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UTILIZATION OF AUGMENTED REALITY TO STUDY ELECTRONICS

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Abstract: In recent years, there has been an enormous increase in the use of Augmented Reality (AR) technology in classrooms, with a specific emphasis on its application in enhancing the learning of electronics concepts. This review paper presents a comprehensive analysis of the studies conducted in this domain, aiming to assess the efficacy of Augmented Reality (AR) in electronics education. A comparative analysis of the Experimental group and the Control group reveals significant trends. The Experimental group consistently demonstrates higher mean performance and lower standard deviations, indicating that AR technology positively influences the learning outcomes and reduces variability in student performance. These findings underscore the potential of AR to revolutionize electronics education by offering more engaging and effective learning experiences. In conclusion, the integration of AR holds promise for improving electronics education and preparing students for the challenges of this dynamic field.

***Index Terms* -** Augmented Reality, Electronics Education, Learning Enhancement, Educational Technology, Interactive learning environments.

I. INTRODUCTION

The utilization of Augmented Reality (AR) technology in the realm of education has emerged as an effective approach [10], particularly in the context of imparting knowledge and understanding complex concepts in the field of electronics. In traditional educational settings, the dissemination of knowledge, particularly in complex domains like electronics, often relies on conventional methods, such as textbooks and two-dimensional (2D) images. However, this conventional approach may fall short in providing students with a deep and engaging understanding of three-dimensional (3D) concepts, leading to diminished enthusiasm and attention during the learning process. Augmented reality (AR) technology, characterized by its ability to have a perfect combination of virtual and physical objects, presents a revolutionary resolution to in education [2]. The studies have shown that incorporating AR into the learning environment has the potential to significantly enhance the educational landscape. It increases students' engagement, making learning a more enjoyable and rewarding experience, while also positively impacting their motivation and comprehension [3]. As technology advances, Augmented Reality and virtual reality (VR)-based applications are gaining traction within all the sectors profoundly leaping faster into the education sector, demonstrating and exploring enormous promises in imparting difficult hardcore concepts and theories in a more natural and expressive, visualizable manner [4][5]. The application of AR technology in learning environments not only aids students in comprehending complex concepts and intricate procedures but also enhances their motivation and interest, thereby facilitating a more effective learning experience [6]. Additionally, it empowers educators and teachers to design instructional content that is visually appealing and engaging. Furthermore, AR has the potential to alleviate the teaching burden on instructors, making the educational process more manageable and efficient [6].

In the context of science and engineering education, where understanding abstract principles and concepts is crucial, technology intervention becomes indispensable. It is essential to enhance students' ability to visualize and grasp intricate and abstract topics, utilizing technology to enrich the learning environment [7]. Integrating technology into education enables students to visualize engineering concepts in multiple dimensions, aiding in knowledge interpretation and maintaining their focus and engagement [8][9].

The following figure 1 illustrates the AR in learning and training.

Figure 1. Concept of AR [10]

AR emerges as a particularly promising technology for enhancing the teaching and learning of subjects like Electronics and Electrical Engineering, where a profound understanding of circuit connections, current flow, and circuit element principles is essential [11]. Complex abstract concepts that are challenging to visualize can hinder students' comprehension and negatively impact their attitudes toward the subject. To address these challenges, the integration of interactive and immersive technologies, such as AR and VR, is becoming increasingly important. These technologies enable students to visualize abstract concepts effectively, thus improving their understanding [12].

For instance, using 3D simulations to illustrate the movement of electrons within a circuit can elucidate the working principles of electronic circuits within a conventional laboratory setting. This approach leads to the development of more relevant educational environments that enhance students' academic achievements and foster positive attitudes toward learning [12]. AR plays a pivotal role in improving teaching-learning environments by offering visualizations of abstract concepts and facilitating practical observations of complex topics that would otherwise be challenging to grasp.

In Consideration of the notable potential of AR in education, the study focuses to investigate the impact of AR technology on school students' interest along with their academic achievements in science learning. AR, being an interactive technology that combines the real world with virtual objects, offers enhanced realities, augmenting digital content such as images, videos, 3D models, animations, and more over the real world. By developing dynamic learning settings, AR has the ability to improve students' interest and motivation, making complicated and abstract subjects more accessible and improving their concentration levels [13][14].

In conclusion, the integration of AR technology into the teaching and learning of electronics and related scientific disciplines holds immense potential. It addresses the limitations of traditional educational methods by providing students with immersive 3D visualizations of complex concepts, thereby enhancing their comprehension, motivation, and overall academic achievements. AR is not merely a technological innovation; it represents a paradigm shift in education, one that is poised to revolutionize the way students learn and engage with complex subjects.

II. AUGMENTED REALITY

Augmented Reality (AR) is a technology which plays an important role podcasting its application to several fields today [15]. A very recent concept increasing in prevalence, AR can be defined as real environments enriched with virtual objects. Figure 2 given below illustrates the necessary elements involved in the architecture of AR.

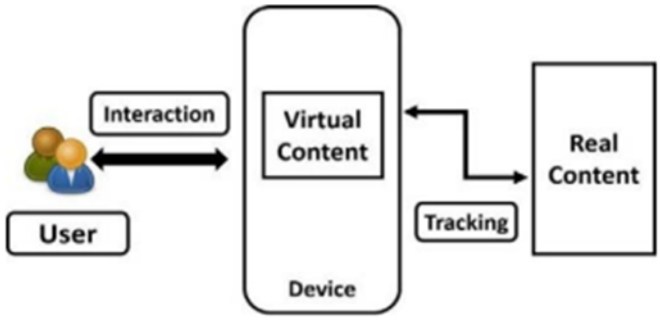


Figure 2. Architecture of Augmented Reality [16]

AR overlays digital imagery onto the real world through hardware players such as Microsoft HoloLens, Google Glass, and Magic Leap [17]. AR thus, combines both physical and virtual objects. AR helps in the simulation of the experiments performed in electronic laboratories, where the practice and theory of electronic engineering are combined. AR has found applications across diverse industries, revolutionizing the way people interact with information and surroundings.

III. APPLICATIONS OF AR

AR is finding diverse and innovative applications across various industries, revolutionizing the way we interact with the world and digital information.

1. **Gaming and Entertainment**: AR has had a profound impact on the gaming industry. Games like Pokémon GO [18] have introduced millions of players to AR by overlaying virtual creatures and challenges onto real-world locations. This fusion of gaming and the physical world has created highly engaging and interactive experiences, enticing players to explore their surroundings and interact with others [19].
2. **Education**: In the field of education, AR is transforming traditional learning methods. It allows educators to create immersive and interactive lessons by overlaying 3D models, historical reconstructions, or informational content onto textbooks or physical objects. Students can explore subjects like biology, history, or astronomy in a more engaging and memorable way [20].
3. **Healthcare:** AR has found its place in healthcare by improving medical training, diagnosis, and patient care. Surgeons can use AR to visualize complex procedures in real time, aiding in precision surgery. Medical students can practice surgeries on virtual patients before operating on real ones. AR is also used for remote consultations and telemedicine, bringing medical expertise to remote or underserved areas [21].
4. **Retail and Marketing**: AR enhances the retail experience by enabling customers to visualize products in their own environment before making a purchase. For example, customers can use AR apps to see how furniture would fit in their home or try on virtual clothing. Marketers use AR to create interactive advertising campaigns, bringing print materials or product packaging to life with multimedia content [22].
5. **Architecture and Design:** Architects and designers utilize AR to visualize and present their creations. They can overlay architectural models onto physical building sites, allowing clients to see the finished project before construction begins. Interior designers use AR to help clients visualize room layouts and design elements [23].

As technology continues to advance, the potential applications of AR are limitless. From enhancing our daily lives to revolutionizing industries, AR is poised to shape the future of human-computer interaction and information visualization.

IV. RESEARCH METHODOLOGY

The below section, discusses related work focusing on use of Augmented Reality for learning concepts of electronics subject learning:

Muthu et al., (2023) [24] conducted a study to improve the quality of Technical and Vocational Education Training and Education (TVET) programs for adolescents and young people. The overarching goal of this study was to evaluate students' preparedness for AR-based instruction and find the most suitable platform for creating AR apps for mobile devices. 83% of respondents to an online survey said Android is their device of choice. Improved retention of information from the Basic Electronic Components module was achieved by the development of a marker-based AR application. Finally, the study provided useful insights for the future development of AR applications in the field of TVET, highlighting the applicability of such applications for improving learning efficiency.

Tuli et al., (2022) [25] investigated the effects of augmented reality learning environments (ARLE) on the electrical engineering education. For first-year engineering students, AR based learning strategy was utilized and compared it to more conventional approaches. The comparative analysis of pre -test and Post-test scores resulted in conclusion that the AR group students had scored academically sound than the control group. Student enthusiasm for studying electronics also increased after AR intervention. The study findings stated that students with a good outreach on AR technology made them a positive learner. This study highlights the revolutionary potential of augmented reality in the classroom, particularly in areas where students have historically struggled, such as electronics vocational training.

Sandoval Pérez rt al., (2022) [26] employed AR technology in the teaching of the core of electronics industry, power electronics, specifically focusing on R, C, L, RC, RL. LC and RLC circuits with application of DC-to-DC converters like Buck-Boost converters. The study developed an AR environment to assess the impact of this technology, comparing it to traditional teaching methods. The results demonstrated a significant positive effect on students, indicating the potential for designing the entire course not only with theoretical aspects but more precisely the practical aspects using AR tools. The study aimed to measure user skills and motivation, revealing a 40% increase in cognitive performance and retention in activities conducted with AR. This suggests the feasibility of developing tools for the entire electronics course.

Kaur et al., (2020) [27] highlighted the role of practical learning in Engineering Education to enhance theoretical knowledge. They observed that many students lack the drive and engaging course material to successfully apply their academic knowledge in real-world situations. Poor student engagement is a common result of the traditional classroom setting, which may prevent students from gaining a thorough understanding of course material. This research looked at AR possibilities as a visualization tool for use in educational settings. The results indicated that the use of AR significantly boosted student motivation, with high scores in **Attention (A), Relevance (R), Confidence (C), and Satisfaction (S)** all exceeding a mean score of 4.

Ojer et al., (2020) [28] proposed a projection-based AR system to improve decision-making in customized manufacturing and electronic component assembly. On the System Usability Scale (SUS), the system described in the study scored an average of 80, with 90 indicating very excellent usability. Any score over 68 is regarded useful; a mean SUS around 70 is good; and a score around 85.5 is exceptional, according to Bangor et al. (28). Although both systems in the research achieved great usability, the AR system significantly exceeded the conventional technique utilized by the manufacturer, demonstrating a considerable preference for the AR extension.

Avil'es - Cruz et al., (2019) [29] introduced a smartphone-based AR system to enhance the learning of fundamental electronic device concepts, including Boolean algebra and logic gates, crucial in electrical and electronics engineering courses. This study uses a smartphone and a breadboard to instantly recognize and describe seven fundamental logic gate integrated circuits (ICs). A smartphone's camera may be used to take a picture of an electrical circuit, and then digital items can be overlaid on the picture to reveal information about the IC, its pins, and its logic architecture. High levels of user satisfaction and technical efficacy of 97.5% were found in the assessment of the AR system.

Alsadoon et al., (2019) [30] aimed to investigate the use of AR software in academic settings. The study focused on three main concerns i.e., their experience with AR apps, their thoughts on AR's potential in the classroom, and the challenges they've encountered bringing AR to their students. Some of the professors from two different universities were chosen at random to take part in an online poll. Professors had an excellent understanding of AR, but they weren't using it in their classes. The results corroborated the widely held beliefs about AR's benefits, showing that teachers see its potential to improve classroom conditions favorably. While opportunities were emphasized, concerns regarding possible hurdles, such as limited technical assistance, were also brought forward.

Phade et al., (2019) [31] demonstrate that the current method for teaching engineering doesn't meet the needs of the business market because students don't have the required skills. People find subjects like Electronics Engineering difficult, which makes it hard to teach them well. Even though standard teaching methods use books, web links, videos, and simple models, they may not be enough to help students fully understand complex theory and practical aspects. The study suggested an AR method to fill this gap. AR brings together the real and virtual worlds to make 4D pictures with noises that help you learn both in theory and in practice. This AR tool can be viewed on smartphones and computers. It gives students up-to-date subject information and engaging learning experiences, such as AR Labs and AR Classrooms.

Hsu et al., (2017) [32] created an AR-based learning experience to instruct students in electrical engineering principles and evaluated its effectiveness. The experimental group in a study of 107 first-year engineering students who were given access to an AR -based Lab Manual fared better on post-tests than the control group. Students' attitudes toward learning and academic success in electronics courses were also shown to be significantly correlated when AR intervention was implemented. Findings revealed that students who participated in AR activities had a more favorable impression of both the electronics course and AR technology.

Figueiredo et al., (2016) [33] emphasized on the significance of encouraging digital-native generations to become engaged participants in the digital ecosystem, as a means of developing their maturity and critical thinking skills. The proposed study claims that qualities like problem-solving, logic, creativity, persistence, and cooperation may be fostered via early programming instruction paired with electronics. The study describes the process of making an AR book that teaches kids about computer science and electronics. This cutting-edge resource uses mobile devices and AR to provide students with support while they assemble electronics in a classroom setting or at home alone or in small groups. The concluded that AR will change the face of education forever by making relevant information readily available on smartphones.

The Table 1 discusses some related work on use of AR for learning concepts of electronics.

Authors	Methods/Technique	Outcomes
Muthu et al., (2023) [24]	AR IBM SPSS	Improved retention of information from the Basic Electronic Components module was achieved by the development of a marker-based AR application.
Tuli et al., (2022) [25]	AR Quasi-experimental	The study found that students who had a good outlook on AR technology also had more positive learning attitudes and higher academic accomplishment.
Sandoval Pérez rt al., (2022) [26]	ANOMA	The study reveals a 40% increase in cognitive performance and retention in activities conducted with AR.
Kaur et al., (2020) [27]	Augmented Reality Questionnaire-based survey	The results indicated that the use of AR significantly boosted student motivation, with a mean score greater than 4 for all ARCS.
Ojer et al., (2020) [28]	Spatial augmented reality	The proposed system scored an SUS of an average of 80, indicating very excellent usability.
Avilés-Cruz et al., (2019) [29]	Markerless methods AR	High levels of user satisfaction and technical efficacy of 97.5% were found in the assessment of the AR system.
Alsadoon et al., (2019) [30]	AR Questionnaire method	The results corroborated the widely held beliefs about AR's benefits, showing that teachers see its potential to improve classroom conditions favourably.
Phade et al., (2019) [31]	ICT based tools AR	The outcomes revealed that AR brings together the real and virtual worlds to make 4D pictures with noises that help in learning both theory and in practice.

Hsu et al., (2017) [32]	AR lessons for hands-on and its simulators	Findings revealed that students who participated in AR activities had a more favourable impression of both the electronics course and AR technology.
Figueiredo et al., (2016) [33]	Augmented Reality	The study describes the process of making an AR book that teaches kids about computer science and electronics.

Table 1. Summary of reviewed Literature

V. RESULTS AND DISCUSSION

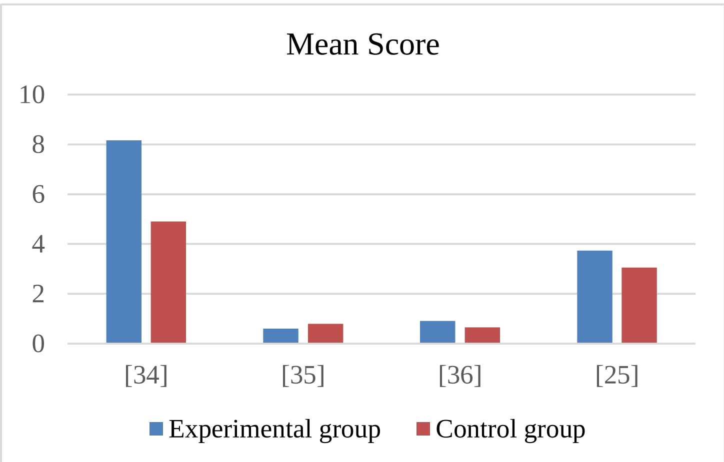
5.1.1 Comparative analysis

In this section, a comparative analysis of the studies that were carried out by a number of different authors is performed. These studies emphasized on the use of AR technology with the goal of improving students' understanding of fundamental concepts in electronics. For this analysis, the authors split the participants into two unique groups: the Experimental group, which was given the opportunity to engage in AR-based learning, and the Control group which relied on more conventional learning strategies. This study entailed the gathering of data and the analysis of the performance of both groups across a variety of situations, providing mean scores and standard deviations (SD), as shown in Table 2.
It could be observed from the Table 2 that that the Experimental group, which learned using AR technology, generally had a higher mean performance compared to the Control group for the tasks related to learning electronics concepts. Additionally, in most cases, the Experimental group exhibited lower standard deviations, indicating more consistent performance. However, there were some variations in specific tasks, as seen in [35] and [36], where the Control group outperformed in terms of mean.

Author	Experimental Group		Control Group	
	Mean	SD	Mean	SD
Singh et al., (2019) [34]	8.16	2.08	4.90	2.73
Anggara et al., (2021) [35]	0.6	0.2	0.8	0.178
Selek et al., (2020) [36]	0.91	0.745	0.66	0.12
Tuli et al., (2022) [25]	3.73	0.48	3.05	0.94

Table 2. Comparative Study

The mean scores for the Experimental group consistently exceed those of the Control group in all four cases as shown in **figure 3**. Illustrated as below with the context of learning electronics concepts using AR



technology, the better performance of the students in the Experimental group was witnessed as compared to those in the Control group which were using conventional methods.

The standard deviations of the Experimental group are generally lower than those of the Control group as shown in **figure 4**. This indicates that the data points in the Experimental group are more closely clustered around the mean, signifying less variability in performance compared to the Control group. In other words, the learning outcomes in the Experimental group using AR technology show more consistency.

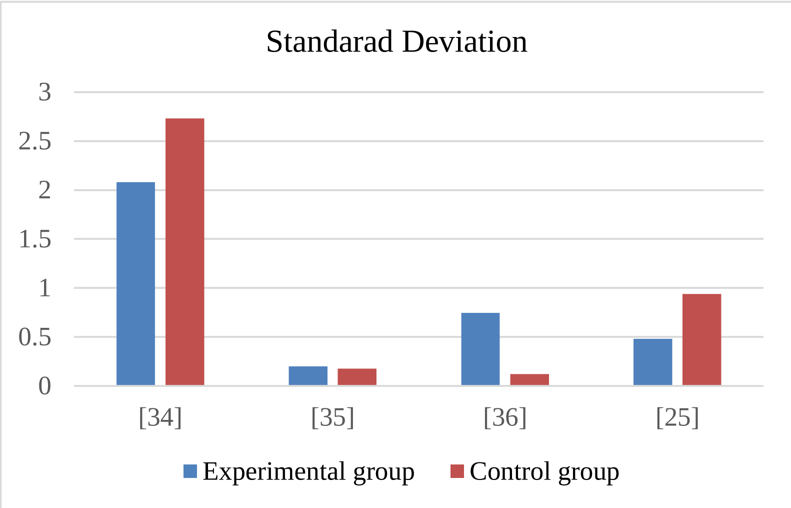


Figure 4. SD of Experimental group vs Control group

Results reveal that the Experimental group, which used AR technology to learn electronics concepts, not only had better mean scores but also displayed decreased variability in their performance, as evidenced by the lower standard deviations. This shows that using Augmented Reality technology improved the Experimental group's overall success and consistency of learning outcomes more than using conventional techniques did for the Control group.

VI. Conclusion and Future Scope

The advantages of AR technology in the classroom have been highlighted through this review that have focused on its usage in teaching electrical concepts. Positive trends in which the Experimental group employing AR technology outperformed the Control group using traditional methods of instruction are indicative of the usefulness of AR for grasping abstract electrical concepts. The conclusions listed illustrated the application of Augmented Reality technology in enhancing students' engagement, collaboration and competence in electronics education.

A further study is needed to better understand how exactly AR helps students learn and what elements contribute to its effectiveness. It would also be beneficial to examine how well students remember and apply information learned via AR-enhanced learning experiences to real-world problems in electronics.

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