction of physics. The purpose of the platform was to provide students with the ability to control virtual objects and investigate complex concepts in a more natural manner. Its goal was to visually convey physics theories in a physical and interactive manner. The purpose of this technique was to encourage a more profound comprehension of physics principles as well as their retention. A complete study was carried out in order to determine the educational effectiveness of the augmented reality-based e-learning platform. As part of this evaluation, metrics such as student engagement, comprehension, and performance were taken into consideration. The preliminary findings suggested that there is a favorable association between augmented reality (AR)-based learning and improved comprehension of physics concepts. This was demonstrated by students demonstrating increased enthusiasm and proficiency in the AR learning environment. At the same time, the research investigated the difficulties that educational institutions encounter while attempting to implement augmented reality-based e-learning platforms. An investigation on the whole cost of augmented reality operating devices and the expenses that are related with them was prompted by the fact that financial considerations surfaced as a significant hurdle.

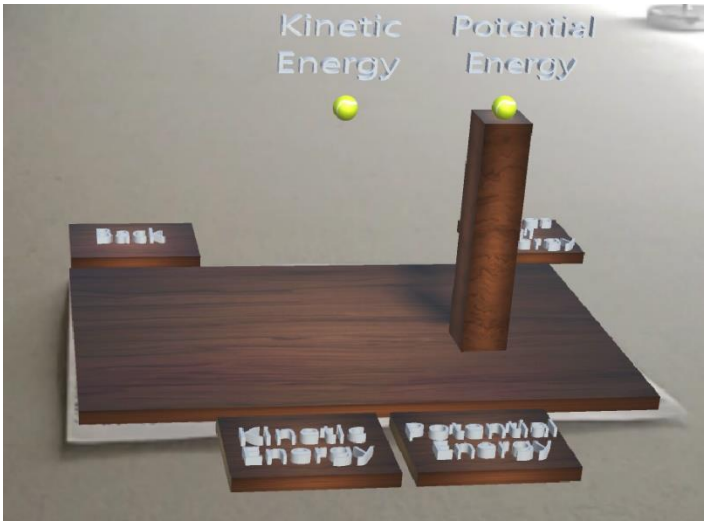

Figure 2 Types of energy menu in app view from an angle

Following that, these costs were contrasted with those of traditional learning approaches, which resulted in the revelation of a deeper understanding of the financial consequences of virtual reality integration. Surprisingly, the research discovered that despite the initial expenditure that is necessary for augmented reality infrastructure, the lifespan of AR devices caused them to become a cost-effective investment over the course of time. The investigation of institutional constraints was given further depth by this insight, which also helped to a more comprehensive understanding of the possibility of augmented reality-based online education. The study shed light on the benefits that augmented reality (AR) could bring to the field of physics education as well as the cost barriers that are preventing its broad implementation. This study made a significant contribution to the field of education by providing vital information for educational institutions that are contemplating the incorporation of innovative technologies. The study calculated the overall cost of augmented reality operating devices and compared it with traditional learning approaches. The findings highlighted the long-term viability of augmented reality (AR)-based e-learning, establishing it as a feasible investment in the process of improving the quality of physics education. At the end of the study, solutions were provided for overcoming budgetary obstacles and encouraging a more inclusive adoption of augmented reality (AR) in educational settings.

IV. Results

Given the significant financial commitment that is required to support these innovative teaching approaches, cost estimation is an essential component that must be considered when determining whether or not it is feasible to incorporate hybrid pedagogies into educational institutions. Educational institutions who are looking to fund and maintain programs of this nature face a severe obstacle in the form of the financial challenge that is posed by these pedagogical shifts. There was a difference in the average cost per student between the conditional group and the experimental group, which was PKR 229.24, PKR 228.08, PKR 255.6, and PKR 303.02. This was determined by excluding the cost of electronic hardware items. It is noteworthy that the

average cost per student for the conditional group continues to be PKR 229.24. This is due to the fact that electronic hardware devices are not a required component. However, when electronic hardware devices for the experimental groups are taken into consideration, there is a significant increase in expenses. As a consequence, the costs per student have increased to PKR 45,228.1, PKR 45,255.6, and PKR 45,403, respectively. These numbers demonstrate that there has been a significant rise in the amount of money spent on each student by these experimental groups, which amounts to 19,729.9%, 17,605.6%, and 14,883.5%, respectively. In conclusion, the exponential increase in costs per student that can be attributed to the incorporation of electronic hardware devices and the expenses associated with gamification rewards suggests that the implementation of these pedagogical changes, in conjunction with the implementation of educational technology, might not be universally applicable to all educational institutions. Nevertheless, the incorporation of these technologies has the potential to dramatically improve the overall learning experience for educational institutions that are able to secure the necessary money. While this highlights the complicated nature of financial issues, it also highlights the necessity for institutions to carefully analyze their financial capacities before embarking on educational programs that have the potential to revolutionize the educational system. Furthermore, in order to acquire a more nuanced comprehension of the monetary repercussions, it is of the utmost need to investigate the precise cost breakdowns that are related with electronic hardware devices and gamification awards. The purpose of this investigation is to throw light on potential areas for optimization and efficiency, which will enable educational institutions to make informed decisions regarding the feasibility and financial viability of implementing these novel pedagogical approaches.

The amount of money (resources) that is necessary to fulfill each methodology's requirements is what is referred to as the resource cost estimation analysis. This analysis takes into account both the conventional instructional model and all of the hybrid pedagogies that were utilized in this experiment. The graph illustrates the total cost of each student sitting in each classroom setup.

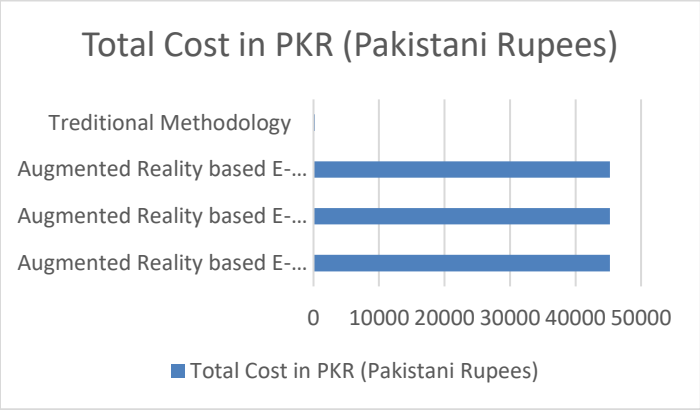

Figure 3 Average Cost per Student in all Groups

This graph also demonstrates the significant disparity that exists between the hybrid classroom environment and the traditional classroom environment. On the other hand, students who were enrolled in the hybrid classroom environment were given the tools that were required to operate the application in order to ensure that the entire instructional process was carried out in the most effective manner possible. The entire cost that the educational institution needs to have in order to support such a hybrid pedogeological situation should be as low as possible, and the hardware should be as economical as possible. The augmented reality (AR) based e-learning application must, at the very least, be able to run on an Adreno 618 graphical processing unit (GPU). Therefore, in order for it to function properly, an ideal Android device would be a phone that is the least expensive, has thermals that are satisfactory, and a GPU that is superior to the Adreno 618. Additionally, the phone should have a minimum of 6 gigabytes of random-access memory (RAM). Therefore, the Xiaomi Mi Poco X4 would be the best possible phone. The Adreno 620 found in the Xiaomi Mi Poco X4 is superior to the Adreno 618, and it also features 8 gigabytes of random-access memory (RAM) and great thermals. The pricing of the Xiaomi Mi Poco X4 is 45,000 Pakistani Rupees (which includes taxes). Therefore, the total money that the students added as their own expenses is increased by the price of the Xiaomi Mi Poco X4, which is 45,000 Pakistani Rupees (PKR). Additionally, a reward system consisting of 5000 Pakistani Rupees was incorporated into the pedagogy that incorporates gamification. A histogram serves as a visual depiction of data, illustrating the frequency and distribution of a given set of values. The histogram presented herein illustrates the responses obtained from forty educators with respect to the viability of an augmented reality (AR)-driven electronic learning application. The educators were requested to offer their viewpoint regarding the viability of the augmented reality (AR) e-learning application, taking into account a range of factors such as available resources. The two possible responses are represented by two bars in the histogram: "For AR" and "Against AR" The vertical dimension of each bar represents the proportion of educators who supplied the corresponding response. 60% of the instructors in this scenario indicated that it is possible to utilize the augmented reality-based e-learning application to learn from all angles, including resources. A taller bar is indicative of this on the " For AR " side of the histogram. Conversely, forty percent of the educators stated that the AR-based e-learning application is impracticable. A shortened bar appears on the "

Against AR " side of the histogram to indicate this.

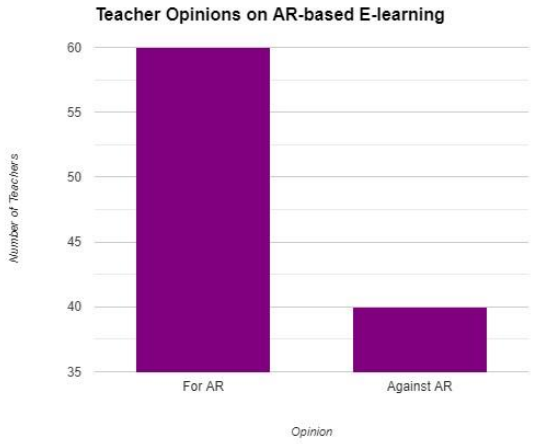

Figure 4 Opinion of Teachers for AR Based E-Learning Application

The histogram offers a lucid visual depiction of the dispersion of teacher perspectives concerning the viability of the augmented reality (AR) e-learning platform. It demonstrates that a considerable minority of educators hold the view that the application is not feasible, whereas the majority perceives it as viable. The utilization of this visual depiction facilitates a prompt and effortless comprehension of the general sentiment expressed by the surveyed educators, thereby providing significant perspectives on the reception of the augmented reality (AR) e-learning application within the realm of education.

V. Conclusion

It is concluded that the incorporation of hybrid pedagogies into educational institutions necessitates a significant financial commitment, as demonstrated by the examination of cost estimation. Institutions that have the goal of funding and maintaining such programs face a substantial impediment in the form of the financial challenge that is posed by these new teaching methodologies. There was a significant disparity between the conditional and experimental groups in terms of the average cost per student, with numbers of PKR 229.24, PKR 228.08, PKR 255.6, and PKR 303.02 respectively. This was the case when electronic hardware products were excluded from the calculation. Given that there were no costs associated with electronic hardware devices, it is noteworthy that the conditional group maintained a stable average cost per student of PKR 229.24. The experimental groups, on the other hand, had a huge increase in costs per student, which reached PKR 45,228.1, PKR 45,255.6, and PKR 45,403 correspondingly. This represents a significant increase of 19,729.9%, 17,605.6%, and 14,883.5%, respectively. It is important to note that the significant increase in expenses brings to light the potential constraints in universal applicability of these pedagogical improvements, particularly when adding electronic hardware devices and gamification rewards. The introduction of these technologies has the potential to significantly improve the overall learning experience for those institutions that are able to get the necessary money, despite the fact that these financial problems may constitute obstacles for certain institutions. In addition, the analysis digs deeper into the assessment of resource costs, highlighting the differences between hybrid and traditional classroom settings. In spite of the additional expenditures that were associated with the hybrid configuration, students who were in this environment were provided with the necessary tools for the most effective operation of the program. It is of the utmost importance for educational institutions to decrease total costs and guarantee that hardware is affordable. Specific recommendations are made for an Android smartphone such as the Xiaomi Mi Poco X4, which provides great performance at a price that is acceptable at 45,000 Pakistani Rupees. When these data are taken into consideration, it becomes abundantly evident that the effective adoption of hybrid pedagogies requires a careful balance between the potential benefits and the related budgetary implications. Before beginning on such revolutionary educational endeavors, institutions need to do a thorough analysis of their financial capabilities. In addition to this, the detailed cost breakdowns that are supplied provide useful insights into prospective areas that could be optimized and made more efficient. Having such a broad understanding gives educational institutions the capacity to make well-informed decisions regarding the practicability and financial sustainability of incorporating these innovative pedagogical approaches within their own educational systems. The histogram presents a comprehensive overview of various viewpoints concerning the viability of an augmented reality (AR)-driven e-learning application, as determined by the responses of forty educators. The visual representation of the distribution, which consists of bars labeled "Feasible" and "Not Feasible," indicates that 60% of educators perceive the application as viable, whereas 40% hold the opposite view. This succinct depiction highlights the uneven reception of cutting-edge educational technologies, underscoring the necessity of recognizing varied perspectives in order to adopt an inclusive stance towards the integration of augmented reality-based e-learning applications in the field of education.

I. Future Work

Future studies should address financial hurdles for hybrid pedagogy institutes. Researching alternate funding structures, partnerships, or affordable technology may provide results. A detailed study of the long-term effects of AR-driven e-learning applications on student results and engagement is needed. These techniques should be tested in multiple educational settings for cultural and institutional scalability. Continuous monitoring and assessment will improve hybrid pedagogies, creating an adaptive and sustainable teaching environment.

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